Setting the Benchmark

A comprehensive approach to problem solving in esthetic dentistry involves representation of several disciplines to redefine complications outside normal boundaries and reach solutions based on a new understanding of complex situations. The coming together of diverse minds representing varied backgrounds can inspire new benchmarks for esthetic dental treatment. However, such an approach can be costly and difficult for obvious reasons. Practitioners today are therefore encouraged to expand their vision by learning more about disciplines outside their field of practice. Professionals highly focused on one field remain necessary, but those who have a comprehensive vision and who seek collaboration and continuous knowledge are most likely to succeed.

Understanding limitations—those of the materials and techniques we seek to employ and of the particular situation at hand, and considering our own limitations as well—is more vital than knowing the success rate of a given treatment approach or plan. In modern dentistry, failures are potentially catastrophic, and their repair is stressful, costly, and painful for the patient as well as the technician and dentist. When the limiting factors are carefully analyzed, failures can be anticipated and prevented, thus being a dynamic opportunity to expand the frontiers and strategies for esthetic dental treatment planning. Although this learning exercise requires commitment, hard work, and perseverance, it leads us to develop a different mindset, fostering an enhanced inner resilience that nurtures success.

For 35 years, *Quintessence of Dental Technology* has been a unique source of inspiration, with articles presenting a benchmark for what is the epitome of esthetic dental rehabilitation. In this commemorative issue, all articles were carefully selected to salute the reader with the finest examples of novel approaches for treatment planning and for mastering the influence of color, light dynamics of esthetic materials, communication, photography, materials science, dental composition, perio-prosthetic connection, tooth preservation, and requirements for advanced esthetic treatment. Please join me in relishing the inspiration generated by this delightful collection of artwork.

Sillas Duarte, Jr, DDS, MS, PhD
Editor-in-Chief
sillas.duarte@usc.edu

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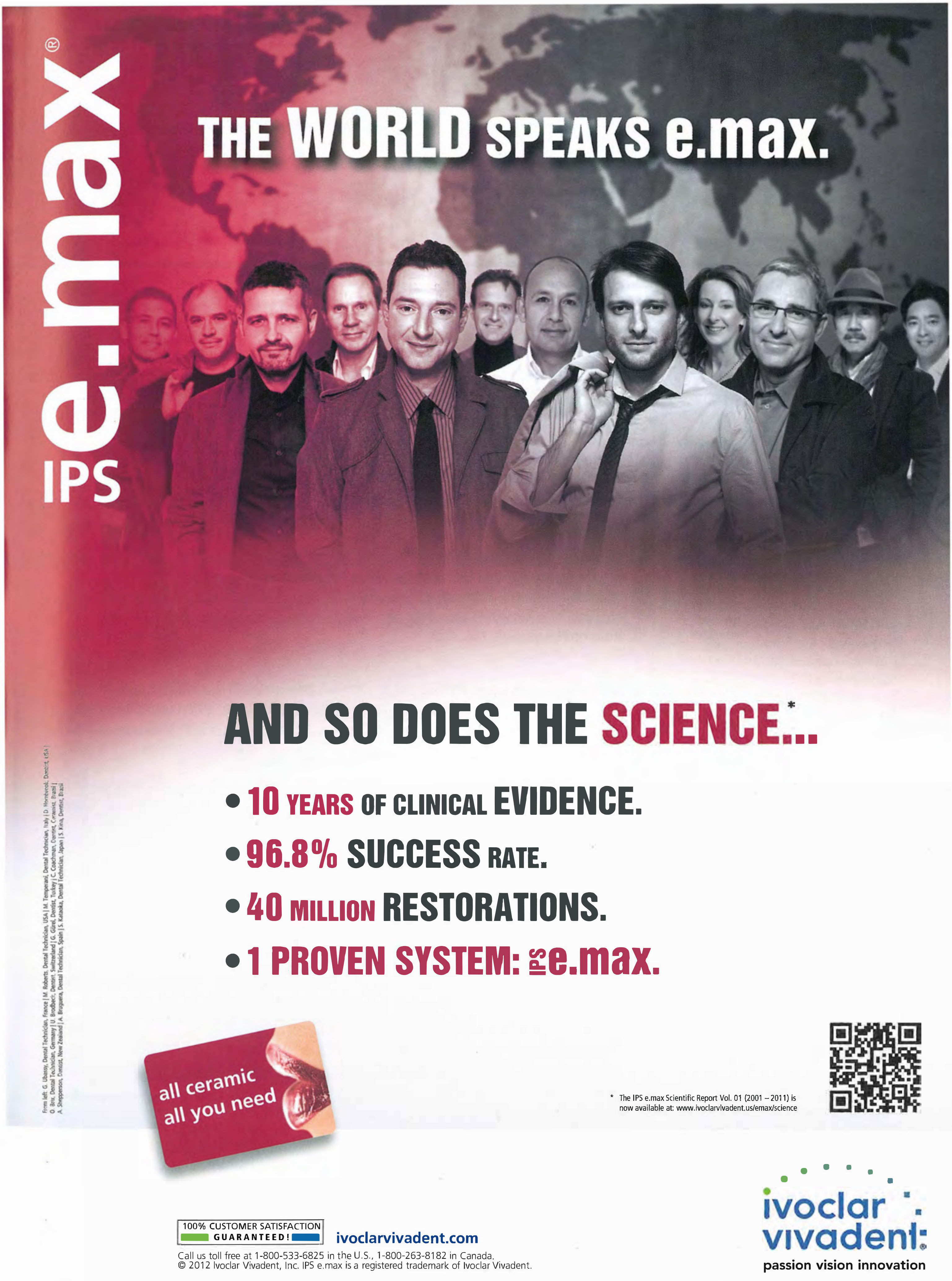
QUINTESSENCE OF DENTAL TECHNOLOGY



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William G. Hartman

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Lori A. Bateman

PRODUCTION EDITOR
Patrick Penney

ADVERTISING/EDITORIAL/ SUBSCRIPTION OFFICE
Quintessence Publishing Co, Inc
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Esthetic Rehabilitation of Compromised Anterior Teeth: Prosthetic Treatment of an Orthodontic Case

Leonardo Bacherini, DMD[1]
Myra Brennan, DMD[2]

There are several treatment options to improve function and esthetics for patients with pathologic migration and incisal abrasion of the anterior teeth. These patients may often require a multidisciplinary treatment approach with orthognathic surgery, orthodontics, and/or complex restorative dentistry in order to reestablish occlusion and to create pleasing facial and dental esthetics. When prosthetic treatment is needed, it is essential that the functional and esthetic goals of therapy be established through a comprehensive systematic analysis and previsualization of the restorations using a diagnostic wax set-up.[1]

The systematic diagnostically driven approach should include the evaluation of facial and dental esthetics, occlusal function, remaining tooth structure, and biological status of the pulp and periodontium.[2] Utilizing a checklist, as described by Fradeani, will ensure the comprehensive collection of data from the face, teeth, and tissues to create the blueprint for successful esthetic, functional, and biological integration of the restorations.[3]

A pleasing and attractive smile and face are influenced by the skeletal anatomy of the jaws, the occlusal relationship of the teeth, and the facial soft tissue profile of the lips and chin.[4] The relative position of the mandible to the maxilla or of the chin to the tip of the nose determines the nature of a person's facial profile. The fullness and mobility of the upper and lower lips determines the extent to which teeth are seen during a smile and at rest position. Both facial profile and lip form can be altered by surgical movements of the jaw, by orthodontic movements of the teeth, or by plastic surgery augmentation of the facial soft tissues.[5] However, only restorative dental treatment can alter morphology of the teeth and simultaneously enhance the facial profile and lip form to create a pleasing and harmonious smile.

Electing a suitable treatment modality to achieve an esthetic goal must be done in accordance with the patient's subjective interpretation of facial and dental esthetics and the understanding of the risks/benefits of

[1]Private Practice, Sieci-Pontassieve-Firenze, Italy.
[2]Private Practice Limited to Prosthodontics, Hingham, Massachusetts, USA.

Correspondence to: Dr Leonardo Bacherini, Studio Odontoiatrico, P.zza Aldo Moro, 7, Sieci-Pontassieve (FI), 50065 Italy.
Email: leonardo@dentsign.it; www.dentsign.it

treatment. This article presents the prosthetic rehabilitation of a patient with pathologic migration and incisal abrasion of the anterior teeth, in which a comprehensive systematic analysis of the face and teeth, and their respective soft tissues, is used to identify the most suitable treatment approach from the many treatment alternatives for malpositioned and unesthetic anterior teeth.

FACIAL ANALYSIS: Jaw Relationship, Tooth Position, Facial Soft Tissue Contours

Cephalometric and photographic analysis of the skeletal anatomy, dental relationships, and facial soft tissue profile are used by oral and plastic surgeons as well as orthodontists to guide treatment that will alter the soft tissue contours of the face before the clinical procedures to move the jaw and teeth three-dimensionally are determined.[6–8] The vertical relationships of the face as viewed from the frontal and sagittal planes are measured from specific anatomical landmarks and compared to ranges of normal. Meaningful esthetic parameters on a cephalometric tracing relative to facial profile and lip form or support and ranges of normal for females are as follows:

- Skeletal classification = Class I
- Lip protrusion = 3.5 mm upper / 2.2 mm lower
- Nasolabial line angle = 110 to 120 degrees
- Interlabial gap = 0 to 3 mm
- Maxillary incisor exposure = 3 to 5 mm
- Overjet/Overbite = 2 to 3 mm

Interpretation and treatment according to these numbers should take into account the variations between ethnic groups.[4]

Facial features and expressions characterize a particular style of an individual and also strongly influence the perception of their personality by others. When analyzing the face on a photograph, vertical reference lines connecting points located at the glabella, tip of nose, and chin are superimposed on the face to assess the coincidence of the facial and dental midlines as well as right and left facial symmetry. Horizontal reference lines at the hairline, eyebrows, ala, and tip of chin divide the face in thirds and are superimposed to assess proportion of the face from the forehead to chin and the dental esthetic occlusal plane. Dental esthetics is most significantly influenced by the lower third of the face, and its normal, convex, or concave appearance is assessed from the lateral view.[9] The decision to alter these relationships and modality of treatment should ultimately be guided by the patient's perception of and desire for facial balance and esthetics.[10]

DENTAL ANALYSIS: Tooth Morphology and Gingival Soft Tissue Contours

Facial profile and lip form are also affected by the dimension, proportions, and teeth display. An attractive smile typically has components of youthfulness, which include a pleasing maxillary incisor length, maxillary central incisor dominance, moderate convex smile line, progression of incisal embrasures, and high brightness.[11] The smile is dynamic and should be observed during relaxed conversation, laughter, and other facial expressions to reveal what is displayed intraorally when the upper and lower lips are apart. By closely listening to both the verbal and nonverbal cues during the initial interview, the dentist can assess the patient's personality, facial expressions, and smile.[12]

Most noticeable in a smile is the display of the maxillary central incisors. The location of the maxillary central incisor incisal edges is a critical aspect to be evaluated in a functional and dental esthetic rehabilitation.[13] Two methods can be used to evaluate and modify the vertical position of the incisal edges of the central incisors:

1. Record the incisal display against the resting upper lip. The range of display can be from 1 to 4.5 mm depending on the sex, age, and patient's esthetic desire.
2. Examine the lip during the "E" sound from the lateral view. The length of the maxillary central incisors is acceptable when the teeth occupy 50% to 80% of the space between the upper and lower lips.

To evaluate and modify the horizontal position of incisal edges:

Figs 1a to 1c Initial presentation of the patient, who is uncomfortable with the appearance of her smile.

1a

1b

1c

1. Record the relation of the incisal edge to the lower lip during the "F" and "V" sounds.
2. Record the angle between the incisal third of the maxillary central incisor and the maxillary posterior occlusal plane.[14]

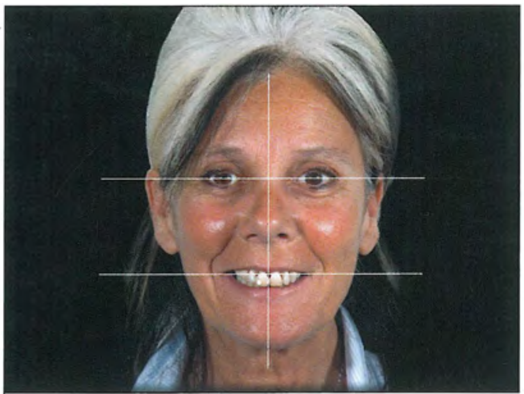
Tooth morphology, dimension, and proportion are also modified by gingival soft tissue contours, specifically the scalloped form and outline of the free gingival margin (FGM) and the interdental papilla form relative to the contact point. For example, a flat FGM and short papilla can make a tooth appear more square, or recession of the FGM can make a tooth appear longer. The outline form and mobility of the lips provide the framework within which alterations to tooth length and convexity of arch form can be made to achieve a pleasing and attractive smile.[15]

Previsualization of any dental shape and form alterations should be done with a diagnostic wax-up on study casts, which can then also be used for an intraoral mock-up with restorative materials, such as composite resin.[1]

CASE PRESENTATION: Systematic Analysis

Step 1: Patient Interview (Fig 1)

The patient, a 50-year-old woman, was unhappy with her smile and lip posture because of her flared and unesthetic maxillary anterior teeth. She stated she had a history of advanced periodontitis that had been treated and stabilized with periodontal therapy, extraction of posterior teeth and replacement with dental implants, and endodontic therapy on the anterior teeth with direct composite restorations. She was in excellent general health and positively motivated to improve her smile.


2a


2b


2c


2d


2e

Figs 2a to 2e Esthetic evaluation of facial symmetry and proportions using the vertical and horizontal reference lines in the frontal and lateral views. The patient has good facial symmetry and acceptable side profile revealing a skeletal Class II jaw relationship with normal lip support and nasolabial angle.

Step 2: Esthetic Analysis (Figs 2 to 13)

Face

She presented with symmetry, balanced facial proportions, and parallel facial interpupillary and dental occlusal esthetic planes (Figs 2a and 2b). In the lateral facial view, all the parameters (eg, e-line, nasolabial angle, and profile) are within the normal range considering sex and race (Figs 2c to 2e). Though she has good upper lip support, the incisal edges of the maxillary anterior teeth extend beyond the wet/dry border of the lower lip.

Smile

The dynamic evaluation of her smile reveals a medium, convex smile line with lip incompetence due to the apparent improper facial angulation of the maxillary anterior teeth (Figs 4a to 4e). The buccal corridor is esthetically pleasing; the occlusal plane is coincident with commissural line; and the philtrum of the upper lip is coincident with the dental midline.


3a


3b


4a


4b


4c


4d

Figs 3a and 3b Excessive vertical overbite and overjet of the maxillary central incisors.

Figs 4a to 4e Photographic progression of the smile is useful for completing the dentolabial analysis.


4e


5a


5b


5c


6a


6b

Figs 5a to 5c Lateral view of varying lip postures, revealing lip incompetence and overcontoured incisal edge position with preexisting composite restorations.

Figs 6a and 6b Three-quarter lateral view reveals poorly positioned incisal edges of the central incisors with respect to the lower lip.


7


8

Fig 7 Complete intraoral frontal view of the mouth.

Fig 8 Intraoral measurement of 10 mm overjet using a periodontal probe and presence of cervical abrasion/abfraction of the anterior teeth.

Incisal Edge Position

The vertical position of the incisal edges appears beyond the normal range and can be reduced (Fig 5c). During "F" and "V" pronunciation, the incisal edges of this patient extend horizontally beyond the wet/dry line of the lower lip, and the angle with the occlusal plane is acute (Fig 5b).

Tooth Dimensions

She has existing incisal wear and interdental composite bonding, which disguise the true dimensions of the individual anterior teeth. However, the length of the central incisor can provide a starting point to recreate proportional tooth dimensions. The length is 12 mm and can potentially be reduced.

Gingival Tissue Contours

She has thick, scalloped gingival tissue with an acceptable scalloped FGM form that blends harmoniously with the FGM outline of the existing posterior restorations.

Fig 9 Occlusal view of interdental composite bonding and spacing between the anterior teeth.

Fig 10 Although the patient's previous periodontal disease has resulted in the loss of periodontal attachment, the remaining outline form of the free gingival margins and the present level of interdental tissue is good for creating pleasing restorations.

Fig 11 Initial radiograph revealing preexisting endodontically treated anterior teeth with periodontal bone loss and posterior implant restorations.

Fig 12 Mandibular anterior incisors occluding with the palate, not the maxillary anterior incisors.

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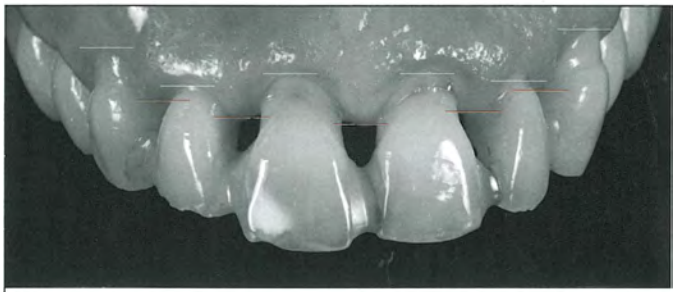

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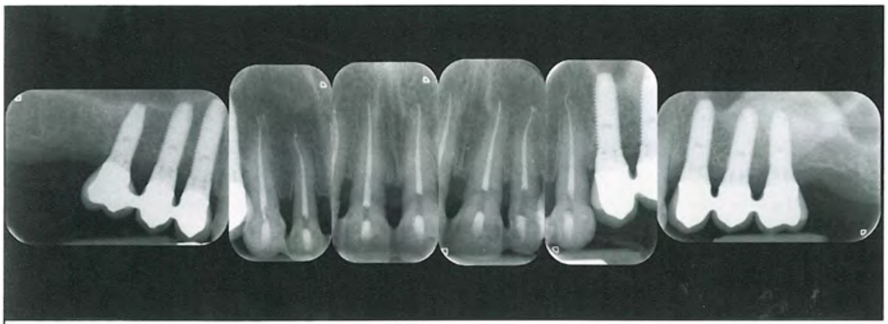

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Step 3: Radiographic Findings

Panoramic

- Maxillary posterior implant restorations; maxillary anterior endodontically treated teeth with 20% to 30% alveolar bone loss

Cephalometric

- Skeletal classification = Class II
- Lip protrusion = 6.3 mm upper / 3.37 lower
- Nasolabial line angle = 112 degrees
- Interlabial gap = 1.8 mm
- Maxillary incisor exposure = 3 mm
- Overjet = 10 mm
- Overbite = 4 mm

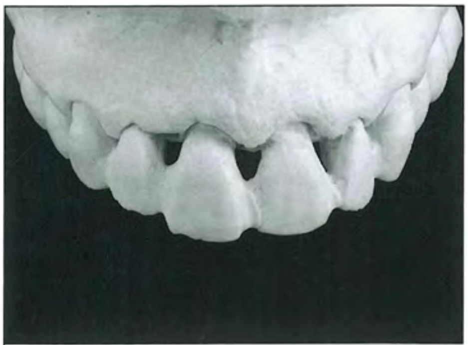
Step 4: Periodontal Evaluation

She was previously treated for chronic periodontal disease; she has good oral hygiene, and probing depths are presently within normal range.

Step 5: Functional Analysis

The mandibular incisors occlude on the palate as a result of the retrusive mandible and labially migrated maxillary anterior teeth. Therefore, she lacks anterior guidance.

There is no history of temporomandibular joint noise or pain. Mandibular range of motion is within normal limits. She has no muscle symptoms and no parafunctional habits.



13a

13b

13c

13d

13e

Figs 13a to 13e Close-up view of stone casts revealing the details of altered gingival contours, tooth positions, and tooth morphology resulting from the periodontal bone loss and splint therapy.

Step 6: Diagnosis and Etiology

The patient was diagnosed with the following:

- Secondary occlusal trauma
- Class II skeletal and dental malocclusion
- Lack of anterior guidance
- Excessive overbite and overjet
- Supraeruption, flaring, and spacing of maxillary anterior teeth
- Abraded and worn incisal edges
- Gingival recession of the maxillary anterior teeth with cervical abrasion/abfraction
- Periodontal alveolar bone loss, but stable periodontal support of maxillary anterior teeth
- Endodontically treated maxillary teeth
- Maxillary implant-supported posterior restorations

The etiology of the malposed, worn anterior teeth with loss of periodontal support was the prior loss of posterior teeth and the bacterial plaque that was present before periodontal therapy and replacement of the posterior teeth with dental implants.

Step 7: Treatment Goals

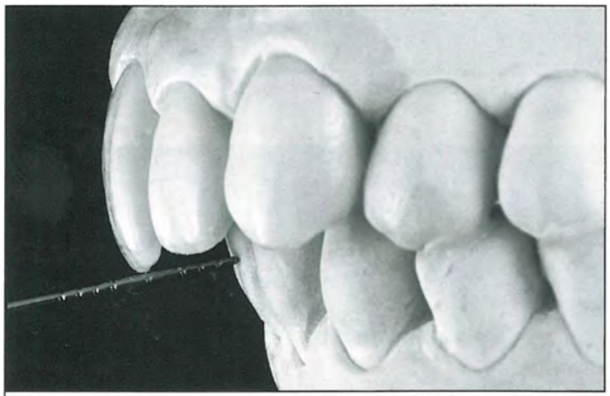
The treatment goals were:

- Reduce overjet and overbite
- Establish anterior guidance
- Restore worn tooth structure and improve the morphology of the maxillary anterior teeth
- Align the maxillary anterior teeth
- Create a pleasing and attractive smile

14a

14b

14c



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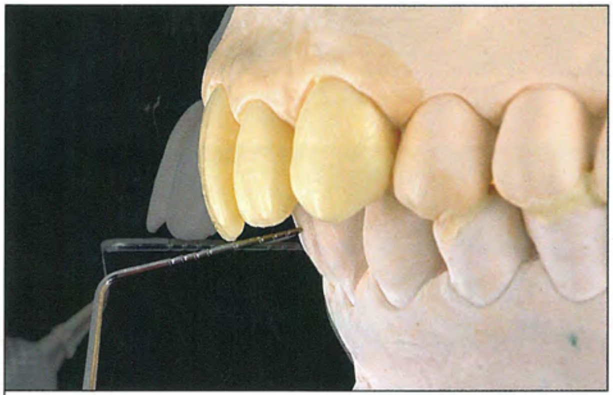

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Figs 14a to 14c Wax-up of the anterior teeth following all the principles of ideal dental composition.

Fig 15 New measurement of the overbite after the complete wax-up.

Fig 16 Superimposition of the photos before and after the wax-up to show the difference in the amount of overbite.

Step 8: Diagnostic Wax-up (Figs 14 to 16)

In this case, good anterior dental composition was possible because the apicocoronal position of the gingival line and the final vertical incisal edge position allowed for a pleasing central incisor length. Moreover, reducing the overjet also reduced the horizontal distance on an anterior curve from the distal of the canines. This allowed for a good proportion of the individual width of each tooth to the length and also good tooth-tooth proportions (Figs 14a to 14c). So, by simply changing the emergence profile of the palatal aspect of the teeth and the inclination of the crowns in the diagnostic wax-up, it was possible to reduce the overbite and overjet, as well as create anterior guidance (Figs 15 and 16).

Step 9: Clinical Treatment Options

To treat the skeletal and dental malocclusion, orthognathic surgery to advance the mandible and orthodontics to retract the maxillary anterior teeth, while maintaining the acceptable gingival scalloping outline form, were considered. However, treatment with orthodontics could potentially reduce the upper lip support; moreover, neither orthognathic surgery nor orthodontics would improve the morphology of the maxillary anterior teeth. Another possibility was to treat the dental malocclusion with prosthetic restorations. Because an acceptable esthetic and functional result could be achieved in the diagnostic wax-up and after discussing the risks and benefits of all treatment possibilities, the patient decided to restore her smile with ceramic crowns.

17a

17b

17c

Figs 17a to 17d Initial tooth preparation performed with the silicone index to create the ideal volume for the final restoration. Every tooth preparation was verified with the silicone index also from the lateral perspective.

17d

18

19

Fig 18 Initial preparation was perfomed using a retraction cord to place the margin of the preparation in the sulcus. By doing so, it is possible to change the emergence profile of the crown to close the interdental space.

Fig 19 Gingival soft tissue response after 1 week of provisionalization. Parameters for ideal gingival and dental composition are met, and tissues and teeth appear balanced and proportional.

Step 10: Provisionalization (Figs 17 to 32)

The MIT technique was used to provisionalize the six maxillary anterior teeth.[17] A preliminary preparation of teeth is performed utilizing a silicone index as a guide to control the reduction of tooth structure and obtain adequate space for the final restoration (Figs 17a to 17d). To close the interdental space, modify the emergence profile of the provisional, and condition the form of the marginal tissue, a retraction cord was used to retract the free gingival margin and reposition the finish line of the preparation into the sulcus. The shell of the provisional was relined, the occlusion was adjusted to achieve anterior contact and posterior disclusion, and

20a

20b

21a

21b

22

23

Figs 20a and 20b Right lateral view before and after provisionalization, revealing improvement in gingival form resulting from the alterations of tooth morphology in the provisional restorations.

Figs 21a and 21b Left lateral view before and after provisionalization, revealing the change of central incisor inclination with the provisional crown restoration.

Fig 22 Lateral view of the lip at the rest.

Fig 23 Frontal view of the smile with the provisional restorations.

then the provisional was cemented with non-eugenol zinc oxide cement (Freegenol, GC Dental, Tokyo, Japan). After 1 month, the patient's speech, appearance, and function were reevaluated and acceptable to the patient. The final impression was then taken using the double-cord technique (Ultrapack, Ultradent, South Jordan, Utah, USA), a light-activated custom tray (Palatray LC, Heraeus Kulzer, Hanau, Germany), and single-impression double-mixing impression technique with a polyether material (Impregum Penta Duo Soft, 3M ESPE, Seefeld, Germany). Jaw relation records were taken with an intraoral facebow and a Lucia jig, and the casts of the provisional restorations were cross-mounted with the master cast of the tooth preparations.

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26a

26b

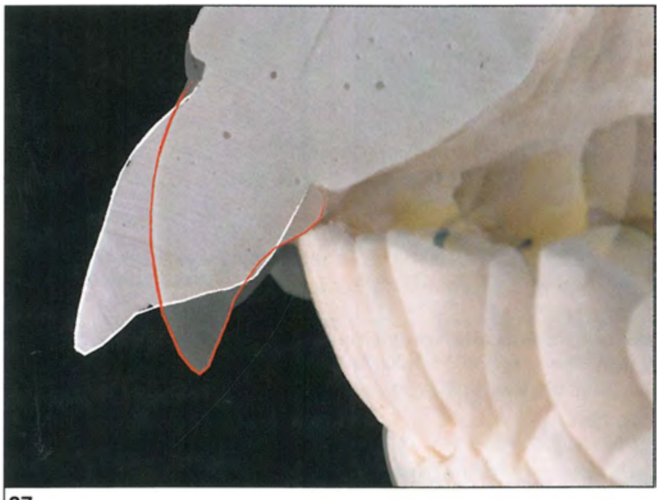

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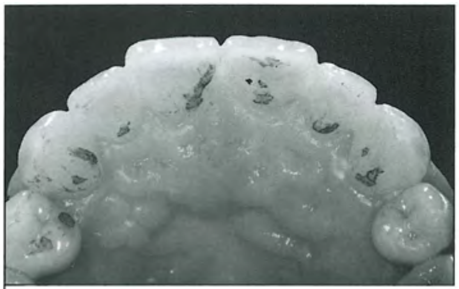
Fig 24 Overjet reduction of 5 mm was possible with the new provisional crown inclination.

Fig 25 New position of the upper lip and length of the central incisors with the provisional restorations during the "E" sound.

Figs 26a and 26b New position of the incisal edges with the provisional restorations during the "F" sound.

Fig 27 Comparison with the initial study cast and the cast of the provisional restoration reveals the improvement in coronal inclination and alteration of palatal form of the central incisor to achieve occlusal contact between the maxillary and mandibular incisors.

28



29

30a

30b

Fig 28 MIP coincident with CR on the casts of the mounted provisional restorations.

Fig 29 Intraoral view of occlusal markings demonstrate anterior guidance and canine disclusion with the provisional restorations.

Figs 30a to 30c Frontal view of posterior disclusion during protrusive, left lateral, and right lateral jaw movements.

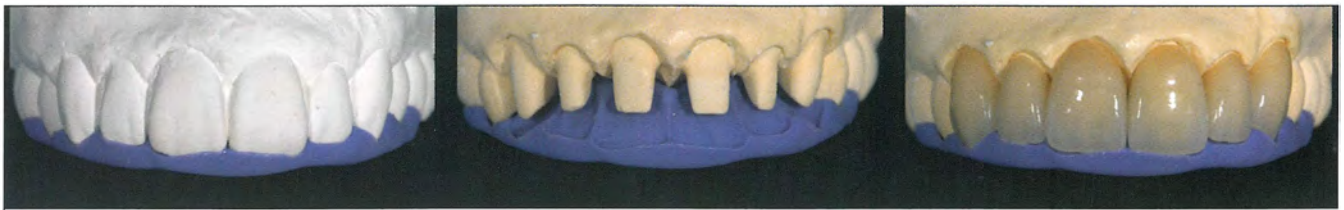
30c

31

Fig 31 After final tooth preparation and reline of the provisional, it is critical to measure the thickness of surfaces of the provisional to verify the amount of tooth reduction needed for the chosen ceramic restoration.

Fig 32 Final preparation of the abutment teeth with the enhanced interdental tissue contour and formation of papilla.

32



33

34a

34b

35a

35b

36

Fig 33 The silicone index is utilized by the laboratory technician to reproduce the morphology of provisional restorations and verify the shape of the ceramic restorations. By doing so, the functional and esthetic features previously tested intraorally during the provisional phase can be developed properly in the laboratory.

Figs 34a and 34b The provisional restorations define the esthetic and functional features of the teeth, but the ceramist uses his artistic sensibility to provide pleasing and natural esthetics through control of shape, shade, texture, perspective, and translucency.

Fig 35a and 35b Lateral views of the restorations with pleasing coronal inclination of the central incisors.

Fig 36 All-ceramic restoration made of lithium disilicate (e-max) before the cementation phase.

Step 11: Laboratory Procedure (Figs 33 to 36)

The master casts were cross-mounted on the articulator with the replica models of the provisional restoration. The silicone matrices were made from the cast of the provisional restorations to copy the tooth arrangement and morphology. The technician used these as guide to create the definitive prosthesis, thereby reproducing the esthetic and functional characteristics tested in the provisional restoration. After the complete replica of the provisional was fabricated with wax, the technician performed the closure and added marginal injection channels to process the lithium disilicate (e.max, Ivoclar Vivadent, Schaan, Liechtenstein) with the lost wax technique. This material was fired using a special oven at a temperature of 920°C.

37a 37b 37c

Figs 37a to 37c Clinical presentation of the gingival tissues and abutments at the day of cementation. The preparation design of the abutment and the emergence profile of the provisional restorations enable creation of pleasing interdental papilla and gingival form.

Fig 38 Occlusal view of the tooth preparations before cementation.

Fig 39 Clinical protocol to prepare the abutment for adhesive cementation.

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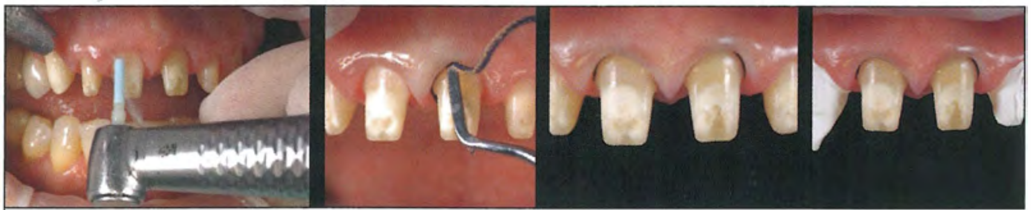

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Step 12: Delivery (Figs 37 to 60)

At the try-in appointment, the restorations were evaluated for marginal integrity of the proximal contacts, esthetic outcome, shade matching, contour, and occlusal relationships. After minimal occlusal adjustment to optimize the contact in CR position and achieve the proper disclusion of the posterior teeth during the excursive movements, the ceramic restorations were sent back to the laboratory for final polishing and glazing.

The cementation of these restorations followed a very precise protocol. Retraction cords were placed in the sulcus of every abutment to minimize the humidity from the crevicular fluid and to act as a barrier for the penetration of the resin cement to the base of the sulcus. The restorations were etched with hydrofluoric acid 4.5% (Ivoclar Vivadent) for 20 seconds, treated with neutralization powder (Ivoclar Vivadent) to neutralize the hydrofluoric acid, and put in an ultrasonic bath with distilled water for 3 minutes. After

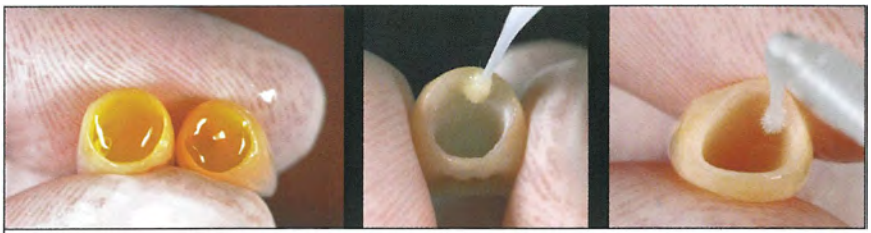

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Fig 40 Clinical protocol to prepare the intaglio surface of the ceramic according to the manufacturer's instructions.

Fig 41 Cementation procedure with the three-step adhesive bonding technique. The two central incisors were cemented simultaneously and then the two canines were cemented. It was performed in this order to facilitate adjustments of the interdental contact area.

Fig 42 After cementation of the central incisors and canines, the contact points of the two lateral incisors were adjusted and then cemented.

thorough air drying, the intaglio surface was silanized (Monobond-S, Ivoclar Vivadent) and dried for 60 seconds. Tooth preparations were cleaned with pumice and polishing silicone burs (Opticlean, Kerr Hawe, Boggio, Switzerland), etched for 30 seconds on enamel and 10 seconds on dentin with 37.5% phosphoric acid (Ultra-Etch; Ultradent, Salt Lake City, Utah, USA), rinsed and carefully dried, leaving the dentin moist. The fitting surfaces, restorations, and teeth were coated with adhesive (Optibond, Kerr Hawe) and, due to the reduced thickness of the ceramic restoration, a light-polymerized composite resin cement (Variolink II, Ivoclar Vivadent) was selected to lute the restorations. The excess cement was removed from the buccal and lingual surfaces with a dental explorer, dental floss, a double-edge blade (surgical scalpel blade no. 12, Swann-Morton, Sheffield, England) and a carver (VD8 carver, Deppeler SA, Rolle, Switzerland).

After cementation, final radiographs were taken of the restorations and the patient returned for a reevaluation after 1 week.


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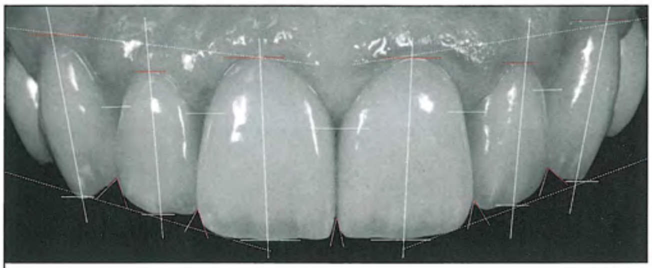
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Fig 43 Clinical presentation of the maxillary anterior teeth before restorative dental treatment.

Fig 44 One week after cementation: The appearance of the soft tissue is still not ideal.

Fig 45 One month after cementation: The biologic integration of the crown is completed.

Fig 46 The ideal dental composition with the ceramic crowns.

Fig 47 Right lateral view 1 week after cementation.

Fig 48 Right lateral view 1 month after cementation.

Fig 49 Left lateral view 1 week after cementation.

Fig 50 Left lateral view 1 month after cementation.


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Fig 51 Occlusal view of ceramic restorations. Note the change in the arch length as compared with Fig 9.

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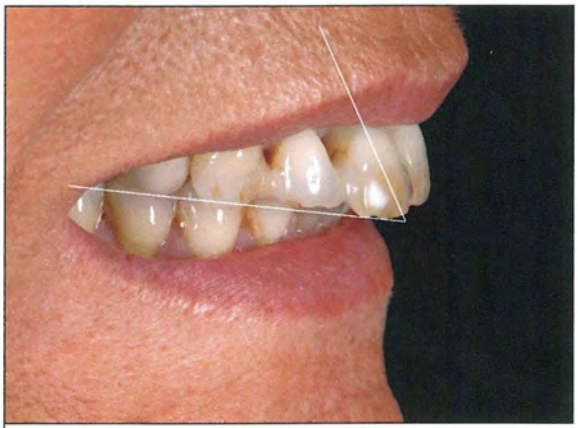

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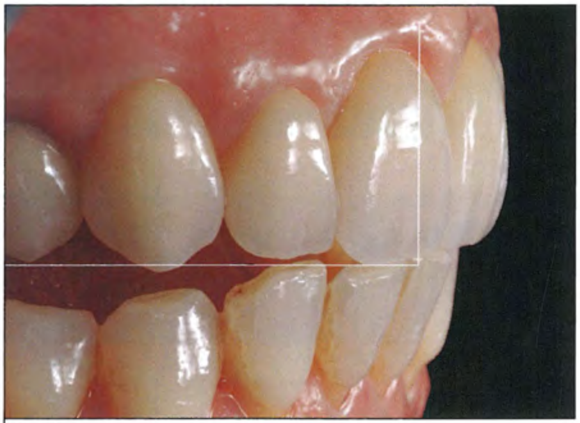

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Figs 52a and 52b Lateral views of the smile. Note the change in the dentolabial relationship as compared with Figs 6a and 6b.

Fig 53 Inclination of teeth before treatment with the acute angle between the incisal third of the maxillary central incisor and the maxillary posterior occlusal plane.

Fig 54 New inclination of the anterior teeth with the right angle between the incisal third of the maxillary central incisor and the maxillary posterior occlusal plane.

Figs 55a and 55b Intraoral lateral views of the restorations.


56a


56b


56c


56d

Figs 56a to 56e Progression of the smile. Note the changes as compared with Figs 4a to 4e.

Fig 57 Periapical radiographs of the final crown restorations. Note that the emergence profile of the crowns closed the interdental space.


56e

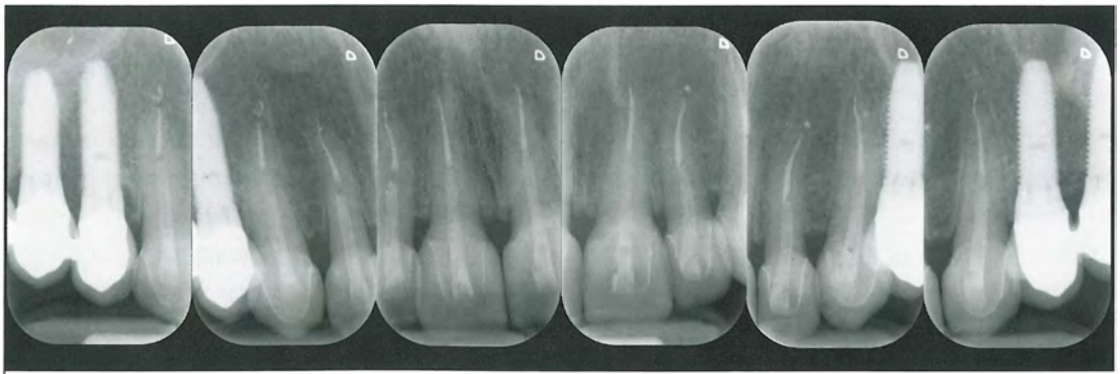
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Fig 58 Occlusal markings during functional jaw movements with the new restorations.

Figs 59a to 59c Esthetic and functional integration of the prosthetic rehabilitation.

Fig 60 Final profile. Note the maintenance of the correct nasolabial angle and the good support of the upper lip.

Fig 61 Final appearance of the patient with her new smile.

61

DISCUSSION

Orthognathic surgery and orthodontic treatment was discussed with the patient to advance the mandible and improve the facial and occlusal relationships. The resulting changes in facial soft tissue would be a reduction of overall facial convexity. She was satisfied with her facial side profile and only dissatisfied with the appearance of her maxillary anterior teeth. Preprosthetic orthodontic treatment was then considered to align the maxillary anterior teeth prior to placing ceramic restorations and to articulate them with the mandibular incisors. After analyzing the cephalometric tracing and discussing the desired dentofacial esthetic goals of the patient, it was suggested that closing the interdental spaces by retraction/intrusion of the incisors would flatten the maxillary anterior arch form/profile and also reduce the upper lip support (eg, nasolabial line angle). Closure of the interdental spaces would also reduce the arch length in the anterior segment, which would decrease the width of each tooth/restoration, making the anterior teeth appear narrower. The overall facial esthetic impact of orthodontics could therefore reduce the dimensions of the anterior teeth, the appearance of fullness to the lips, and the facial prominence of the smile, which was not desired by the patient.

A diagnostic wax-up was done on the study casts to evaluate if treatment could be performed with only restorative dentistry to accomplish both the functional and esthetic goals of treatment. The position of the gingival margins as a result of the periodontal alveolar bone loss was fortuitous. It was possible to create vertical tooth lengths as measured from the gingival margins to the incisal edges that were esthetic and proportional to one another. The arch length and arch form as a result of the flaring of the teeth also made it possible to create horizontal tooth widths that were proportional to the lengths and to one another. With respect to tooth structure removal, devitalization of the pulps was not a concern because of preexisting endodontic therapy. This allowed for sufficient tooth preparation to reduce the overjet and overbite. Moreover, the axial inclination was acceptable, such that adequate tooth structure could be maintained and articulation with the mandibular anterior teeth achieved with anterior guidance and posterior disclusion. The overall esthetic result with respect to the smile and tooth proportions was harmonious without orthodontic treatment.

CONCLUSIONS

The esthetic rehabilitation of a patient with both a skeletal and dental malocclusion is complex. There are a variety of treatment modalities to accomplish the desired esthetic and functional goals of therapy. For this patient, key biological factors allowed a natural esthetic outcome without orthodontics: the initial clinical presentation of an adequate tooth-to-tooth gingival margin height relationship, adequate interdental spacing to create pleasing tooth width-to-height proportions, and sufficient interdental gingiva to form interproximal papilla and to close gingival embrasures with ceramic restorations. The development of the diagnostic wax-up was the critical step in this systematic analysis that revealed the potential for ceramic crowns to functionally and esthetically rehabilitate her dentition and smile. Electing restorative dentistry as the treatment modality to achieve the desired esthetic goal was done in accordance with the patient's subjective interpretation of facial and dental esthetics and the understanding of the risks/benefits of all treatment modalities.

ACKNOWLEDGMENTS

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Ultimate Ceramic Veneers: A Laboratory-Guided Ultraconservative Preparation Concept for Maximum Enamel Preservation

Oswaldo Scopin de Andrade, DDS, MS, PhD[1]
José Carlos Romanini, CDT[2]
Ronaldo Hirata, DDS, MS, PhD[3]

The use of ceramic laminate veneers is a well-documented, effective, and predictable treatment option.[1,2] This predictability results from the physical properties of the ceramic, which remain stable in terms of color and shape as long as proper treatment planning is carried out. Further, ceramic demonstrates low plaque adherence, thus permitting soft tissue stability. Harmony among the soft tissues, esthetics, and function depends of the bonding ability of the material. Altering the intaglio surface of ceramic using hydrofluoric acid associated with a silane coupling agent enables better bonding to dental structures by providing a smooth interface between the restoration and enamel.

Among the materials available for laminate veneers, glass-ceramic made using the refractory die technique is the most documented.[3] Nevertheless, many clinicians and dental technicians encounter difficulties with this technique, partly because powder-and-liquid glass-ceramic has a very low fracture resistance prior to bonding.

From a laboratory perspective, the refractory die technique is time consuming, and the ceramic buildup used to control all phases of treatment must be fabricated without incorporating air bubbles, which can influence the final physical and optical properties of the restoration. From a clinical perspective, the try-in procedures and lack of stability before bonding make the technique difficult to execute in some cases, such as those with minimal or no tooth preparation.

An experienced ceramist can produce laminate veneers as thin as 0.2 mm, resulting in a very conservative treatment.[4] However, a restoration of this thickness is difficult to fabricate and to handle, which makes the procedure expensive and therefore unavailable to

[1]Director, Advanced Program in Implant and Esthetic Dentistry, Senac University, São Paulo, Brazil.

[2]Dental Technician and Ceramist, Romanini Dental Laboratory, Londrina, Parana, Brazil.

[3]Director, Advanced Program in Restorative Dentistry, Latin American Institute of Dental Research and Education, Curitiba, Brazil.

Correspondence to: Dr Oswaldo Scopin de Andrade, Rua Barão de Piracicamirim 889, Apt 61, Piracicaba, São Paulo, Brazil 13416-005. Email: osda@terra.com.br

many patients. This limitation has been reduced in the last two decades following the development of pressed ceramic in the early 1990s.[5] The addition of leucite to the composition of ceramic enabled pressing of the material, such as through the lost wax technique, which represented a landmark development for ceramic restorations. The advantages of pressed ceramic include less technique-sensitive laboratory procedures and easier clinical handling due to its enhanced physical properties.

Unfortunately, the first generation of this type of ceramic required more space to build the restoration compared with the refractory die technique, making it impossible to fabricate restorations with a conservative preparation in most cases. Additionally, the esthetic characteristics of pressed ceramic were less life-like than those of glass-ceramic. Despite these limitations, veneers and crowns fabricated with pressed ceramic have been widely used and reported.[2,6]

Following the success of the pressed technique, a new class of glass-ceramic was developed based on lithium disilicate crystals. Lithium disilicate glass-ceramic (LDGC) has a wide range of applications for esthetic indirect restorations. Formerly developed as Empress 2 (Ivoclar Vivadent, Schaan, Liechtenstein), this heat-pressed ceramic was indicated for crowns and short-span fixed partial dentures up to the second premolar.[7] For the latter indication, the manufacturer recommended a strict protocol to achieve sufficient resistance to the occlusal forces. For anterior and posterior restorations, high survival rates were observed in short-, mid-, and long-term clinical studies,[8–10] confirming the results obtained in laboratory tests.[11]

The use of LDGC for single-unit restorations was restricted to crowns and posterior partial restorations due to the opacity of the core material. This opacity limited the esthetic results in cases with conservative preparations or restorations with reduced thickness. To solve this limitation, an advanced version of LDGC (IPS e.max Press, Ivoclar Vivadent) with improved physical properties and translucency was developed.[12]

Compared to the original system, the flexural strength of the material jumped from 350 to 440 MPa. Thanks to its increased mechanical properties and better shade control, the pressable LDGC can now be used beyond its original indications using a monolithic technique.[13] The range of indications for this material now include applications such as inlays, onlays, overlays, and laminate, occlusal, and full veneers. The adhesive characteristics were maintained in the new version. The intaglio surface can be etched by hydrofluoric acid for 20 seconds, and the use of a silane coupling agent increases the bond between the ceramic structure and resin cement.[14]

Laboratory results show that this material can be used for minimally invasive restorations, and current clinical data demonstrate high survival rates for partial restorations as well as for complete crowns and fixed partial dentures.[15] Laminate veneers represent a particularly effective use of this material.[16] The rise of minimally invasive dentistry and biologically driven preparations that aim to conserve sound tooth structure caused the dental field to rethink the application of veneers and return to the primary concepts of minimally invasive restorations.[17,18] Currently, the development of LDGC and the concept of ultraconservative veneers enable clinicians and ceramists to apply these techniques to a large number of patients.

This article presents the ultimate ceramic veneer (UCV), an innovative technique for ultraconservative veneer treatment. Tooth preparation for a UCV is laboratory-guided and fabricated after final impression taking, which means that, if necessary, the ceramist trims the cast only where there is no space for the ceramic material. Utilizing customized laboratory-made preparation guides, the clinician may reduce a specific tooth area, but only if necessary. The UCV technique is a highly conservative approach to bonded ceramic veneers in which all preparations are kept in enamel, thus ensuring preservation of the tissues, which is essential for bonding stability and for successful long-term clinical results.

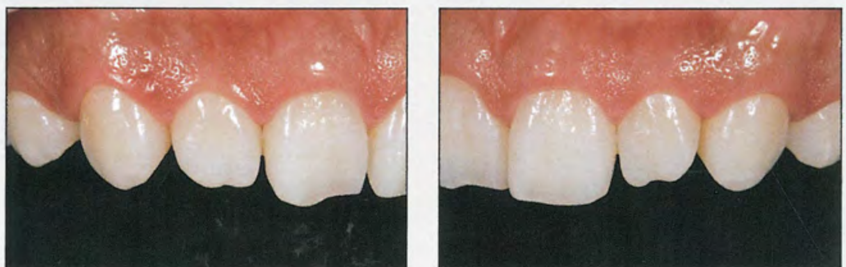
CASE REPORT

The primary complaint of the young female patient was the "anatomy of her smile," which showed misalignment and irregularities at the incisal edge (Figs 1 to 3). All treatment options were discussed with the patient, eg, direct composite resin restorations. Ultimately, the patient and clinician chose an esthetic rehabilitation of the six maxillary anterior teeth with ceramic laminate veneers.

CASE REPORT

1a 1b 1c

2a 2b 2c



3a 3b

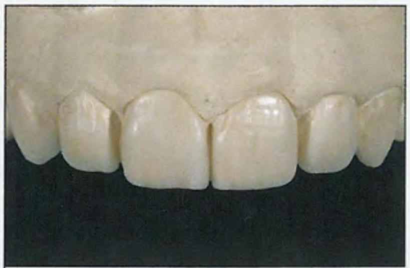
Figs 1a to 1c Preoperative smile views showing irregularities at the incisal edge and misalignment from canine to canine.

Figs 2a to 2c Preoperative intraoral views.

Figs 3a and 3b Lateral views showing the lack of symmetry on both sides, resulting in an unesthetic smile.

Diagnostic Approach and Treatment Planning

The initial clinical procedure included careful analysis of the occlusion, periodontal examination, and facial and intraoral photography. A preliminary impression was taken with an accurate material that can be poured more than once with the same precision. The authors prefer to work with vinyl polysiloxane (VPS) even for initial impressions used for treatment planning. The patient had intact canine and anterior guidance. Canine guidance is important not only as an esthetic parameter, but also to help maintain adequate functional height and the quantity and quality of disocclusion. This role is crucial to preserve the long-term quality of any restorative treatment in anterior dentition. Facial photography helps the ceramist attain the correct midfacial line, detect any inclination of the smile line, and establish harmony between the soft tissues and smile line. A facebow record was taken and transferred to a semi-adjustable articulator.


4a


4b


4c


5a


5b

Figs 4a to 4c Initial additive wax-up for the mock-up procedure.

Figs 5a and 5b Mock-up made with bis-acrylic resin loaded into a vinyl polysiloxane template.

Figs 6a to 6c Patient's smile with the mock-up in place.


6a


6b


6c

Additive Preliminary Wax-up

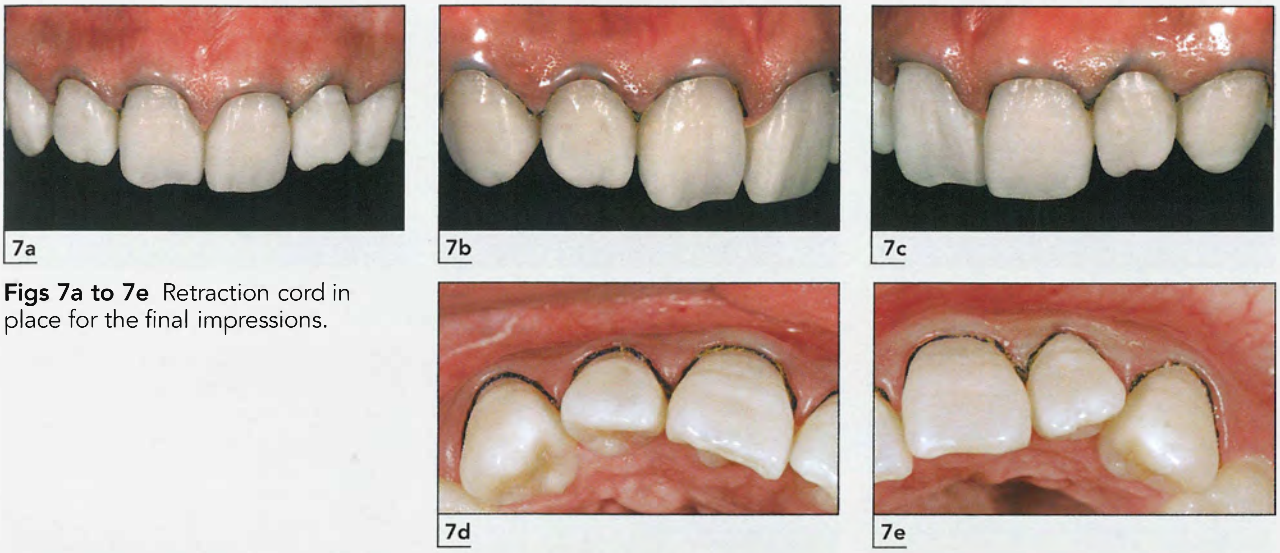
For cases in which a minimal preparation is planned, the wax-up procedure must be conducted with an additive technique (Fig 4). The information collected through the photography protocol and semi-adjustable articulator enabled the development of all characteristics required for a successful smile during the additive wax-up, based on an esthetic checklist.[19]

The ceramist added wax to the preliminary cast based on the anatomical parameters of natural teeth and respecting the function and occlusion. In this step, the technician should recover the desired smile and establish adequate occlusal function.

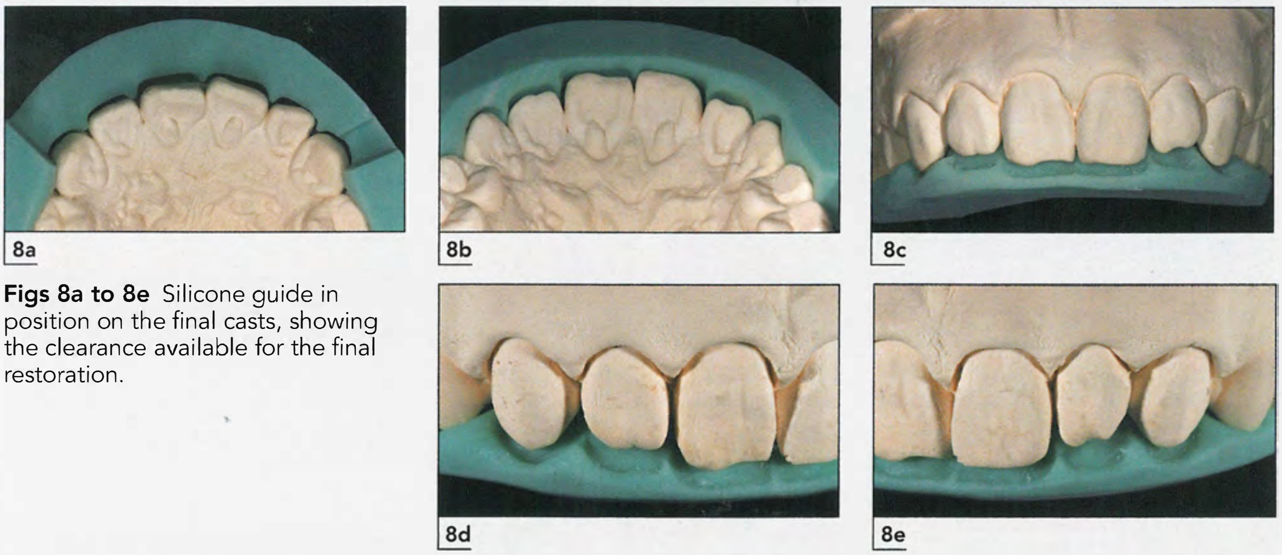
Another important issue in cases with no or minimal preparation is the lack of a provisional stage. Therefore, the patient must approve the final esthetic design in the mock-up session.

Mock-up

The waxed-up preliminary cast was transferred to the mouth for clinical evaluation in terms of shape, size, and length. The mock-up acts as a blueprint for the final restoration. A bis-acrylic resin (Protemp 4, 3M ESPE, St Paul, Minnesota, USA) was used. The material was loaded into a silicone guide made on the wax-up (Fig 5) and positioned in the patient's mouth (Fig 6). Any alterations desired by the patient or deemed necessary by the clinician must be analyzed. This step is important in any treatment involving laminate veneers because it will help the ceramist finalize the smile design. After patient approval, all information was collected from the mock-up using digital photography and an alginate impression to obtain a cast. The mock-up was then removed from the mouth, and the teeth were cleaned and pumiced for impression procedures.



Figs 7a to 7e Retraction cord in place for the final impressions.



Figs 8a to 8e Silicone guide in position on the final casts, showing the clearance available for the final restoration.

Impression Procedures

A VPS one-step, double-mix impression technique was used to produce an appropriate reproduction of the teeth and surrounding tissues. Two impressions of each arch were taken to ensure proper control. Thin retraction cord (Ultrapack no. 00, Ultradent, Salt Lake City, UT, USA) was placed in the sulcus for better visualization of the cervical region. In this case, there was no intrasulcular margin even though the cord was placed to deflect the gingival tissue (Fig 7). This procedure helps to establish the limits of the restoration in the final cast. In some cases, the interproximal areas of the mold may tear during removal from the mouth. If this occurs, the interproximal spaces must be filled with composite resin (Opal Dam, Ultradent).

Laboratory Procedures

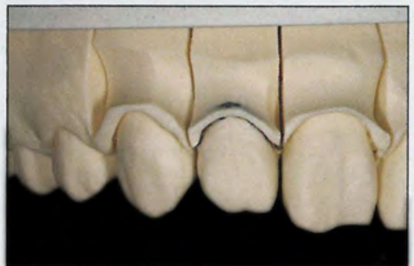
All information obtained from the mock-up, including a new set of photographs and alginate impressions, was sent to the laboratory. Two casts were poured from the same mold. The molds were poured and remounted on the articulator. One was kept intact and the other was sectioned. Based on the wax-up and the cast obtained by the mock-up, the ceramist determined the space available for the veneers (Fig 8).


9a


9b


9c


10a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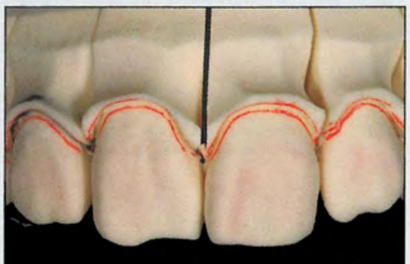
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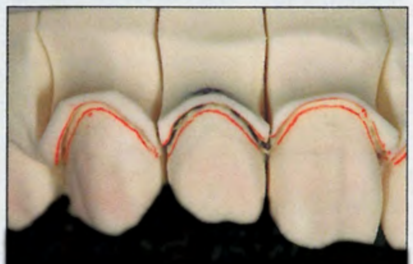
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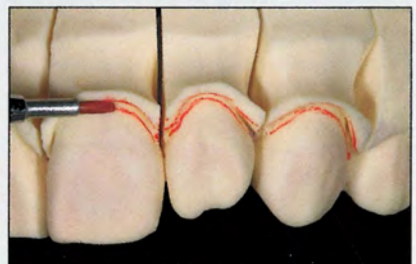
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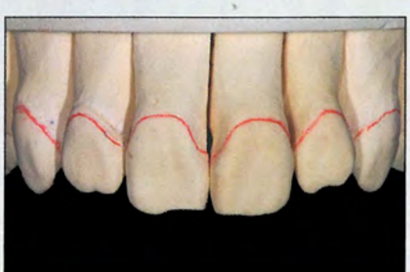

12a


12b

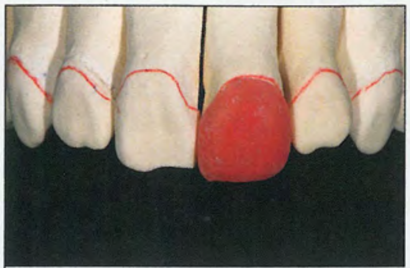
Figs 9a to 9c Final master cast before preparation to produce the final restorations.

Figs 10a to 10c Sectioned cast preserving the area reflected by the retraction cord.

Figs 11a to 11c The limits of the gingival margins were marked with red pencil.

Figs 12a and 12b The cast and dies after the stone margin was trimmed. Note that the red line marks the limit of the restoration and helps maintain the veneer at the level of the gingival margin.

An important step in this technique is the stone cast preparation of the sectioned mold. The retraction cord used for the final impression permits better visualization of the intrasulcular area (Fig 9). An initial trimming procedure was carried out 1 mm below the gingival margin of each individual die (Fig 10). A line was drawn with red pencil at the level of the gingival margin (Fig 11). As the retraction cord reflected these areas, the red line marked the finishing line of the future restoration. Next, each die was trimmed (Fig 12).



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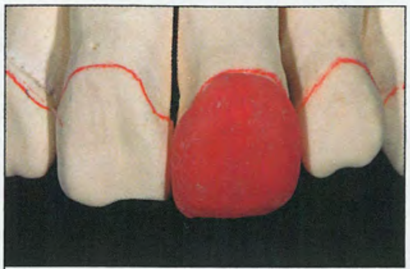

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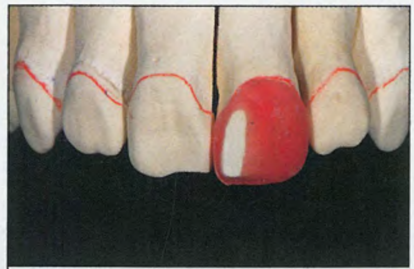

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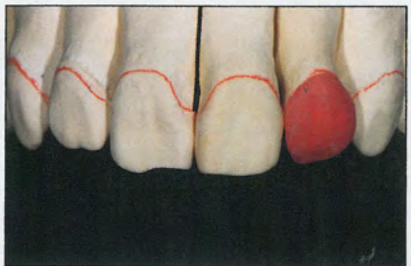

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13e

Figs 13a to 13e UCV preparation guide for the left central and lateral incisors. Tooth preparations were performed through the guide window only where insufficient space was available for the veneers.

Figs 14a and 14b Red marks on the solid master cast showing the prepared areas.

14a

14b

For this treatment modality, the path of insertion of the future restoration must be evaluated. The UCV is based on the concept that tooth reduction should be performed only when there is insufficient clearance for the restoration. As planned, the laboratory would guide any reduction necessary. Only areas that showed no path of insertion or insufficient space for the ceramic would be altered on the cast. After determining those areas, if any, the technician must create a preparation guide to use in the patient's mouth. Thus, before preparation of the cast, the ceramist for this case created the UCV preparation guide with acrylic resin (GC Pattern Resin, GC America, Alsip, Illinois, USA). The guide was fabricated in the specific area that required reduction. The reduction was carried out through the window of the guide (Fig 13). After proper reduction, the preparation guide was removed, and the clearance was checked using the previously made silicone guide obtained from the wax-up. If more room was necessary, the guide was repositioned on the cast and more stone was removed. The same UCV preparation guide used in the cast would be used for intraoral tooth reduction. In this case, only the facial aspect of the left central and lateral incisors required reduction (Fig 14).

15a

15b

15c

15d

Figs 15a and 15b Master cast with the final wax-up.

Figs 15c and 15d Wax sprues in position for the investing procedure.

The wax-up of the final restoration was fabricated on the modified master cast (Fig 15). Six laminate veneers were injected with a high-translucency LDGC ingot (IPS e.max Press, Ivoclar Vivadent). A careful divesting process was carried out in two steps: rough divesting with polishing beads at a pressure of 4 bar (60 psi) and fine divesting with the same material at 2 bar (30 psi). Sprues were cut off using a diamond disk. Any morphologic corrections and marginal adaptation were performed, and the veneers were adjusted on the solid master cast. Marginal adaptation was checked on the sectioned cast.

The restorations were stabilized for occlusal adjustments, and confirmation of the anterior guidance was obtained in the wax-up. Final anatomy and morphology were also determined at this time (Fig 16a).

With the final morphology defined, stains were applied to achieve life-like characteristics. For example, blue stain was used for the incisal edge and interproximal areas, while white stain was used for the mammelons. The veneers were then baked. Glass powder was used to protect the stained surface, and superficial gloss was applied using a rubber wheel and pumice powder. The thin veneers were checked again in the master cast and delivered to the clinician (Figs 16b to 16f).

Fig 16a Laminate veneers adapted to the master cast before staining and glazing.

Figs 16b to 16d Final restorations on the solid master cast after polishing.

Figs 16e and 16f The final veneers were kept very thin.

16a

16b

16c

16d

16e

16f


17a


17b


17c


18a


18b


18c


18d

Fig 17a Solid master cast with the stone reduction of the left central and lateral incisors.

Figs 17b and 17c Sectioned master cast with the UCV preparation guide in position.

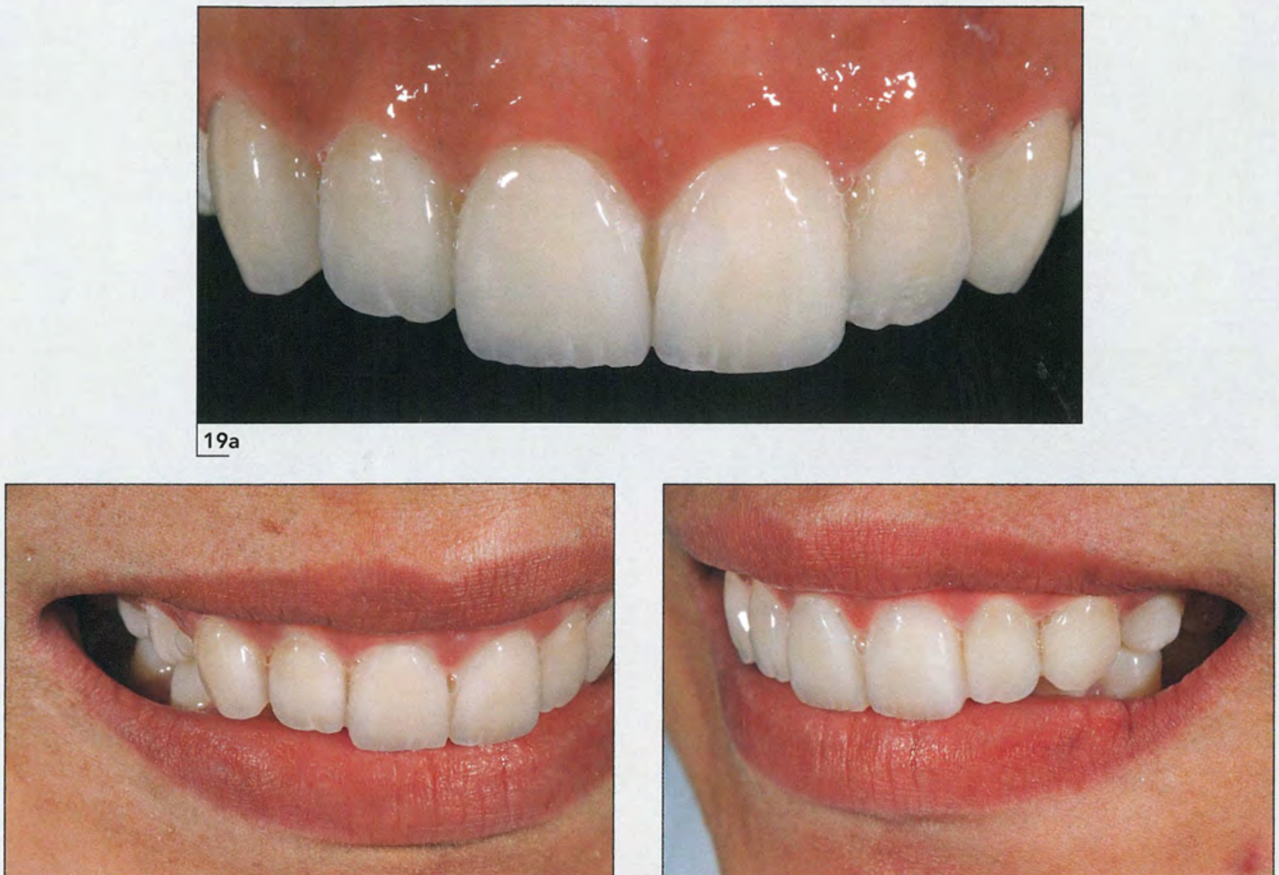
Figs 18a to 18c UCV preparation guide in position before enamel reduction.

Fig 18d Diamond bur used for the preparation through the guide window (previously trimmed in the laboratory).

Tooth Preparation

The laboratory sent the following materials to the clinician: the solid prepared cast, sectioned prepared cast, UCV preparation guide (Fig 17), and final restorations.

The preparation guide was positioned in the mouth for tooth reduction. It is extremely important to stabilize the guide for preparation (Figs 18a to 18c). A thin tapered diamond bur (Fig 18d) was used to reduce the labial crests of both teeth as in the laboratory phase. Finishing procedures were carried out with finishing disks (Soflex, 3M ESPE) only at the areas prepared with the diamond burs. As for any procedure involving laminate veneers, the marginal adaptation, interproximal contact, anatomical characteristics, and shade were then examined.



19a

19b

19c

Figs 19a to 19c Glycerin-based try-in paste used to evaluate the fit and shade of the resin cement.

Try-in and Bonding

Since no provisional restoration was used, the soft tissue remained stable and healthy. For this reason, it was not necessary to apply any special hemostatic control protocols for try-in and bonding.

Correct selection of the resin cement plays an important role in the final result when using laminate veneers. Try-in paste (Variolink Veneer Try-in Paste, Ivoclar Vivadent) was used to determine the appropriate shade. Once the restorations were in place and filled with the try-in paste, the clinician and patient checked the final result (Fig 19).

The LDGC restorations were prepared for bonding. Initially, the intaglio surfaces of the veneers were etched with 9% hydrofluoric acid for 20 seconds. After washing to remove the acid, the UCVs were placed in a glass container with distilled water and cleaned ultrasonically for 5 minutes to remove any residual material. The surface was air dried, and a silane coupling agent was applied for 2 minutes. Evaporation of the solvent was completed with a constant blow of air. The intaglio surface was coated with a hydrophobic bonding agent (Heliobond, Ivoclar Vivadent) and thinned by a gentle blow of air. The adhesive was left uncured, and the previously selected resin cement (Variolink Veneer +2, High Value, Ivoclar Vivadent) was injected carefully into the veneer. The veneer was protected with a plastic cover to avoid premature adhesive polymerization.

The enamel was pumiced, followed by air abrasion with aluminum oxide particles at 40 psi (PrepStart H_2O, Danville, San Ramon, California, USA). The surface of each tooth was etched with 37% phosphoric acid (Ultraetch, Ultradent) for 60 seconds, washed, and dried. The same adhesive used for the intaglio surface of the ceramic was applied (Heliobond) and also left

20a

20b

20c

Figs 20a to 20f Final result showing the six laminate veneers after 4 months.

uncured. For laminate veneers, light-cured resin cement (Variolink Veneer, Ivoclar Vivadent) is indicated for better color stability.

Next, each restoration was positioned on the specific tooth. Excess resin cement was removed, and a light source was used for curing for 40 seconds in four directions. A glycerin-based jelly (Liquid Strip, Ivoclar Vivadent) was applied to block the air. Each surface was light cured once more for 20 seconds. A new and sharp scalpel was used to remove excess adhesive and resin cement. For interproximal areas, finishing procedures were performed with abrasive composite resin

20d

20e

20f

strips (Epitex, GC America). To prevent scratching of the ceramic surface, the use of diamond strips should be avoided and the procedure must be carried out with caution.

For better control of the bonding sequence, the veneers were cemented one at a time. Occlusal adjustments were made with a diamond polishing system designed specifically for ceramic (Optrafine, Ivoclar Vivadent). All interproximal spaces were flossed to remove any excess material. Figure 20 shows the final result after 4 months.

CONCLUSIONS

The clinical success of laminate veneers depends on careful treatment planning. Among the factors responsible for success, enamel preservation is the most important. When teeth are prepared for ceramic veneers without proper planning, overpreparation often leads to dentin exposure, thus reducing long-term clinical success. However, when the case is carefully planned and the tooth preparation is guided by the laboratory technician, maximum hard tissue preservation can be ensured. The UCV technique proposed in this article can be used to minimize tooth preparation and maximize enamel preservation. In addition, etchable LDGC associated with this technique facilitates superior handling and bonding procedures. The UCV makes it possible to provide highly esthetic restorations with minimal tooth preparation to a large number of patients.

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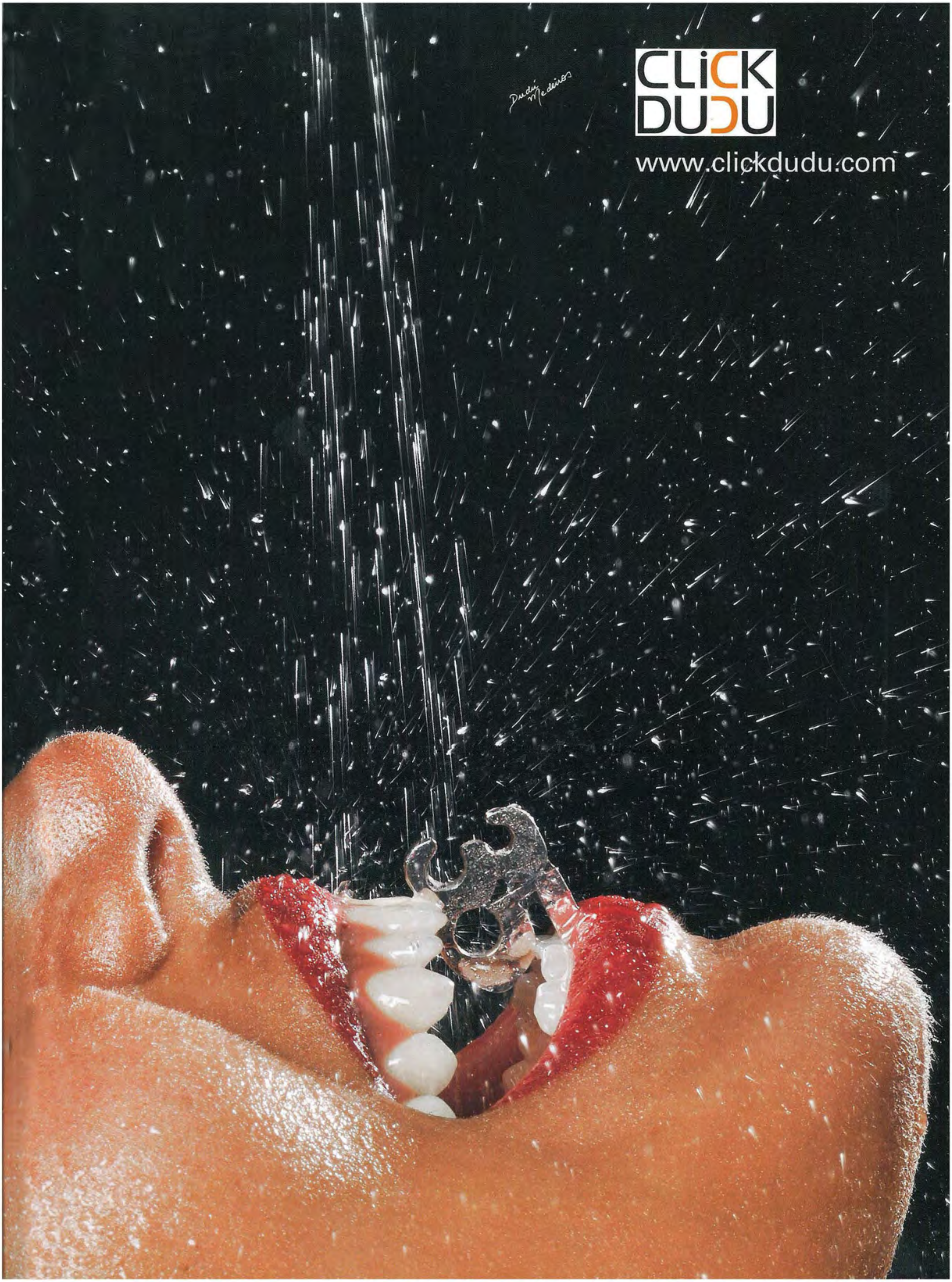
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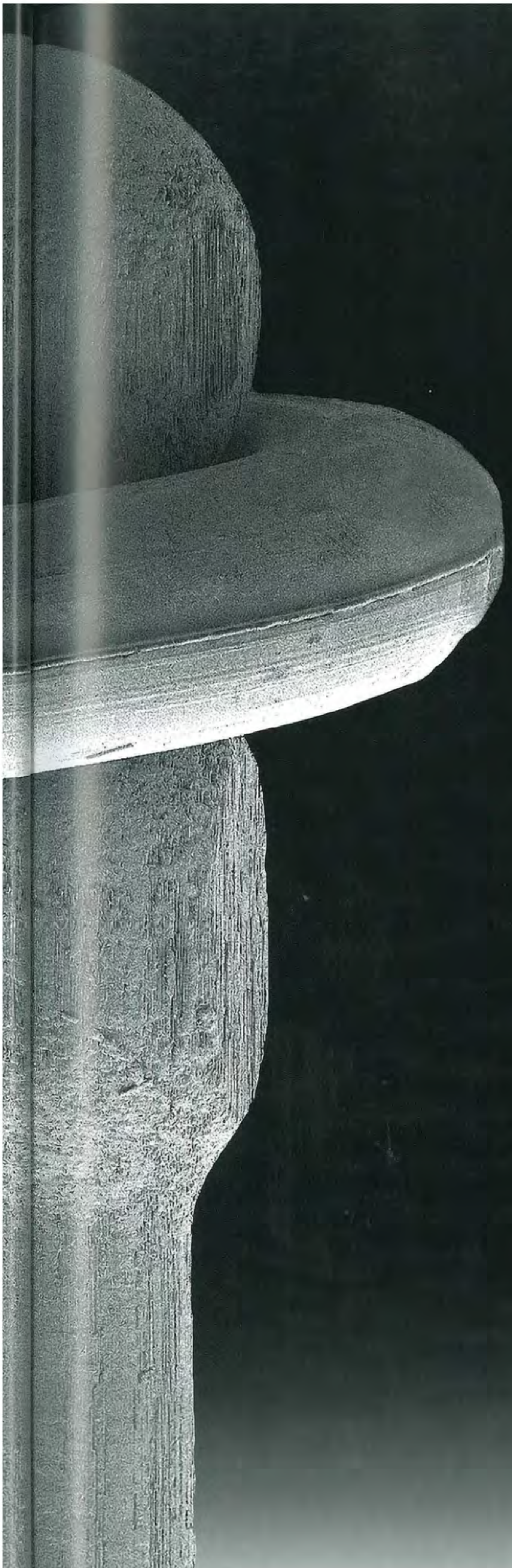


A Comprehensive Guide for Post and Core Restorations

Jin-Ho Phark, DDS, Dr Med Dent[1]
Neimar Sartori, DDS, MS, PhD[2]
Luana Oliveira, DDS, MS, PhD[3]
Sillas Duarte, Jr, DDS, MS, PhD[4]

The survival of endodontically treated teeth depends on many factors, such as occlusal contacts,[1,2] the number of proximal contacts,[3] tooth location in the dental arch,[4,5] crown placement,[6,7] type of abutment,[4,7] the apex st atus,[8] hard tissue loss due to carious lesions, previous restorations or endodontic access,[9–12] and the periodontal status.[13,14] As endondontically treated teeth often have insufficient coronal tooth structure, placement of a post is sometimes necessary to provide adequate retention for the core and final restoration. In such cases, the amount of remaining tooth structure,[15–17] the post and core material,[10,18] the luting agent,[19,20] the overlying crown,[21,22] and functional occlusal loads need to be considered as well.[23,24]

This article explores the current concepts for bonding fiber-reinforced posts to root canals and for core buildup. Two main topics are addressed: *(1)* the biomechanical concerns of fiber-reinforced composite (FRC) post and core buildup and *(2)* challenges in bonding to root canals.

[1]Assistant Professor, Division of Restorative Sciences, Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA.

[2]Assistant Professor, Department of Restorative Dentistry, University of South Santa Catarina, Tubarao, SC, Brazil.

[3]Assistant Professor and Director, Postgraduate Program in Operative Dentistry, Nova Southeastern University, Fort Lauderdale, Florida, USA.

[4]Associate Professor and Chair, Division of Restorative Sciences, Director of Advanced Program in Operative Dentistry, Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA

Correspondence to: Dr Jin-Ho Phark, Ostrow School of Dentistry of USC, DEN 4112, 925 W 34th Street, Los Angeles, CA 90089-0641, USA. Email: phark@usc.edu

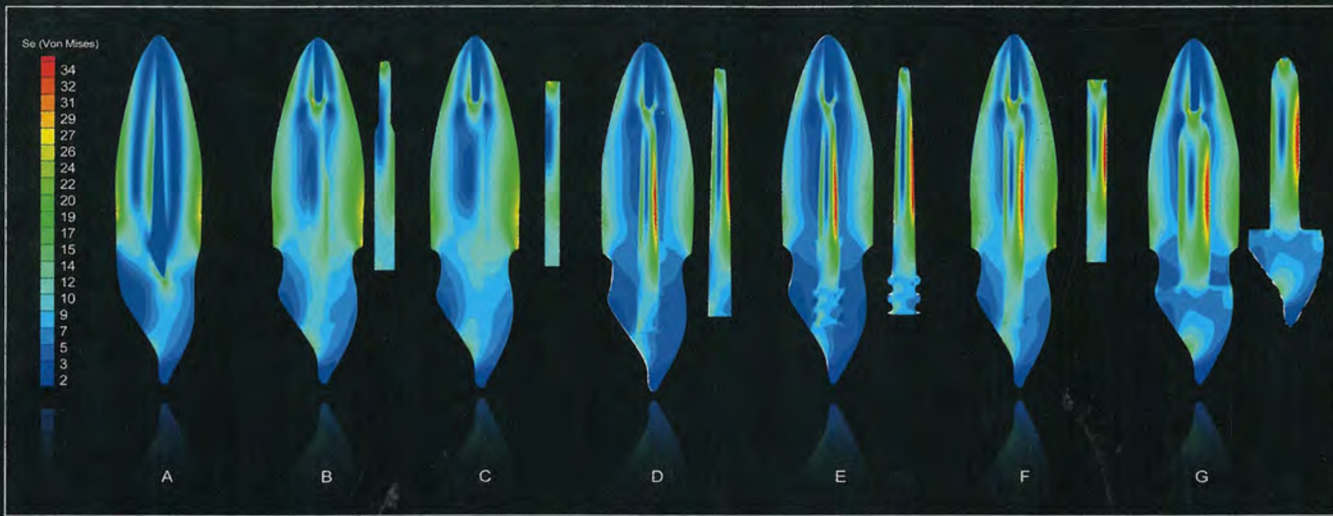


Fig 1 von Mises stresses in endodontically treated tooth after crown preparation: (A) intact tooth, (B) carbon fiber, (C) glass fiber, (D) zirconia, (E) stainless steel, (F) titanium, (G) cast metal.

BIOMECHANICAL CONSIDERATIONS FOR FRC POSTS

Stress Distribution

Biomechanical changes of endodontically treated teeth restored with posts and cores have been a subject of interest to clinicians, educators, and researchers for many years. Although cast posts have a long history of clinical use, demand for FRC posts to restore endodontically treated teeth has already impacted the quotidian general and prosthodontic practice.[25] In spite of this, questions regarding the biomechanical properties of FRC posts and associated tooth behavior remain controversial.[26,27]

The main purpose of a post is to retain the coronal restoration of an endodontically treated tooth with extensive loss of coronal tooth structure.[28] Understanding the biomechanical factors that affect the ability of a post to retain a restoration and protect the remaining tooth structure is paramount for long-term success. Finite element analysis (FEA)[29] and photoelastic[5] studies have been used as valuable methodology to analyze the stress of endodontically treated teeth restored with different post systems. When a post is bonded to the root canal of a structurally compromised tooth, a significant change in its biomechanical behavior occurs.[30] Stress is directly proportional to deformation. Thus, the type of post (fiber, quartz, zirconia, gold, stainless steel, or titanium) determines the stress distribution and it has a significant effect on the stress concentration.[29] This fact was shown by analyzing the stress distribution of a maxillary central incisor restored with different post materials in a 2D finite element study (Fig 1). Areas of stress concentration represent an increasing risk of tooth fracture and debonding of interfaces.[31]

Critical areas of stress concentration are located at the external cervical area of the tooth and at the middle third of the root canal in a maxillary central incisor during occlusion (Fig 2). During occlusion, stress is observed at the external coronal portion of the root just below the clinical crown (Fig 2, A). However, when a post is placed, an increased stress concentration is found at the internal buccal plate of the root where the post contacts the tooth (Fig 2, B). Carbon fiber and glass fiber posts produce the least amount of stress at the buccal portion of the root at the post-root interface compared to other post materials (Fig 3). Stress concentration around the post increases the stress at the adhesive interface, which may jeopardize bonding and decrease the survival rate of the restorative complex. Considering that the post–dentin-bonded interface is the critical area for stress concentration, any dental intervention that may lead to excessive removal of sound tooth structure can increase the risk of root fracture.[32]

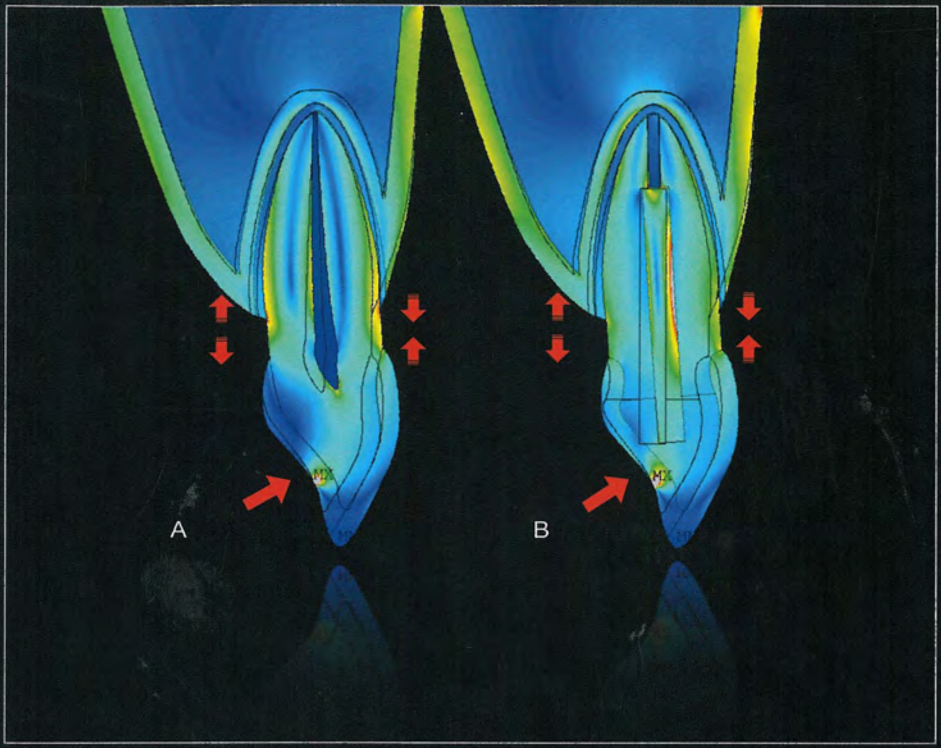


Fig 2 Stress concentration during occlusion: (A) intact maxillary central incisor, (B) endodontically treated maxillary central incisor restored with all-ceramic crown and post.

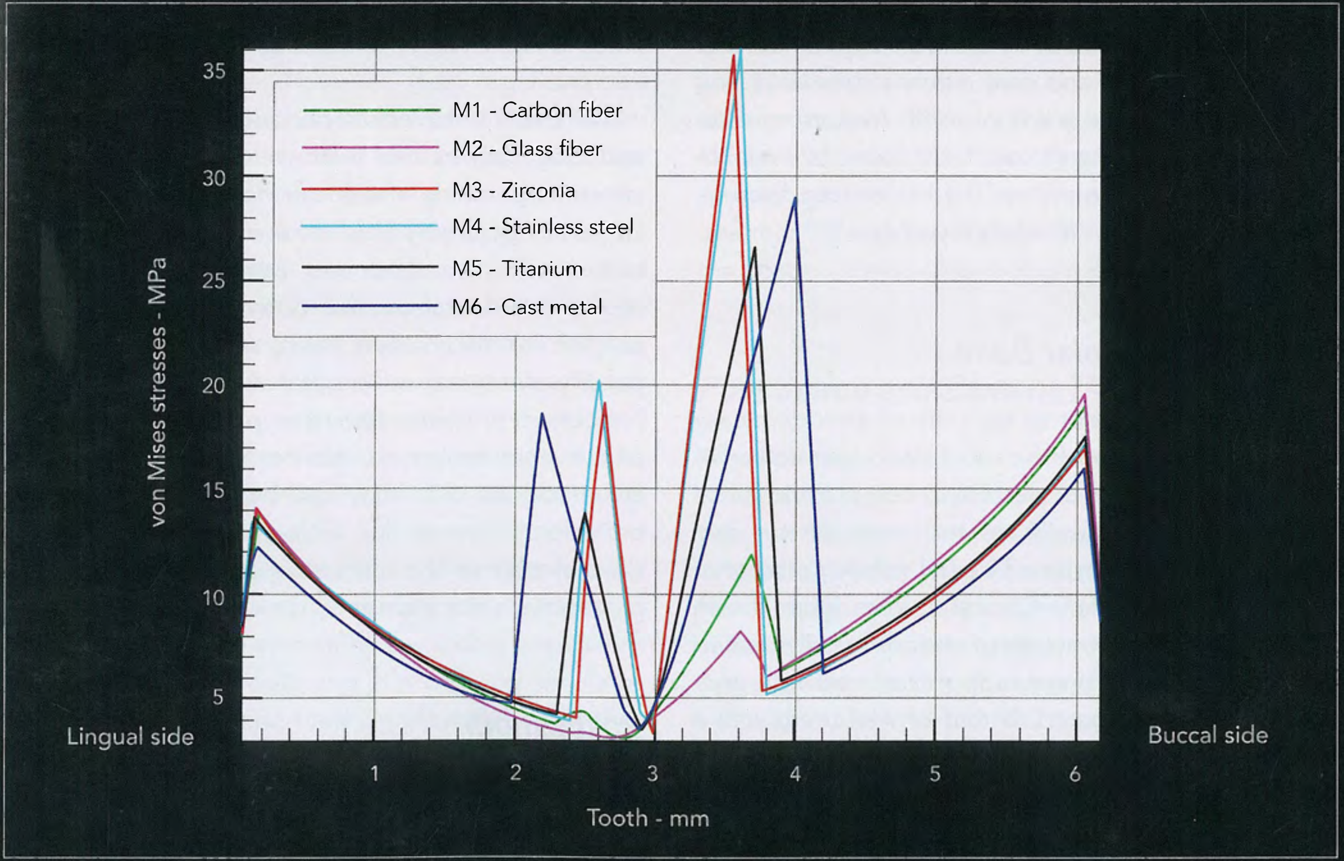


Fig 3 Distribution of von Mises stress (buccal-lingual cross section) at the cervical third of a maxillary central incisor restored with different post systems.

Table 1 Physical Properties of Dental Tissues Compared to Endodontic Post Materials

	Elastic modulus (GPa)	Thermal expansion coefficient (X10-6/oC)	Ultimate tensile strength (MPa)
Enamel	~ 80	~17	~10
Dentin	~14	~11	~44–105
Fiber post	45–220	5.4–7.2	760–1020
Titanium	~110	8.6–11.9	550–930
Zirconia	300	10.3	~25–40
Stainless steel	200	9.9–17.3	860
Gold	~100	14.4	221–759

Adhesively luted FRC posts have demonstrated satisfactory long-term survival rates.[33] The long-term success of these restorations has been attributed mainly to the biomimetic behavior of FRC posts. Table 1 shows the physical properties of different post materials. The stiffness of the post and core induces stresses during loading, increasing the risk of tooth fracture or catastrophic failure of the restorative system.[34,35] Prefabricated FRC posts can reduce the risk of root fracture, and failures are often clinically repairable.[35–37]

Remaining Alveolar Bone

The status of periodontal support of endodontically treated teeth is one of the most important considerations for indication of posts and cores. Periodontal failure of endodontically treated teeth is the second most frequent type of dental failure (32%) after crown fracture (60%).[13] Clinical studies have shown an increased risk of fracture of endodontically treated teeth with reduced bone support restored with endodontic posts compared to that of vital teeth with a comparable bone condition.[14] Finite element analysis (FEA) studies have suggested that mechanical stress increases as bone support is reduced.[38] At the lowest level of bone height, root stresses were 4 to 10 times greater than in teeth with normal bone height. An in vitro study simulating bone loss around teeth restored with posts showed that those without bone loss had the highest load capability, whereas bone loss of 25% and 50% height markedly decreased load capability.[39] Thus, alveolar bone loss increases the risk for root fracture.[38]

The decision to restore periodontally compromised endodontically treated teeth with posts or by surgical crown lengthening should be made carefully. Crown lengthening surgery may result in inadequate crown-to-root ratio, compromised esthetics, possible loss of the interdental papilla, potential compromise of support for the adjacent teeth, and reduced load capability. When crown lengthening is not desirable or possible, orthodontic forced eruption may solve some of the aforementioned risks but not all of them. The crown-to-root ratio may still be compromised, and orthodontic intervention adds significant time and additional cost to the restorative procedure, making it unfeasible in many cases.[15]

Post Length

Retention increases with the length of the posts, irrespective of what material the post is fabricated (fiber, titanium, or cast).[40–42] Frictional retention is directly proportional to the contact area: the larger

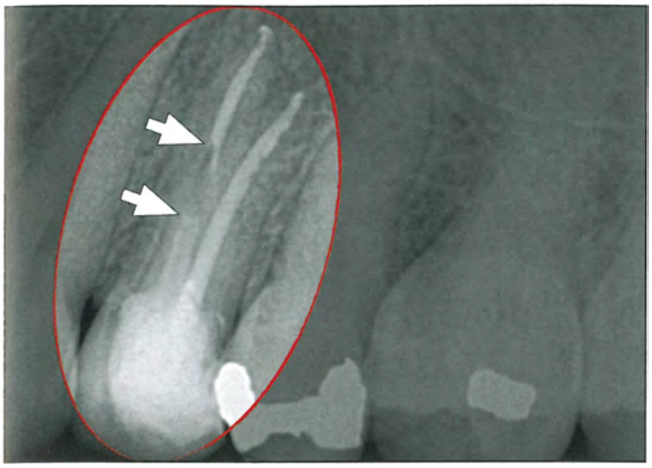


Fig 4a Periapical radiograph showing excessive gap between the tip of the post and the remaining gutta-percha.

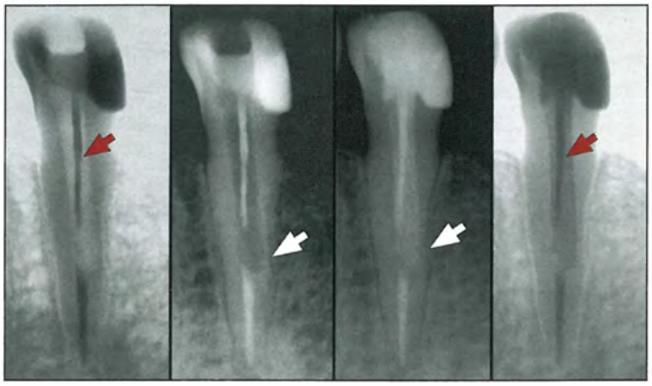


Fig 4b Periapical radiograph showing remaining gutta-percha in the prepared post space, which might impair proper bonding of the FRC post *(red arrow)*, and deviation of the canal post space due to the original canal direction and incorrect pilot bur angulation and size (note the reduced root dentin thickness—*white arrow*).

the contact surfaces, the better the retention. This fact explains the results found in macro pull- or push-out tests, in which the complete post was pulled or pushed out.

Another aspect influenced by the length of posts is fracture resistance. However, data regarding this topic is not conclusive. Studies showed that in stainless steel posts,[43] cast posts and cores,[36] and fiber posts,[43,44] post length did not influence the biomechanical performance of the restored teeth. A recent in vitro study showed that endodontically treated teeth restored with short fiber posts survived fatigue loading as well as long fiber posts.[45] Short posts may lead to more favorable failures than long posts, thus allowing re-intervention and preservation of the tooth.[45] Higher fracture resistance for short posts may also be explained by the less invasive buildup approach than that required for long posts.

However, it was reported that 10-mm-long posts increased fracture resistance compared to 6-mm-long posts.[36] In another in vitro study evaluating even shorter posts after cyclic fatiguing in a chewing simulator, 6-mm-long posts performed significantly better than 3-mm-long posts.[46] Post length should be evaluated carefully, taking into consideration the amount of bone support around the root, remaining root dentin thickness, stress concentration, and the type of restorative treatment indicated.

The amount of remaining root canal filling material is fundamental, since the apex is an area of greater anatomical complexity, with many lateral and accessory canals.[47,48] Endodontically restored teeth that have at least 5 mm gutta-percha left in the apex region show low numbers of apical periodontitis.[49] Yet, gaps between root canal filling and the apical tip of the post must be avoided because of possible periapical pathosis (Figs 4a and 4b). The success rate of endodontic treatment is significantly affected by the gap between the post and remaining root canal filling.[49]

Post Space and Cement Thickness

When placing posts in accordance with standard clinical protocols, pilot drills are used to create a form-congruent root canal up to the apical third of the root to ensure primary post fit and retention (Fig 5). This "form-congruence" aims to create maximal adaptation of the post to the surrounding root canal walls with a thin and even post-root cement interface.[50] A better adaptation and fit of the FRC post to the root canal facilitates stress distribution along the canal wall during clinical function.[51] The retention of prefabricated posts cemented with non-adhesive techniques is inversely proportional to the disparity between the diameter of the post and that of the canal.[50,52,53]

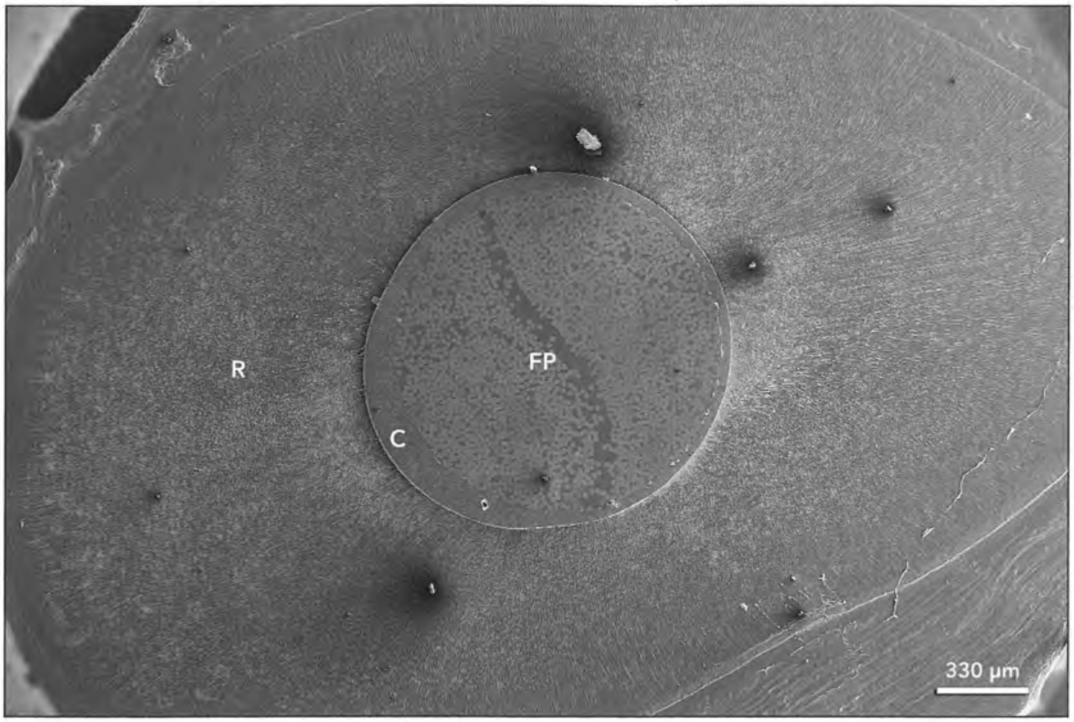


Fig 5 Form-congruence of post and dentin. C, cement; R, root; FP, fiber post.

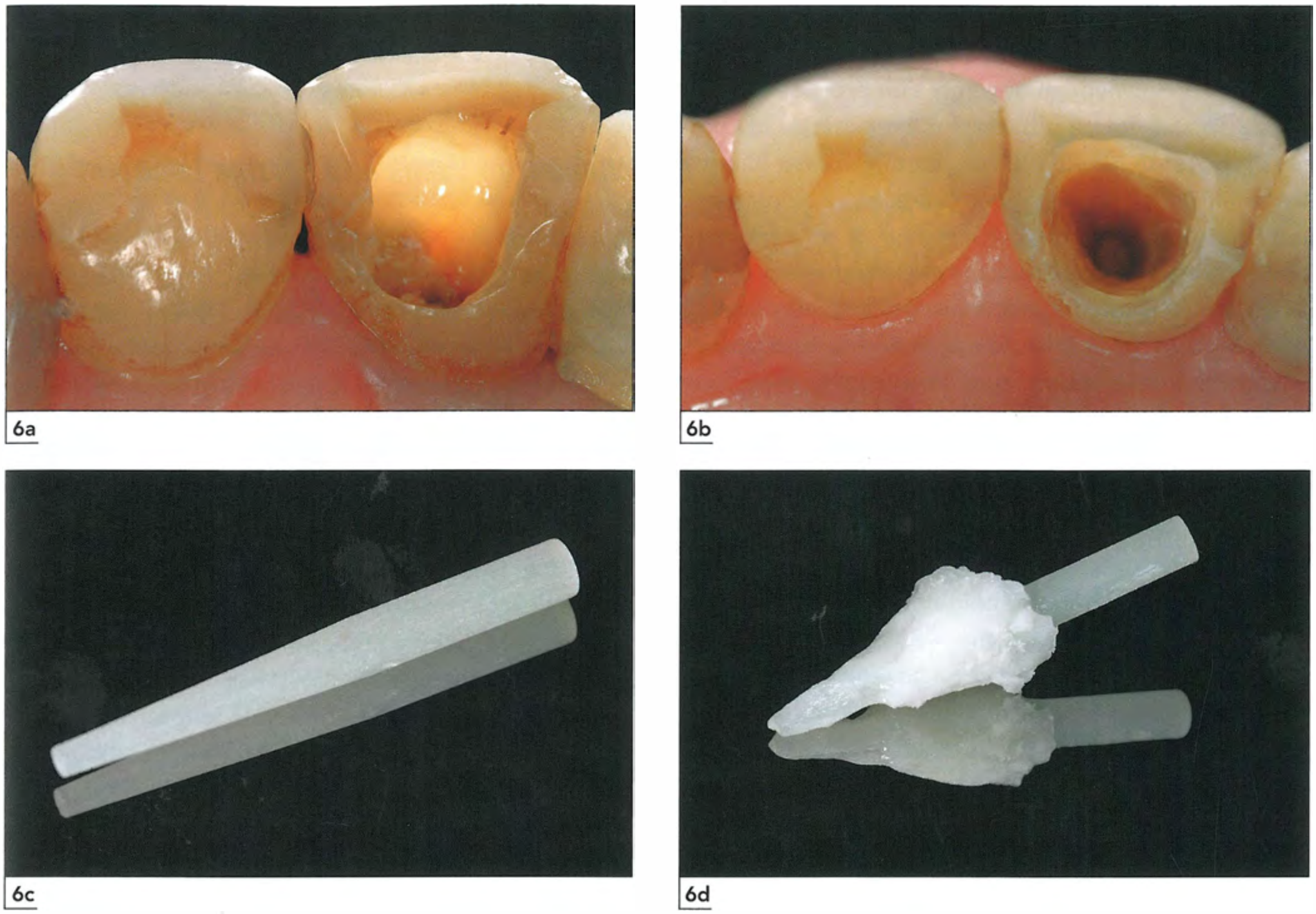
Especially in teeth with oval or irregularly shaped canals, preparation of a round and form-congruent post space can lead to excessive removal of the inner dentin, resulting in weakening and reduced fracture resistance of the tooth.[54] In irregularly shaped canals (no form-congruence)[46] the use of oval posts and preparation tips[55,56] is necessary to avoid excessive tooth reduction. A post must always be selected with the aim to preserve the inner dentin structure; therefore, to correspond best to the natural root-canal diameter with no or minimal preparation of the root canal.

Post Diameter

For metal posts, the diameter seems to have a significant impact on fracture resistance. Increasing the diameter has been shown to lower fracture resistance,[43,57] evidently by the additional removal of dentin to accommodate the larger post diameters. However, for FRC posts, no influence of the post diameter in biomechanical performance[43] or bond strength tests[58] has been observed.

Flared Root Canals

Despite data indicating that cement space does not affect bond strength in ideally shaped canals, bonding to wide and flared root canals is still a concern. The high configuration cavity factor (C-factor) within the canal may lead to gap formation because of polymerization shrinkage of the thicker cement either along the cement-dentin interface or the cement-post interface.[59,60] Additionally, thicker cement layers might present voids or air bubbles, which are frequently introduced during application of the cement into the canal.[61–65]



Figs 6a and 6b Tooth showing weakened root due to wide and flared canal. *(a)* Lingual view. *(b)* Incisal view. *(c)* FRC post. *(d)* Customization of FRC post after reline with composite.

To overcome the aforementioned issues, relining fiber posts with resins, fibers, or additional auxiliary posts is an attempt to minimize the cement gap and customize the post to the shape of the root canal. Relining a post increases its retention and the fracture strength of the teeth.[37,66] In addition, relining is also beneficial to reduce the stress transfer to the cervical root surface (Figs 6a to 6d).[67] Auxiliary fiber posts also increase fracture strength, but they do not necessarily increase post retention.[68]

Influence of Ferrule on Fracture Resistance

The origin of the term *ferrule* is thought to come from the Latin terms *viriola* (small bracelet) and *ferrum* (iron). In technical terms it is an encircling band or clamp, mostly made of metal for fastening, joining, or reinforcement of fibers, wires, or posts. In dentistry the ferrule or ferrule effect is defined as a "360-degree metal collar of the crown surrounding the parallel walls of the dentin extending coronal to the shoulder of the preparation. The result is an increase in resistance form of the crown from the extension of dentinal tooth structure."[69] Providing resistance to dislodgment, it also prevents fracture. Often the term *ferrule* is misinterpreted; it is used synonymously as an expression of the amount of remaining sound dentin above the finish line. In fact, it is not the remaining tooth structure but rather the actual bracing of the complete crown over the tooth structure in the gingival aspect above the preparation margin that constitutes the ferrule effect.[15]

The ferrule is considered crucial to stabilize endodontically treated restored teeth and for their prognosis.[16,23,24] However, in severely compromised teeth, ferrule should not be provided at the expense of coronal or root structure.[15,17] It is important to bear in mind that a ferrule effect is just one piece of a complex system that ensures correct restoration of an endodontically treated tooth. The clinical performance of the entire restorative complex is also affected by several other factors, including the post and core material, luting agent, overlying crown, and functional occlusal loads.[70]

Ferrule Height

Having sufficient dentin height is fundamental for a stable restorative system. The ferrule height significantly increases the fracture resistance[71] and the number of loading cycles before failure.[72,73] While 1.0 mm of vertical height appears to be a minimum compared to teeth without a ferrule,[69,73] other studies reported that 1.5 to 2.0 mm or even more remaining vertical tooth structure provided superior long-term performance.[72,74–78] Even though some studies reported no benefit of the ferrule in comparison to teeth with no ferrule,[79,80] fracture patterns were more favorable when a ferrule was present. Furthermore, the majority of fractures in teeth without a ferrule are nonrestorable.[79]

Ferrule Width

It is the thickness of the coronal extension above the crown margin that is thought to be significant in the fracture resistance of crowned teeth.[15] The thickness of the buccal wall can be severely compromised by aggressive preparation to suit esthetic demands or previously existing large caries lesions or existing crowns. Clinically, dentin walls less than 1.0 mm in width might be considered too thin.[15] Even so, minimal thickness of 1.0 mm for the remaining dentin walls is frequently accepted,[23,81] but such thin walls tend to fracture more often than 2.0- or 3.0-mm-thick walls.[82] Therefore, the preparation for post and core buildup must be as minimally invasive as possible. Maximum preservation of dentin walls is the aim to obtain adequate ferrule.

Number of Walls and Ferrule Location

Various studies have demonstrated superior performance of a homogeneous and circumferentially even ferrule over a ferrule that varies in different parts of the tooth.[83–86] However, it is not always clinically possible to prepare a circumferential ferrule of uniform height. A ferrule of non-uniform height, ranging between 0.5 mm proximal and 2.0 mm buccal and lingual, or a 2.0-mm ferrule present just on the palatal or buccal aspect, or even a ferrule interrupted by biproximal cavitation, is less effective in preventing failure than a uniform circumferential 2.0-mm ferrule.[84,85] Conversely, the presence of only a buccal or palatal wall improves the performance of a tooth that has no ferrule at all.[87,88] A tooth with a non-uniform ferrule length is still more fracture resistant then a tooth without ferrule.[83,85] Some strategies like crown lengthening or orthodontic forced tooth eruption might be necessary to provide an adequate ferrule.[15] Therefore, it is suggested that a 2.0-mm ferrule should be provided at least on the buccal and lingual walls.

Biomechanical Considerations of Core Buildups

The core material has a significant influence on the success of an endodontically treated tooth. Composite resin bonded to dentin can strengthen the tooth and reinforce cusps,[89] in addition to increasing the load capacity of endodontically treated teeth.[90] When adequate ferrule is present, the placement of a post does not significantly improve fracture resistance compared to teeth restored only with composite cores and no posts.[91,92] The survival rate for crowns with underlying composite buildups with and without posts and cast posts and cores is not different, only the remaining height of dentin after preparation is of influence.[93] Also, Jung et al reported no differences in survival and complication rate for cast post-and-core buildups and direct composite post buildups.[94] Thus, the amount of remaining tooth structure is what dictates the placement of a post.

The association of composite core buildup and fiber-reinforced posts leads to less catastrophic failure compared to that of titanium posts.[90] An in vivo 5-year and a 10-year study showed that composite buildups with prefabricated posts performed clinically similar to cast posts and cores.[93,94]

The procedures for post cementation and core buildup usually involve two steps, where the post is cemented first followed by the buildup usually with a composite-based material. Some resin cements, however, can be used as buildup material as well in a one-step procedure (eg, Paracore, Coltene Whaledent, Altstätten, Switzerland) because of their low viscosity. Recently the performance of a self-adhesive cement used simultaneously for cementation of the post and as buildup material was investigated.[95,96] However, the mechanical properties of self-adhesive cements need to be enhanced to validate this technique clinically.

Composite-based materials for core buildup still need to be applied in increments to reduce polymerization shrinkage. Polymerization shrinkage can lead to undesired microleakage at the gingival margins.[18] Recently developed low-shrinkage and bulk-fill composites may be an acceptable alternative to composite core buildup. In addition, composites offer the opportunity rebuild the abutment esthetically, providing not only adequate tooth color but also fluorescence. These optical properties are fundamental for anterior reconstruction when using thin veneers or glass-based ceramics. During composite placement, exposed fiber posts must be covered with the buildup material.

The provisional material used for temporary restoration may negatively affect the integrity of composite core buildups. Composites are affected by moist heat stress,[97] thus, when making acrylic resin provisionals on composite core buildups, the methacrylate exothermic reaction must be relieved by continuous water cooling. Conversely, bis-acryl provisional materials can adhere to composite core buildups if the oxygen inhibition layer is not completely removed after final polymerization and before fabrication of the provisional restoration.

BONDING CONSIDERATIONS OF FRC TO ROOT CANAL

Effect of Chemical Irrigants on Bond Strengths of FRC Posts

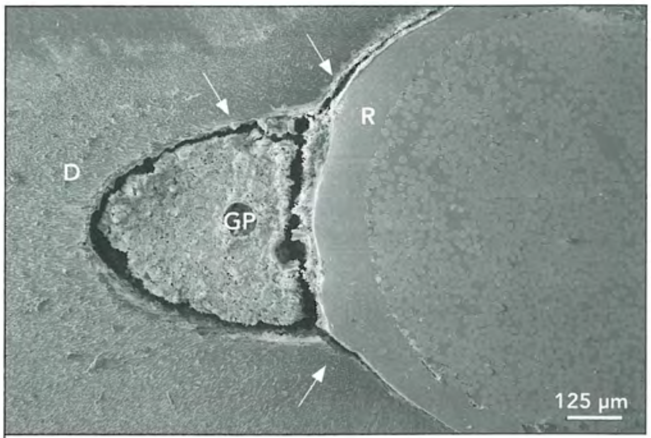
Hand and rotary instrumentation techniques used in endodontic treatment produce an irregular, granular, and amorphous layer that covers the dentin root canal.[98] Chemical irrigant solutions are used to clean the root canal and remove the smear layer created during root canal instrumentation. Chemical irrigants alter the dentin surface significantly and thus affect bonding to the root canal.[99–101] Nonetheless, the use of chemical irrigants during endodontic treatment is essential to remove pulp remnants and residual bacteria from the intricate root canal systems.[102,103]

Ethylenediaminetetraacetic acid (EDTA) is commonly used as a pre-final irrigating agent. EDTA demineralizes dentin and cleans root canal walls, improving the contact between the obturation material and dentin walls.[104] Sodium hypochlorite (NaOCl) also promotes debridement, lubrication, disinfection, tissue dissolution, collagen layer removal, and dentin dehydration.[103] Long-term exposure of dentin to a high-concentration sodium hypochlorite has a detrimental effect on dentin elasticity and flexural strength.[105,106] Microscopically, NaOCl causes permanent erosion of intertubular and peritubular root canal dentin.[107,108] Sodium hypochlorite reduces the bond strength between the root canal dentin and adhesive resin cements,[109] and its use as final irrigation should be avoided.[107]

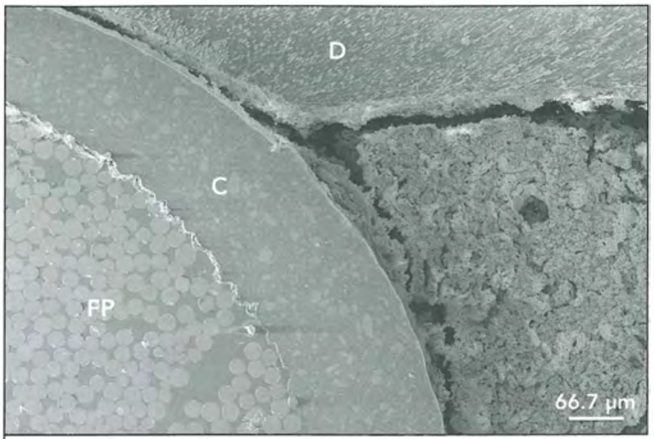
Chlorhexidine digluconate (CHX) has been increasingly employed as a potential chemical irrigant due to its antimicrobial properties and low-grade toxicity.[109,110] CHX can be used for final irrigation, at the end of the endodontic treatment, as a substitute for the NaOCl to promote additional disinfection without having any adverse effect on bond strength.[111–113]

Post Space Preparation, Smear Layer Removal, and Disinfection

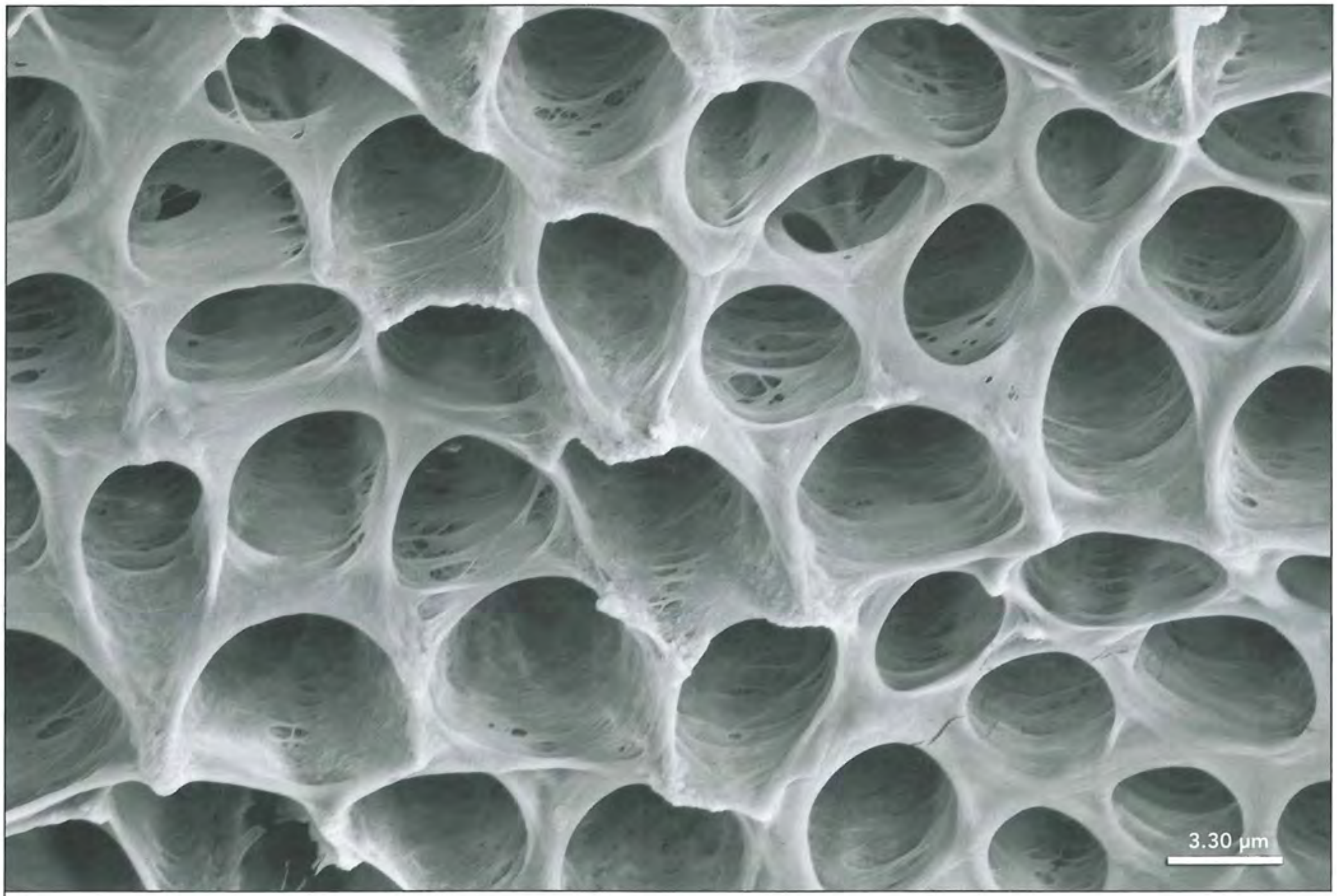
Post space preparation of endodontically treated teeth is needed to shape the root lumen according to prefab-



7a



7b



8

Figs 7a and 7b The presence of residual gutta-percha leads to gap at the adhesive interface between the cement and dentin. *(a)* Elliptical root canal showing remaining gutta-percha. *(b)* Higher magnification showing gap at the adhesive interface. D, dentin; FP, fiber post; GP, gutta-percha; C, cement.

Fig 8 Root dentin etched with 35% phosphoric acid for 15 seconds.

ricated posts. Mechanical preparation of the root canal improves the fit of prefabricated FRC posts to the root canal walls. Although post space preparation removes sound tooth structure, the superficial root canal dentin altered by canal irrigants or medicaments, or filled with canal sealers, is also removed.[114] The presence of residual gutta-percha in the canal prevents the adhesion between cement and dentin, leading to debonding at the adhesive interface or leakage (Figs 7a and 7b). However, rotary instruments are commonly employed without ideal irrigation, producing a thick smear layer with remnants of plasticized gutta-percha and sealer.[25]

Attaining clean dentin surfaces after mechanical post space preparation is an essential step for optimal post retention and bonding.[115] Acidic monomers presented in self-etching dentin adhesives or the self-etching resin cements are less predictable to modify the thick smear layer and to form the hybrid layer along the walls of the post space.[116] Moreover, the top of the hybrid layer produced by self-etch agents contains disorganized collagen fibrils that degrade over time, reducing post retention.[117] Acid etching of root dentin with phosphoric acid followed by copious water rinsing with an endodontic needle is helpful to remove the smear layer created after post space preparation (Fig 8).[118] However, the effectiveness of acid etching is questionable at the apical level, because intricate narrow and deep canals cannot be completely cleaned and free from the smear layer.[25,119–121]

Chemical irrigation with ultrasonic agitation was shown to be helpful for removal of the thick smear layer before the bonding procedures.[119,122,123] However, chemical solutions—often used during endodontic procedures (EDTA and/or NaOCl)—lead to severe erosion on the root canal dentin surface.[123,124] Specifically, NaOCl adversely effects the bond strength of self-etching adhesive systems[111] due to the oxidation of some dentin matrix component,[125] forming protein-derived radicals[126] that would compete with the spreading of vinyl free-radicals, resulting in premature chain termination and incomplete polymerization of the adhesive resin.[127] Recently, it was found that 17% EDTA significantly inhibits endogenous dentin matrix metalloproteinase (MMP) activity, minimizing hybrid layer degradation after bonding.[128] EDTA is a mild chelating agent that removes the hydroxyapatite and noncollagenous protein, selectively facilitating the mechanical interlocking of resin cement to interfibrillar collagen.[119] Nonetheless, long-term clinical studies are still needed to validate the efficacy of EDTA as a cleaning solution before bonding fiber posts.

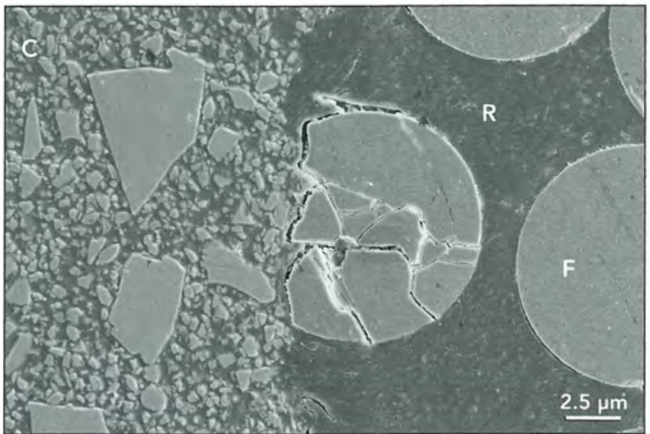
Disinfection of the root canal is imperative before any bonding procedures. For this purpose, CHX can be used as an effective disinfecting solution. The final irrigation with CHX promotes additional disinfection and stops the chelating effect without any adverse effect on bond strengths.[111–113] CHX is a strong MMP inhibitor, improving long-term bonding to decalcified dentin.[129] Disinfecting procedures after root space preparation are essential to increase and sustain adequate bond strength of fiber posts to the root canal.[111–113]

Pretreatment of FRC Posts

Bonding effectiveness in the root canal is decisive for the fiber post retention.[130] Special attention must be paid to the bonding interface of the composite cements and fiber posts.[116,130–132] The absence of a chemical union between methacrylate-based resin composites and the resin matrix of fiber posts—which are often made of epoxy resin—makes the procedure even more difficult.[131]

In an attempt to improve the resin bonding to fiber posts, numerous surface treatments have been proposed.[116] These approaches can be divided into three categories: *(1)* increase of the surface roughness, *(2)* chemical bonding, or *(3)* combined micromechanical and chemical treatment.[116,133]

To increase the surface roughness of fiber posts, etching with strong acid, air abrasion with aluminum oxide, and tribomechanical coating have been indicated.[134–136] Because the silica and quartz present in the fiber-reinforced posts are comparable in chemical structure to ceramic materials, hydrofluoric acid was recently proposed for etching post surfaces.[134] Although hydrofluoric acid may enhance the post–resin cement bond strength, it can produce substantial damage to the glass fibers, ranging from microcracks to longitudinal fractures of the fiber layer, affecting the integrity of the post.[134,137] Thus, the use of a strong acid for etching fiber posts is not advisable.[116] Air abrasion with alumina particles results in an increased surface roughness and surface area, allowing mechanical interlocking with the resin cement[135] and, consequently, a significant increase in surface retention.[136] In tribo-



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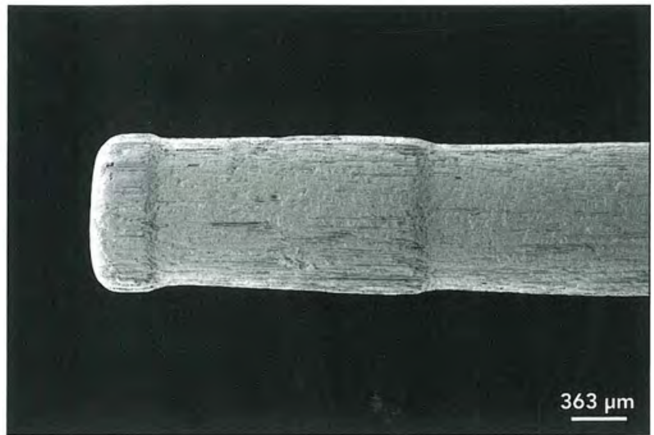
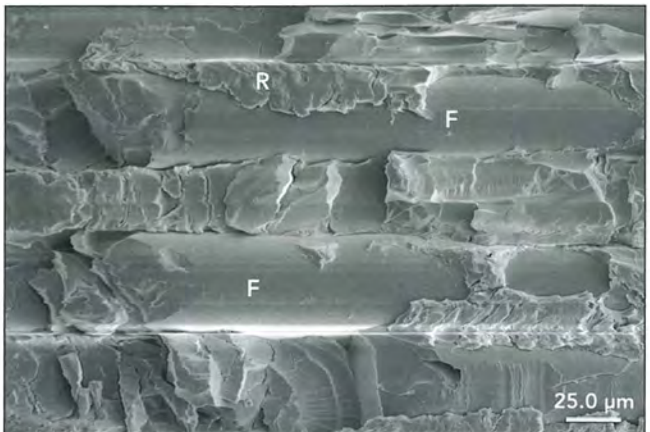
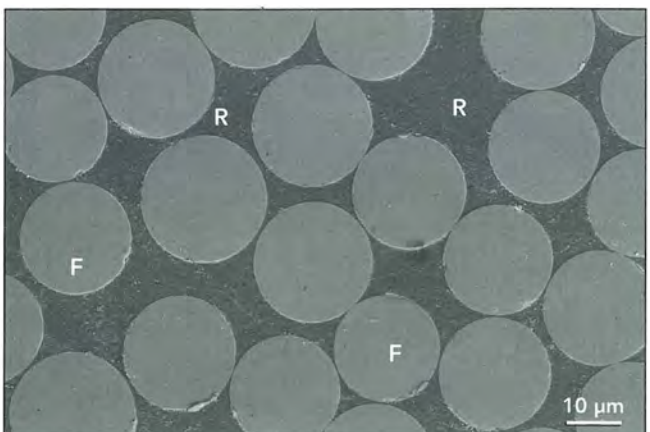


10a



10b



10c

Fig 9 Fiber crack due to air abrasion (F, fiber; R, resin; C, cement).

Figs 10a to 10c FRC post. *(a)* External surface of a FRC post; note the surface irregularity. *(b)* Higher magnification showing the fibers and resin of a FRC post. *(c)* Cross-section view of a FRC post. F, fibers; R, resin.

chemical coating, a silicate layer is welded onto the post surface, allowing penetration of the particles of about 15 microns.[137] Tribochemical coating must be associated with silanization in order to improve the bond strength between fiber post and resin cement, thus combining micromechanical and chemical retention.[116]

Since surface pretreatment of posts might improve the adhesion to resin cement, different solutions have been tested in an attempt to dissolve or alter the epoxy matrix of the post without damage to the fibers.[138,139] Acetone, chloroform, potassium permanganate, hydrogen peroxide, and sodium ethoxide have been employed to dissolve the epoxy resin of the post surface and expose glass fibers of the post.[132,134,139–142] Pretreatment of the post surface with hydrogen peroxide was suggested as an easy and clinically feasible method for enhancing interfacial bond strengths between fiber posts and resin cements.[132,134,141] However, a recent study showed that hydrogen peroxide had no influence on bond strength values.[143]

After post try-in, debris and smear layer of the post space preparation penetrates into the microspaces between the fibers and the epoxy matrix, jeopardizing the bond at that interface. Careful air abrasion[135] followed by cleaning with ethanol[143] appears to be an acceptable approach for better bonding between resin cement and the post. By removing the surface layer of epoxy resin matrix, a larger surface area of glass fibers is exposed. The spaces between these exposed fibers provide additional sites for micromechanical retention of the resin composites.[116] However, even gentle air abrasion can create cracks in the fibers of FRC posts (Fig 9). Therefore, since most of the post exhibits adequate surface roughness, only cleaning is indicated (Figs 10a to 10b).

Selection and Polymerization Mode of Resin Cements

Light-cured resin cements have better handling properties, but light transmission through the post space inside the root is extremely limited.[144] Conversely, controlled placement of the post within the canal using self-cured resin cements can be difficult because of limited working time.[144] Thus, dual-cured resin cements are the cement of choice for posts to the root canal.[145] Dual-cured resin cements offer longer working time and, by inclusion of chemical initiators, the ability to polymerize in the absence of light.[146,147]

Dual-cured resins cements provide rapid polymerization in areas where the curing light penetrates effectively and a slower chemical polymerization in areas far from the reach of the curing light.[145] The self- and light-activation modes in dual-cure resin cements are independent. However, when dual-cured resin cements are not exposed to the curing light (or light is attenuated), a decrease in the degree of conversion is found.[148,149] Poorly polymerized resin cement results in compromised mechanical properties and deleterious effects on periodontal tissue, such as inflammatory reactions, cytotoxicity, mutagenesis, and apoptosis.[150–152]

Glass fiber posts with higher potential for light transmission can be used to improve the polymerization degree of dual-cured resin cements within the root canal.[149] Yet, glass fiber posts showed a decrease in the amount of light transmitted as the depth increased.[153] To improve the degree of conversion of dual-cure resin cements, photoirradiation time of resin cements through fiber posts must be increased to achieve an adequate polymerization degree at the cervical and middle thirds of the post space.[154,155] Nonetheless, at the apical third the amount of light that reaches the resin cement is not effective for setting off a light-induced polymerization, thus relying only on the self-curing mode.[156]

Post retention rises significantly from 15 minutes to 24 hours after cementation.[157] Dual-cure polymerization (light-induced and chemical polymerization) takes longer to achieve an adequate degree of conversion, and this fact can explain the increased post retention over time. Moreover, some authors have also reported a significant increase in post retention after artificial aging.[158] For RelyX Unicem (3M ESPE)—a self-adhesive dual-cure resin cement—there is a rapid initial rise in pH (from 2 to 4) over the first hour of the setting process, which is followed by a long gradual rise in pH after 24 to 48 hours post-cure until it becomes neutral.[159,160] Dual-cure resin cements are not fully set just after cementation, even if light-polymerization is used. Therefore, after the post is bonded to the root canal, a waiting period of 24 to 48 hours before final tooth preparation must be respected to ensure maximum polymerization and post retention.

CONCLUSIONS

Preservation of coronal and radicular tooth structure is essential for long-term success of FRC posts adhesively bonded to teeth. For maximum preservation of the dentin walls, the aim is to provide a 2.0-mm circumferential ferrule. Post length should be evaluated carefully, taking into consideration the amount of bone support around the root, remaining root dentin thickness, stress concentration, and the type of restorative treatment indicated. At least 5.0 mm of gutta-percha must be left at the apical third of the root periapical pathosis. FRC posts can be customized according to the root canal to reduce the cement thickness and improve fracture resistance and stress distribution. A composite core buildup must be incrementally made to reduce polymerization shrinkage and microleakage. Chlorhexidine is indicated for final irrigation (at the end of endodontic treatment) and after post space preparation. Cleaning of the post with ethanol is indicated after post manipulation to ensure adequate bonding to the resin cement. Dual-cured resin cements/adhesives and self-adhesive resin cements are recommended for post adhesive cementation. However, a waiting period of 24 to 48 hours before final tooth preparation must be respected to ensure maximum polymerization and post retention.

APPENDIX

Findings of clinical studies on nonmetallic posts and of studies comparing fiber with metal posts are presented in Tables 2 and 3, respectively. Table 4 shows the chemical composition and shape of selected fiber-reinforced posts.

Table 2 Clinical Studies of Nonmetallic Posts

Study	Mean observation period (mo)	No. of teeth included	Amount of residual coronal structure	Post brand name and manufacturer	Type of post	Type of restoration	Tooth type	Failure rate
Fredriksson et al[161] (Retrospective)	32	236	NS	Composipost (RTD)	Carbon	All-ceramic / metal-ceramic full crown	All teeth	2%
Ferrari et al[162] (Retrospective)	31	1304	NS	Composipost vs Aestheti-Post vs Aestheti-Plus (RTD)	Carbon Quartz	All-ceramic / metal-ceramic full crown	All teeth	3.2%
Ferrari et al[163] (Retrospective)	90	985	NS	Composipost vs Aestheti-Post vs Aestheti-Plus (RTD)	Carbon Quartz	All-ceramic / metal-ceramic full crown	All teeth	8%
Hedlund et al[164] (Retrospective)	26	65	NS	Composipost vs Endopost (RTD)	Carbon	All-ceramic / metal-ceramic full crown / veneers	All teeth	3%
Glazer 2000 [165] (Prospective)	28	59	NA	Composipost (RTD)	Carbon	All-ceramic /metal-ceramic full crown	All teeth	7.7%
Mannocci et al[7] (Prospective)	36	114	Class II premolars	Composipost (RTD)	Carbon	Direct composite / metal-ceramic crown	Premolars	6%
Malferrari et al[166] (Prospective)	30	180	NS	Aestheti-Plus (RTD)	Quartz	All-ceramic / metal-ceramic full crown	Premolars	6.2%
Monticelli et al[167] (Prospective)	24	225	NS	Aestheti-Plus (RTD) vs DT (RTD) vs RFC Postec (Ivoclar)	Quartz Glass	All-ceramic crown	Premolars	6.2%
Naumann et al[168] (Prospective)	24	105	1–5 walls remaining	Luscent Anchor (Dentatus) vs FibreKor (J Pentron)	Glass	All-ceramic / metal-ceramic	All teeth	12.8%
Naumann et al[169] (Prospective)	39	149	NS	Luscent Anchor (Dentatus) vs FibreKor (J Pentron)	Glass	All-ceramic / metal-ceramic	All teeth	19.7%
Grandini et al[170] (Prospective)	30	100	Anterior: 50% residual tooth structure; Posterior: 2–3 walls	DT (RTD)	Quartz	Direct composite	All teeth	0%
Cagidiaco et al[171] (Prospective)	24	162	NS	Composipost (RTD)	Carbon	All-ceramic / metal-ceramic full crown	All teeth	7.3%
Ferrari et al[163] (Prospective)	24	120	1–4 walls, ferrule, no ferrule	DT (RTD) vs no post	Quartz	All-ceramic / metal-ceramic full crown	Premolars	7.5%
Cagidiaco et al[172] (Prospective)	36	120	1–4 walls, ferrule, no ferrule	DT (RTD) vs no post vs Ever Stick (Stick Tech)	Quartz	All-ceramic / metal-ceramic full crown	Premolars	9.1%
Bitter et al[173] (Prospective)	32	120	≥2 walls, 1 wall, no wall, but ferrule	DT Light (VDW) vs no post	Quartz	Direct composite / full crown	All teeth	Post: 7% No post: 10%
Paul et al[174] (Retrospective)	51	145	NS	Experimental zirconia post vs Cosmopost (RTD)	Zirconia	Composite core / glass-ceramic core / all-ceramic crown	Incisors, canines, premolars	Composite: 0% Ceramic: 5%
Nothdurft et al[175] (Retrospective)	29	30	NS	Cerapost (Brasseler) vs Cosmopost (Ivoclar)	Zirconia	Glass-ceramic core / all-ceramic full crown	All teeth	0%

NS, not specified.

Table 3 Clinical Studies Comparing Fiber with Metal Posts

Study	Mean observation period (mo)	No. of teeth included	Amount of residual coronal structure	Post brand name and manufacturer	Type of post	Type of restoration	Tooth type	Failure rate
Schmitter et al[176] (Prospective)	14	50 vs 50	NS	Glass-fiber posts (ER, Brasseler) vs metal screw posts (BKS, Brasseler)	Glass vs metal	Full crown	All teeth	Glass fiber: 6.5% Metal screw: 24.6%
Schmitter et al[177] (Prospective)	61	50 vs 50	NS	Glass-fiber posts (ER, Brasseler) vs metal screw posts (BKS, Brasseler)	Glass vs metal	Full crown	All teeth	Glass fiber: 28.2% Metal screw: 50%
Ferrari et al[162] (Prospective)	48	100 vs 100	NS	Composipost (RTD) vs cast post and core	Carbon vs metal	All-ceramic / metal-ceramic full crown	All teeth	Composipost: 2% Cast: 9%
King et al[178] (Retrospective)	87	10 fiber vs 16 metallic posts	NS	Carbon posts vs cast metallic posts	Carbon vs metal	Full crown	Maxillary anterior teeth	Carbon: 40% Cast: 4%
Mannocci et al[89] (Prospective)	60	110 vs 109	Class II premolars	Carbon posts vs amalgam	Carbon vs amalgam	Direct composite	Premolars	Carbon: 3.8% Amalgam: 2%

NS, not specified.

Table 4 Chemical Composition and Shape of Selected Fiber-Reinforced Posts

Post	Manufacturer	Fibers	Resin matrix	Shape
RelyX Fiber Post	3M ESPE, St Paul, USA	Glass	Resin	Double-tapered
ParaPost Taper Lux	Coltene Whaledent, Altstätten, Switzerland	Glass	Resin	Serrated, double-tapered, three-sphere head
ParaPost Fiber Lux	Coltene Whaledent, Altstätten, Switzerland	Glass	Resin	Serrated, two-sphere head
LuxaPost	DMG, Hamburg, Germany	Glass	Resin	Tapered, circumferential head grooves
FRC Postec Plus	Ivoclar Vivadent, Schaan, Liechtenstein	Glass	UDMA, TEGDMA, Ytterbium, trifluoride, silicon dioxide	Tapered
GC Fiber Post	GC, Tokyo, Japan	Glass	Methacrylate	Double-tapered
DT Light Post Illusion/DT Light Post	RDT, Grenoble, France	Quartz	Epoxy	Double-tapered
Macrolock Illusion Post	RDT, Grenoble, France	Quartz	Epoxy	Double-tapered
Radix Fiber Post	Dentsply Maillefer, Ballaigues, Switzerland	Zirconium enriched glass	Epoxy	Double-tapered
DT Light Safety Lock	VDW, Munich, Germany	Preconditioned quartz	Epoxy	Double-tapered
Dentin Post X	Komet, Lemgo, Germany	Glass	Epoxy	Tapered with a retentive head
Snowpost	Abrasive Technology, Lewis Center, Ohio, USA	Zirconia-rich glass	Epoxy	Cylindrical with long apical cone
Reforpost	Angelus, Londrina, Brazil	Glass	Bis-GMA	Serrated
FibreKleer Serrated Post	J Pentron, Wallingford, Connecticut, USA	Glass	Bis-GMA, UDMA, HDDMA	Serrated
Composipost	RTD, Grenoble, France	Carbon	Epoxy	Two-stage parallel

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Minimally Invasive Treatment of Initial Dental Erosion Using Pressed Lithium Disilicate Glass-Ceramic Restorations: A Case Report

Francesca Vailati, MD, DMD, MSc[1]
August Bruguera, MDT[2]
Urs Christoph Belser, DMD, Prof Dr Med Dent[3]

Dental erosion is spreading rapidly among younger generations of patients. Clinicians often underestimate the extent of this disease and postpone its treatment due to a lack of awareness or to uncertainty regarding the proper course of action. The discussion of when and how to treat young individuals affected by dental erosion has split the dental community into two groups: clinicians who treat eroded teeth excessively and clinicians who do not treat eroded teeth at all.

In this case report, a young adult patient affected by generalized dental erosion was treated even though his tooth degradation was only at an initial stage. The rationale behind this early intervention was that no or minimal tooth preparation would be required for treatment. In fact, only additive adhesive procedures were implemented to replace the missing tooth structure and protect the remaining dentition from further damage.

CASE REPORT

A 25-year-old male Caucasian patient presented to the School of Dental Medicine at the University of Geneva, Geneva, Switzerland. His chief complaint was the weakening and fracturing of his maxillary incisal edges. During a previous dental consultation, a parafunctional habit (bruxism) was suggested as the main cause of lost tooth structure; however, no occlusal guard had been prescribed. Clinical examination revealed that the patient also showed generalized initial dental erosion (Figs 1 to 6).

The patient presented accelerated loss of enamel, especially on the palatal aspect of the maxillary anterior teeth and occlusal surfaces of the premolars. In addition, the mandibular first molars presented concave occlusal surfaces with reduced areas of contact with the antagonistic teeth. Wear facets at the canines were also present, indicating moderate parafunctional habits. The remaining dentition was intact.

[1]Private Practice, Geneva, Switzerland; Senior Lecturer, Department of Fixed Prosthodontics and Occlusion, School of Dental Medicine, University of Geneva, Geneva, Switzerland.
[2]Director, Disseny Dental Laboratory and Dental Formation Center, Barcelona, Spain.
[3]Chairman, Department of Fixed Prosthodontics and Occlusion, School of Dental Medicine, University of Geneva, Geneva, Switzerland.

Correspondence to: Dr Francesca Vailati, School of Dental Medicine, rue Barthelemy-Menn 19, University of Geneva, 1205 Geneva, Switzerland. Email: Francesca.vailati@unige.ch

CASE REPORT

1

Fig 1 Initial situation. Note the very conservative smile, showing the patient's insecurity regarding the eroded teeth. Also note the darker yellowish color of the maxillary central incisors.

Figs 2a to 2c The patient was asked to show an exaggerated smile with an open mouth, but the patient could not fully relax because he had learned to smile while covering as much of the teeth as possible. No gingiva was visible in the maxillary arch. Note the presence of a reverse smile due to the fracturing of the incisal edges of the maxillary anterior teeth.

2a

2b

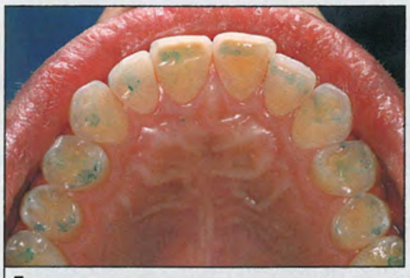
2c

3

4

Fig 3 Intraoral view. At this early stage of dental erosion, the teeth had not supraerupted, thus simplifying the restorative treatment plan.

Fig 4 The mandibular anterior teeth were intact, as is often the case with dental erosion.



5a

5b

Figs 5a and 5b Occlusal view and contact points. Since the patient did not have a deep bite (shallow vertical overlap), the risk of incisal edge fracture was high even at this early stage.

6a

6b

Figs 6a and 6b The maxillary premolars presented thinning of the enamel and small areas of exposed dentin. The mandibular first molars also presented thinning of the occlusal enamel and a concave occlusal surface.

The patient was questioned regarding the possible etiology of the dental erosion, and he denied any excessive consumption of acidic beverages or food. The clinician recommended further investigation of a possible intrinsic origin of the acid (eg, gastric reflux) through a visit to a gastroenterologist. However, the patient did not comply with this suggestion, and the etiology of the dental erosion remained unknown.

Anterior erosive classification (ACE)[1] was used to determine the extent of erosion. Following examination, the patient's erosion was classified as ACE class III because the palatal dentin was exposed at the level of the contact points with the antagonistic mandibular teeth and the incisal edges were starting to fracture (loss of less than 2.0 mm of the original tooth length). Since reduced vertical overlap (overbite) was a risk factor for accelerated damage of the incisal edges and the etiology of the problem was still unknown, the potential for a higher ACE classification was a concern (see Fig 5).

The benefits of early intervention were discussed, with special consideration paid to the young age of the patient. It was decided to restore the patient's affected teeth with no or minimal tooth preparation following exclusively adhesive principles.

ACE class III maxillary anterior teeth may be restored using palatal veneers. To obtain the necessary interocclusal space to deliver the restorations without tooth preparation, an increase of the vertical dimension of occlusion (VDO) may be considered as long as no orthodontic measures are implemented. Since the posterior teeth also showed signs of dental erosion, it was decided to increase the VDO by restoring the posterior teeth as well.

In addition to the loss of tooth structure related to dental erosion, the patient presented esthetic problems at the maxillary central incisors (see Figs 1 to 4). Even though the facial aspect of these teeth was intact (except for their incisal edges), their coloring was darker compared to the rest of the dentition. Several unsuccessful attempts at external bleaching had been made in the past. The central incisors had changed color following prior trauma to the anterior teeth. At the radiographic examination, both pulp chambers were obliterated, and the vitality test was negative. However, neither radiographic signs of periapical lesions nor symptoms related to a loss of vitality were evident. The percussion test was also negative. After consultation with an endodontist, it was decided to maintain the status quo without performing elective endodontic therapy until signs or symptoms of pulp necrosis arose. Consequently, two facial veneers were also planned to mask the discoloration.

Delivering two veneers, one palatal and one facial, to restore a single tooth is called the "sandwich approach," which has been proven to be the most conservative treatment for ACE class IV to VI anterior teeth. However, in this ACE class III patient, the sandwich approach was dictated more by the patient's esthetic demands than by loss of tooth structure.

Modified Three-Step Technique

Generally, patients at the University of Geneva affected by dental erosion are treated following the three-step technique.[2–4] Due to the early detection of the erosion, this patient did not require full-mouth rehabilitation. Thus, a modified three-step technique was used.

The typical first step (maxillary vestibular mock-up) was not necessary because the occlusal plane did not require alteration and the shape of the maxillary anterior teeth needed only minor modification (lengthening of the incisal edges). Instead, treatment began directly with the increase of the VDO and creation of anterior open bite (step two). Due to the minimal increase of the VDO, no provisional restorations were necessary. Consequently, instead of the posterior provisional stage in the classic three-step technique, final restorations for the posterior teeth were fabricated.

During the first visit, two alginate impressions were taken, and casts were mounted on a semi-adjustable articulator using a facebow in maximum intercuspal position. The VDO was arbitrarily increased to obtain the space necessary to restore the occlusal surfaces of the posterior teeth and the palatal aspect of the maxillary anterior teeth.

The space gained in the posterior quadrants by the increased VDO was shared between the maxillary premolars and mandibular molars (Fig 7). Posterior support at the increased VDO was obtained only by insertion of the eight ceramic onlays. The remaining posterior teeth were not involved in the restorative treatment.

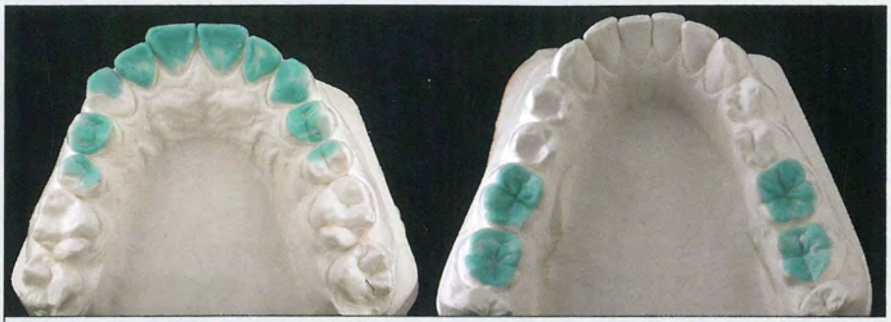


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Fig 7 As confirmed by the diagnostic wax-up, the interocclusal space obtained at the posterior quadrants was shared between the mandibular molars and maxillary premolars. Interdental spaces were kept free of wax during wax-up procedures.

Once this stage of treatment was finalized, the patient was scheduled for another appointment. The final impression of the maxillary and mandibular arches was made using vinyl polysiloxane to fabricate the working casts.

Posterior Ceramic Onlays

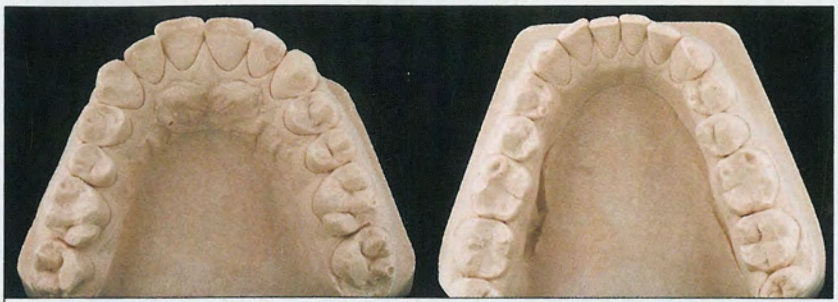
An additive diagnostic wax-up was used as the starting point for fabrication of exceptionally thin and highly conservative posterior lithium disilicate ceramic onlays. Developing thin occlusal ceramic onlays while simultaneously providing adequate occlusal function is a complicated procedure. Conventional ceramic onlays require a minimum thickness of 1.5 to 2.0 mm, whereas thin occlusal ceramic onlays have a maximum thickness ranging from 0.5 to 0.6 mm. These highly conservative restorations can be produced with minimal or no tooth reduction and are highly indicated to restore eroded posterior teeth.

Thin occlusal ceramic onlays are very fragile and may fracture during waxing or fabrication procedures. The first step is to make the investment casts. The working casts must be duplicated in the investment (Fig 8). The working casts are painted with die spacer (Color Spacer, Yeti Dental, Engen, Germany) and then duplicated using vinyl polysiloxane (Zhermack Elite, Zhermack, Badia Polesine, Italy) and phosphate-bonded investment material (IPS Press Vest Speed, Ivoclar Vivadent). When so-called Geller or alveolar casts are used as the working casts, the teeth to be restored can be easily duplicated with the investment material (Fig 9).

The wax-up of the occlusal onlays must be made directly on the investment replica following the morphology obtained in the wax-up. Waxing directly to the investment is a far more delicate procedure than waxing directly on the microstone. Since investment material is less rigid than stone, contact of the hot waxing instrument on the investment may damage its surface, resulting in permanent distortion (Figs 10 and 11).

Correct placement of the sprue is crucial during the fabrication of thin occlusal ceramic onlays (Fig 12). An inadequate placement and amount of wax for the sprue may result in loss of the ceramic onlay's peripheral contour. A solution for this drawback is to wax the sprue directly over the investment. This procedure allows better contour and marginal fit without removing the wax before investment into the cylinder. Once the restorations are waxed with the correctly located sprue, the investment material surrounding the restorations is carefully trimmed, leading to individual waxed investment dies. Trimming the investment around the waxed tooth facilitates positioning into the investment ring. However, before positioning the whole set into the investment ring, the investment dies should be soaked in alcohol to prevent them from absorbing moisture from the investment coating too quickly.

The thin occlusal onlays were made with a highly opalescent shade ingot (Impulse 01, IPS e.max Press,



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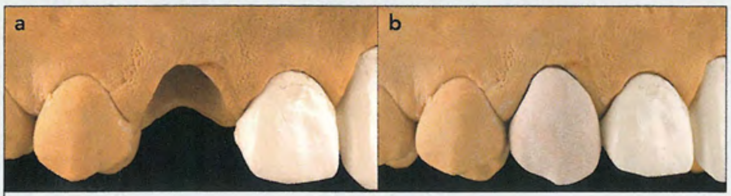

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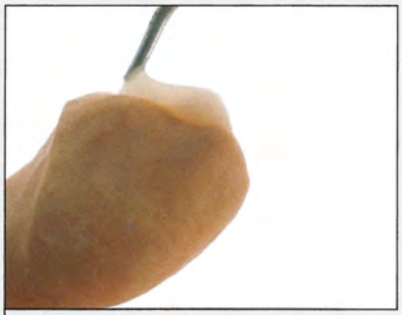
Fig 8 The preoperative casts were duplicated in investment material to facilitate waxing of the thin occlusal onlays.

Figs 9a and 9b With Geller or alveolar casts, only the teeth to be restored can be duplicated in investment material.

Fig 10 To avoid permanent distortion, the hot waxing instrument must not touch the investment.

Fig 11 The study wax-up must be replicated in the investment casts.

Figs 12a to 12c *(a)* Close-up view of the waxed restoration; *(b)* the investment surrounding the wax-up was carefully trimmed; *(c)* correct placement of the sprues for thin occlusal onlays.



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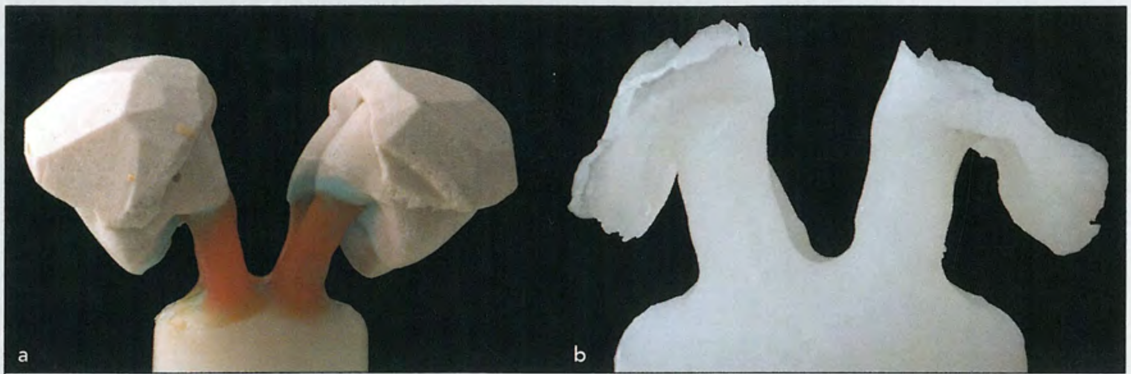


13

14

Figs 13a and 13b *(a)* Thanks to this new investment technique, thin occlusal onlays can be pressed on top of retentive areas; *(b)* pressed thin occlusal onlays.

Fig 14 Highly opalescent ingots.

Figs 15a and 15b *(a)* Occlusal view of the thin occlusal veneers after adjustment to the master cast; *(b)* 0.6-mm thin occlusal onlays.

15a

15b

Ivoclar Vivadent) to match the natural teeth (Figs 13 and 14). According to the manufacturer, opal ingots can be used as enamel replacements because of their optical properties and adequate strength. To provide suitable optical properties, the maximum thickness of the opalescent ingot must not exceed 0.5 to 0.6 mm (Fig 15). Thicker restorations often result in an undesirable increase in value. The final step is to glaze the restorations as recommended by the manufacturer.

The patient was informed that the third appointment would be a long one since the eight ceramic onlays had to be inserted at the same visit. No anesthesia was required, and the field was isolated with rubber dam. Figures 16 to 23 demonstrate the placement procedures. Enamel was etched (37% phosphoric acid) for 30 seconds, and the adhesive resin (Optibond FL, Kerr, Orange, California, USA) was applied on the teeth and left unpolymerized.

The pressed lithium disilicate glass-ceramic onlays were etched with hydrofluoric acid for 20 seconds and cleaned in alcohol in an ultrasonic bath. Three coats of silane were applied (Monobond Plus, Ivoclar Vivadent) to the intaglio surfaces of the restorations, and a final layer of the adhesive resin was added without curing.

A microhybrid composite resin (Enamel plus, Micerium, Avegno, Italy) was heated and applied to the restorations before they were placed on the teeth and light polymerized. The challenge was to bond the ceramic onlays while maintaining the original interproximal contacts. The extremely thin onlays also required additional attention to avoid fracture during the bonding procedure.

Figs 16a and 16b Extremely thin onlays were delivered to restore the mandibular molars.

Figs 17a and 17b Irregular margins were smoothed with a diamond bur.

Figs 18a and 18b Onlay try-in at the maxillary premolars. The two onlays were bonded at the same time. Metal strips were used to keep the teeth apart.

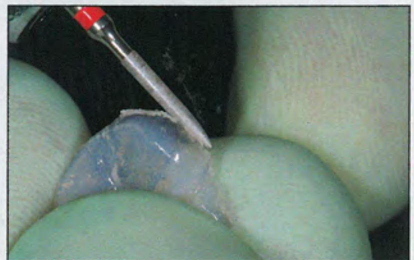
Fig 19 The exposed dentin was roughened with a coarse diamond bur to eliminate the most superficial layer.

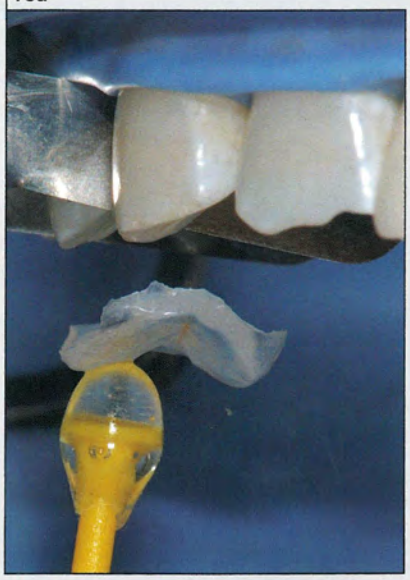
Fig 20 Enamel was etched with phosphoric acid for 30 seconds. Dentin was etched for 15 seconds.


16a


16b


17a


17b

18a



18b


19


20


21


22a

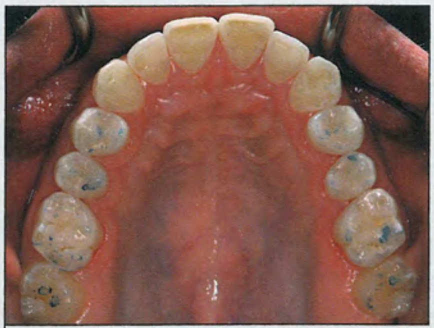

22b


23

Fig 21 An ethanol- and water-based three-step etch-and-rinse was used (Optibond FL). The bond was not cured. Immediate dentin sealing was not carried out before the final impression due to the minimal dentin exposure and risk of creating interference with the occlusion.

Figs 22a and 22b Some excess cement remained due to the closed interproximal contact and the presence of the metal strips.

Fig 23 A scalpel was used to remove the excess composite resin.



24a

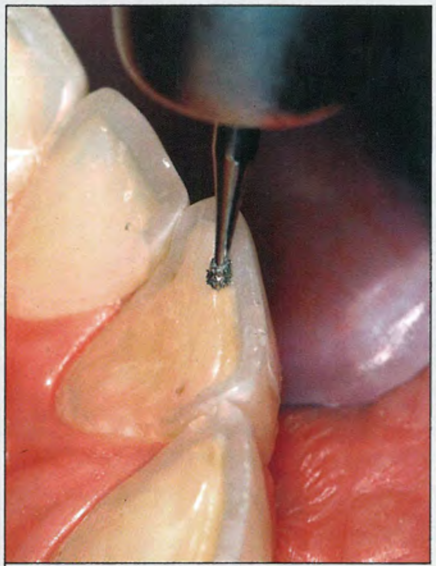
24b

Figs 24a and 24b After delivery of final posterior restorations, the patient presented stable occlusion in the posterior quadrants.

25

Fig 25 The increased VDO with the contact points only on the posterior teeth generated an anterior open bite. This space was sufficient for the palatal veneers.

26a



26b

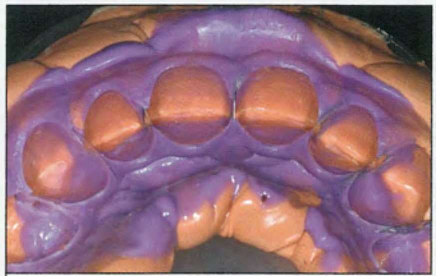
Figs 26a and 26b Preparation for the six palatal veneers. The unsupported enamel prisms were smoothed at the incisal edge, and the exposed dentin was sealed before the final impression.

Anterior Veneers

The patient's new occlusion was controlled after 1 week to intercept occlusal interferences (Figs 24 and 25). The patient was comfortable, and no signs of temporomandibular joint disorders were detected.

In the following appointment, the palatal aspect of the maxillary anterior teeth was prepared for the palatal veneers (Fig 26). All exposed dentin was immediately sealed without anesthesia. The palatal dentin was cleaned with nonfluoridated pumice, and the most superficial layer was removed with diamond burs. The exposed sclerotic dentin was etched with 37% phosphoric acid for 15 seconds and immediately sealed with three-step etch-and-rinse ethanol- and water-based adhesive (Optibond FL) and flowable composite resin (Tetric Flow T, Ivoclar Vivadent) just before the final impression was taken.[5–9]

27a



27b

Figs 27a and 27b The final impression was taken with the interproximal contacts closed. To facilitate trimming of the dies, metallic matrix bands were placed in between the teeth. Access holes and the application of adhesive were used to ensure that the strips were removed with the tray during impression taking.

Fig 28 Die spacer was applied to the master cast before duplication.

Fig 29 In the investment cast, the palatal veneers were waxed similarly to the occlusal onlays.

Figs 30a to 30c Palatal view of the finished veneers. The maxillary lateral incisors and canines were made with highly opalescent pressed ceramic (Impulse 1, IPS e.max Press), whereas the maxillary central incisors were made with composite resin (Adoro).

28

29

30a

30b

30c

Finally, the irregular margins of the incisal edges were smoothed. No additional tooth preparation was necessary. The interproximal contacts between the maxillary anterior teeth were left closed, and the final impression was taken using metal strips in between the teeth, as for the posterior teeth (Fig 27). No provisional restorations were delivered.

It was decided to fabricate the palatal veneers in pressed lithium disilicate glass-ceramic (IPS e.max Press) for the maxillary lateral incisors and canines and in composite resin (Adoro, Ivoclar Vivadent) for the maxillary central incisors. The presence of composite resin on the palatal aspect would facilitate not only the bonding procedure with the future ceramic facial veneers (sandwich approach), but also the eventual creation of an access hole for future root canal treatment.

The same laboratory technique described for the thin occlusal ceramic onlays was adopted for the palatal veneers, with the exception of those for the maxillary central incisors (Figs 28 and 29). For the central incisors, a laboratory microfilled composite resin was used (Fig 30).

31

Fig 31 Each palatal veneer was individually bonded using rubber dam. Note the closed interproximal contacts.

Figs 32a and 32b *(a)* Before and *(b)* after reestablishment of the anterior contacts and guidance using palatal veneers.

Fig 32c Occlusal view of the palatal and occlusal veneers on the premolars.

32a

32b

32c

33

Fig 33 Frontal view after completion of the modified three-step technique. The new edges of the lateral incisors were well blended, whereas the central incisors showed a highly translucent band at the interface with the palatal veneers. Due to the color discrepancy, it was proposed to remove the length added by the composite resin restorations. However, the patient preferred to keep the teeth longer until the facial veneer preparation.

After 2 weeks, the six palatal veneers were bonded, one at a time, under rubber dam without anesthesia (Fig 31). A 3-hour appointment was necessary. The sealed palatal dentin was tribochemically coated (Cojet, 3M ESPE, St Paul, Minnesota, USA), the surrounding enamel was etched with 37% phosphoric acid for 30 seconds, and the adhesive (Optibond FL) was applied to the enamel and dentin and left uncured.

The intaglio surfaces of the two palatal composite resin veneers were also tribochemically coated. The four pressed ceramic palatal veneers were instead etched with hydrofluoric acid for 20 seconds.

All veneers were cleaned in alcohol and placed in an ultrasonic bath, followed by the application of three coats of silane (Monobond Plus). A coat of the adhesive resin was placed and left unpolymerized.


34a


34b


35a


35b


35c

Figs 34a and 34b Profile views *(a)* before and *(b)* after restoration of the incisal edges using palatal veneers.

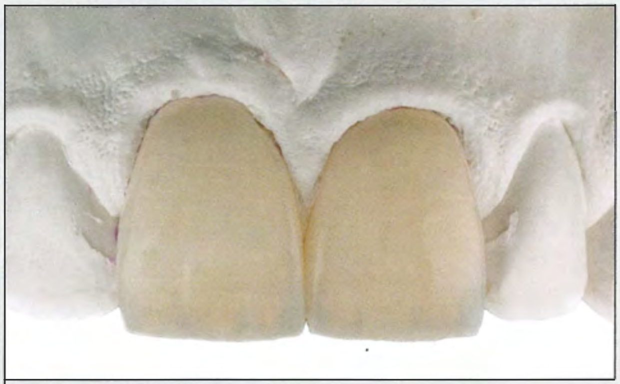
Figs 35a to 35c Facial veneer preparation. The original teeth were very wide mesiodistally. Minimal preparation was necessary at this level. The original tooth length was preserved.

Composite resin (Enamel plus) was heated and applied to the restorations before they were placed on the teeth and then light polymerized for 90 seconds for each surface. Following the completion of the modified three-step technique, the patient presented stable occlusion at an increased VDO (Figs 32 and 33). The incisal edges were also strengthened by the presence of the palatal veneers (Fig 34).

To complete the treatment, the next step was the restoration of the facial aspect of the maxillary central incisors. Unfortunately, the initial position of these teeth was very labial. To keep the tooth preparation to a minimum, the prospect of a slightly bulkier facial surface was discussed with the patient (additive approach). Thanks to the preview provided by the mock-up on the central incisors, the patient agreed to the slightly thicker teeth. The option to restore the facial aspect of the lateral incisors was not considered due to the principle of minimal invasiveness. Unfortunately, minimal tooth preparation of the central incisors was inevitable due to their dark yellowish color. Facial veneers with a thickness of 1.0 mm were necessary to mask the underlying color. Because the teeth did not respond to the vitality test, no local anesthesia was necessary for the preparation (Fig 35).

After the final impression, provisional restorations were fabricated directly in the mouth using a provisional composite resin material (Telio, Ivoclar Vivadent), and

36a



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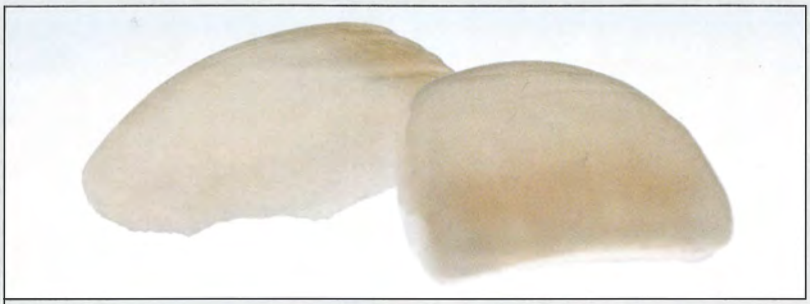

36c

37

Figs 36a to 36c *(a)* Feldspathic porcelain veneer buildup; *(b and c)* extremely thin and highly translucent porcelain veneers.

Fig 37 Rubber dam isolation for veneer placement. A clamp with a retraction cord was used to ensure exposure of the gingival margins. The veneer preparation was confined to enamel. Remaining composite resin is still visible at the incisal surface. No dentin was exposed.

retention was achieved by the contraction of the product and the presence of minimal interproximal excess.

The labial veneers were fabricated using the refractory die technique and feldspathic porcelain (Fig 36). Ceramic layering was performed to better match the color and optical details of the adjacent anterior teeth. These highly translucent facial veneers blend easily with the underlying preparation.

Bonding of the feldspathic ceramic veneers was carried out after 2 weeks, following the protocol developed by Magne et al (Fig 37).[10–14] Final external bleaching provided a pleasing esthetic outcome. The patient was very satisfied with the overall treatment (Figs 38 to 40). In terms of biologic success, no tooth preparation was performed for this almost full-mouth rehabilitation except for the facial surfaces of the maxillary central incisors.

The incisal edges of the maxillary anterior teeth were reinforced by the presence of the restorative materials, the exposed dentin was covered, and the thinner enamel was also reinforced. An occlusal guard was delivered to the patient to control his light parafunctional habit, and a visit to a gastroenterologist was again recommended.


38a

Figs 38a and 38b The onlays restored the convex profile of the occlusal surfaces.

Figs 39 and 40 Final result.


38b


39a


39b


40

CONCLUSION

This article presented a case report of a patient affected by initial dental erosion. Early intervention was performed due to the exposed dentin and risk of fracture of the anterior teeth. Only time will tell if this type of early and minimally invasive approach is the best solution for patients affected by dental erosion.

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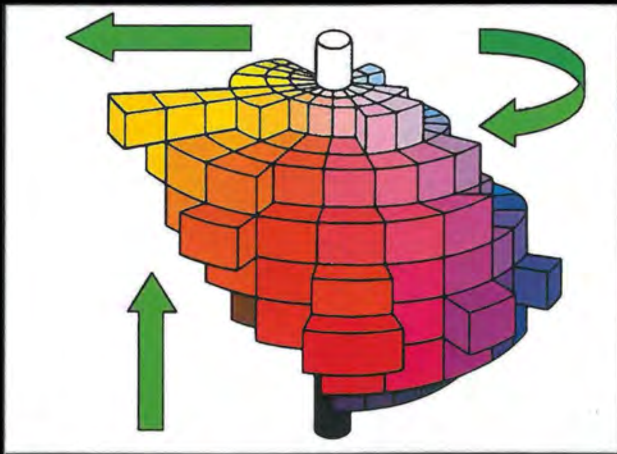
VALUE, HUE, AND CHROMA

Control of Value for Accurate Color Reproduction

Tomoyuki Hashinaka, RDT
Tottori Dental Technology
2-435-16 Matsunami
Tottori City
Tottori, Japan
Email: t.dental.technology@vivid.ocn.ne.jp

The technician's goal is to fabricate long-lasting prostheses that fulfill structural, biological, functional, and esthetic requirements. The author has found through daily cases that it is not easy to satisfy patients' esthetic demands, particularly in terms of color. Many patients are more sensitive to the color of a crown or fixed partial denture than to its shape or alignment. All-ceramic material alone does not solve the problem.

In an attempt to reproduce natural tooth color, the author considers value to be the most dominant factor of the three color elements (value, hue, chroma) and has found that a shade-taking procedure that gives priority to value can make color reproduction simpler. In this article, techniques of shade taking, color representation, value prioritization, and reproduction of the incisal edge utilizing the contrast effect of value are presented.



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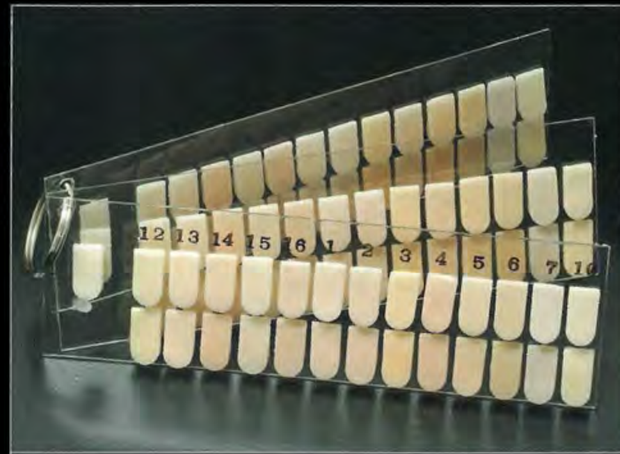

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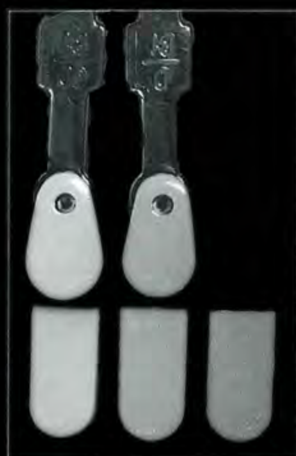
3a



3b

Fig 1 Munsell color wheel. The vertical component is value, the surrounding component is hue, and the horizontal component is chroma.

Fig 2 Color wheel of author's self-made shade tabs in dentin porcelain. The shade tabs are categorized and arranged into three different value groups. Shade-taking focuses on value followed by hue and chroma. The self-made shade tabs are also arranged in order of value→hue→chroma.

Figs 3a and 3b *(a)* Comparison of different values. From left: opacious dentin B1, dentin B1, dentin B1+ CL-O. Value changes by degree of translucency even with the same hue and chroma. *(b)* Value can be confirmed easily under monochromatic tone.

VALUE, HUE, AND CHROMA OF CERAMIC CROWNS

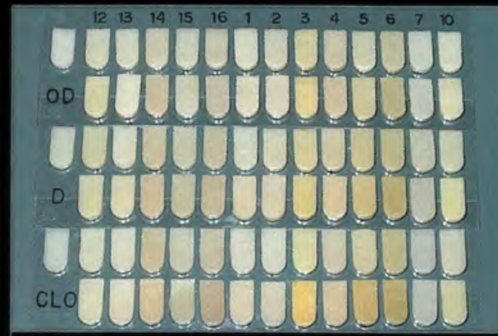
The three characteristics of color need to be considered when natural tooth color is to be represented in dental ceramics.[1] Hue is the most obvious characteristic of a color, chroma is the purity of a color, and value is the lightness or darkness of a color (Fig 1). Clinically, a small mismatch in hue or chroma is less noticeable than a small mismatch in value. When the value of a crown is not well balanced within the patient's dentition, even a small difference can be noticed within speaking distance.

The color of a tooth is dominated by the color of the dentin layer and its shape. Hence, the color of the opaque layer, shoulder porcelain,[2] and cervical porcelain that correspond to the dentin layer become important. The author has developed dentin shade tabs made in Creation dental porcelain (Jensen Dental, New Haven, CT, USA) that are categorized by hue, chroma, and value. The concept of the Munsell color wheel is applied to line up these tabs to select the correct color (Fig 2). The shade tabs are used to confirm hue and chroma as well.

The value of dentin is controlled by the amount of translucency using Opacious Dentin, Dentin, and Dentin + CLO (translucent porcelain). It has been shown that the value decreases as the translucency is increased[1,2] (Fig 3). Hue is controlled by adding In-Nova or Make Up Instant (Fig 4), which are hue controllers containing fluorescence, in dentin porcelain with three different values. Chroma is controlled by the amount of In-Nova and Make Up Instant added.

In general, there are two techniques to control color: the additive technique (mix of the light of colors) and the subtractive technique (mix of colors). In the fabrication of ceramic crowns, the subtractive technique is mainly used. In the subtractive technique, the color gets darker as more colors are mixed. This characteristic needs to be taken into consideration when different colors are mixed as the porcelain is built up. Since value tends to decrease as translucency and chroma

Figs 4a to 4c *(a)* Hue and chroma of shade tabs are controlled by adding *(b)* In-Nova and *(c)* Make Up Instant to dentin porcelain in three different values.

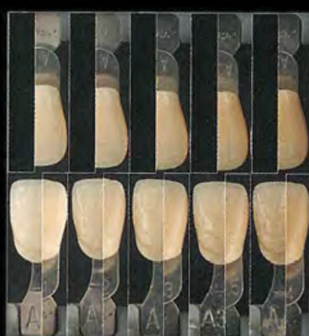


4a

4b

4c

5a



5b

5c

Figs 5a to 5c Comparison of the Vita Shade Guide and Gradia Shade Guide. *(a)* Hue and chroma of Vita *(bottom)* and Gradia *(top)* shade guides are similar, but there is clear difference in value. The value of a particular case can be confirmed easily by using these two shade guides with their distinctively different values. *(b)* It is evident that the Gradia shades *(right)* have higher value than Vita shades *(left)*. *(c)* If the Vita shade is the target value, regular dentin porcelain is used; if the Gradia shade is the target value, opaque dentin is used.

increase, B1 dentin porcelain (highest value and lowest chroma) is chosen as the base porcelain to which other colors will be added.

USING SHADE GUIDES WITH DIFFERENT VALUES

A shade-taking system that can confirm different values is necessary. The author uses two shade guide systems, the Vita Shade Guide (Vident, Brea, CA, USA) and the Gradia Shade Guide (GC America, Alsip, IL, USA) (Fig 5a), to confirm the value. In these two shade guide systems, hue and chroma are comparable but there is distinctive difference in value. The Vita system has lower value and the Gradia system has higher value (Fig 5b). Since Creation porcelain is based on the Vita shade, in a case requiring the color of the Vita shade (see Fig 2), the shade is selected from the regular dentin shade chart. If a case requires the Gradia shade, the shade is selected from the opacious dentin shade chart, which has higher value than regular dentin (Fig 5c). If a case requires even higher value than the Gradia shade, OD43, which has low translucency, is added on the opacious dentin to make the value higher. If a case requires lower value than the Vita shade, CLO (trans-porcelain) is added on the regular dentin porcelain to lower the value by increasing the translucency.

6a

6b

Figs 6a and 6b *(a)* Before staining and *(b)* after staining only on the incisal edge with high-value porcelain. Translucency by contrast effect is evident on the stained crown. This effect is emphasized as the difference of values is greater. A certain amount of translucency could be achieved without using translucent, blue, gray, or violet porcelain.

Three Groups of Value and Value Contrast

Natural teeth have a wide variety of colors. However, when using a shade guide, the value of teeth can be classified into three groups: teeth that are brighter in color, teeth that have the same brightness, and teeth that are darker in color than the shade guide. The shade-taking procedure can be simpler and more precise by using two shade guide systems. Moreover, the procedure can be even more predictable by using self-made shade tabs confirming hue and chroma.

Choosing the right dentin shade is important for establishing the base color to reproduce the gradation of the value and proper incisal color. The color of the incisal area is also complex, containing a translucent layer and opal effect.[3] Trans-porcelain and opal porcelain are used to reproduce those layers. As mentioned previously, translucent porcelain, which has strong translucency, or opal porcelain tends to lower the value of the ceramic crown, causing unbalanced color that is noticeable in speaking distance.

The incisal area is reproduced by controlling the value as well (Fig 6). To emphasize the translucency by contrast effect, mamelon porcelain or incisal-halo porcelain of high value is applied right next to the target area where more translucency is needed. The higher the value, the more the translucency of the target area is emphasized. The hue and chroma of trans-porcelain and surrounding porcelain are adjusted to reproduce the complex color of natural teeth. In the incisal area, the gradation of value is done in the mesial-distal direction.

The steps in the shade-taking process through porcelain application, along with the final results, are presented in the following three clinical cases.

CASE 1 (FIGS 7 TO 10)

Treatment area: Maxillary central and lateral incisors
Porcelain material: Creation CC (Jensen), W (Ivoclar Vivadent, Schaan, Liechtenstein)
Patient: Female/age, 20s
Chief complaint: Esthetics of the maxillary four incisors (color, shape, and alignment) and gingival contour

This patient's maxillary anterior teeth were malaligned and the gingival contour was unesthetic (Fig 7).

Three value samples from the two shade guides (Vita and Gradia) were used to determine the better value match to the mandibular incisors (Fig 8). In this case, the value of the mandibular incisors was found to be higher than the Vita Shade Guide but similar to the Gradia Shade Guide. Hence, In-Nova or Make Up Instant was added to the opacious dentin porcelain. The exact material color and the amount were determined by checking with the self-made shade tabs.

As long as there is no time restriction, the author prefers to use negative film over digital images.

The image of full dentition is used to confirm the value.

The S-shape emergence profile concept,[4-7] proposed by Nameta, was applied to the prosthesis to improve the gingival architecture. To match the mandibular incisors, a brighter shade was selected to overcome the dark color of the abutments. Since the value of the abutments was considerably low, the translucency of the incisal area was controlled conservatively (Fig 9).

The black triangle, which was obvious at the time of insertion of the prosthesis, was closed by well-aligned gingiva 10 months later (Fig 10). The patient was very satisfied with the result. Utilizing the self-made shade guide was the key to success in this case.

Fig 7 Case 1 preoperative situation.

Figs 8a to 8c *(a)* Three different values from the Vita shade system are compared. The mandibular incisors have a higher value than Vita shade guide. *(b)* Three different values from the Gradia shade system are compared. The value of the mandibular incisors is similar to that of the Gradia shade guide. *(c)* The author's self-made shade tabs are used to check and determine the exact material color and amount.

7

8a

8b

8c

9a

9b

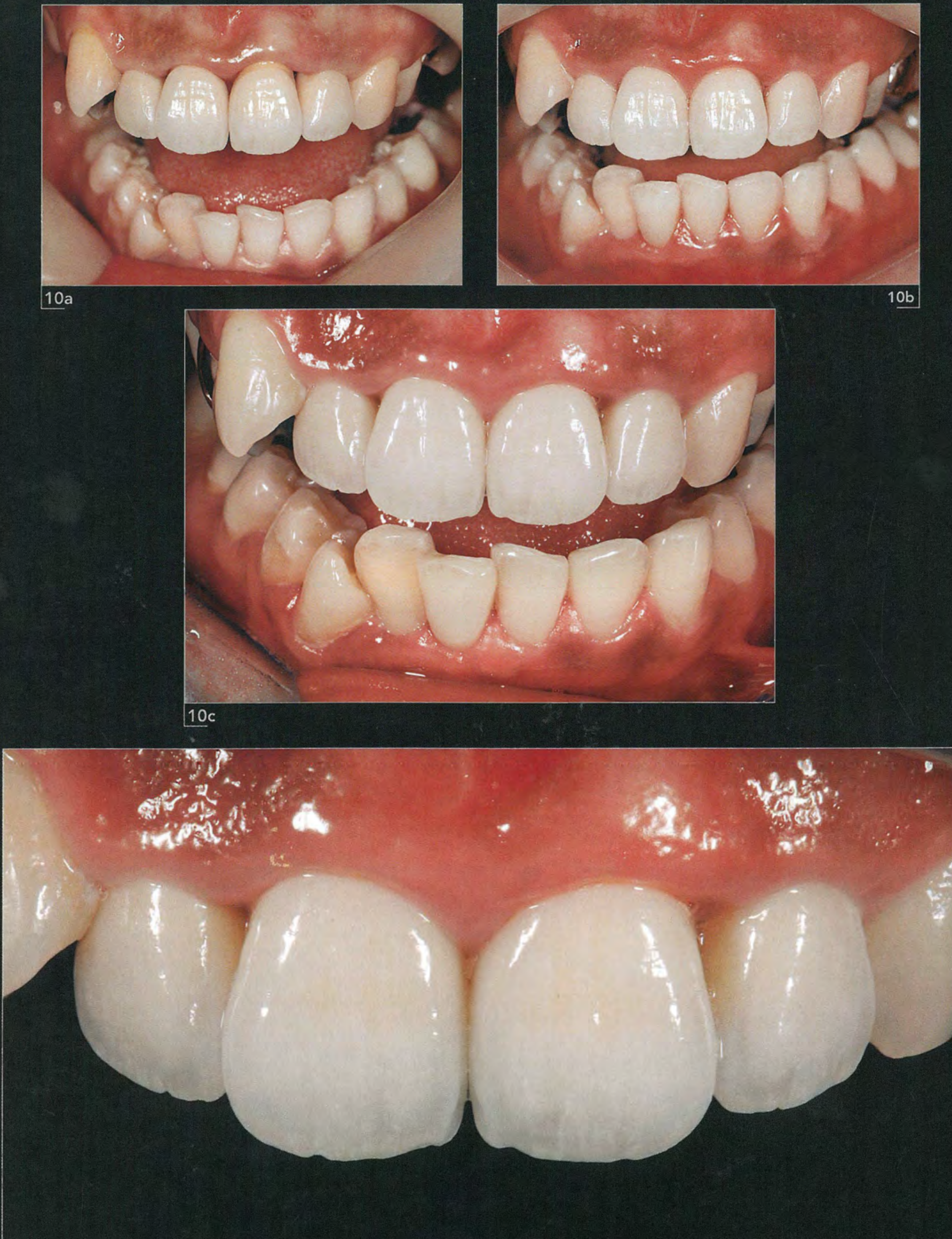
9c

9d

9e

9f

Figs 9a to 9f After opaque, shoulder, and OD43 porcelain are applied at the cervical area, opacious dentin porcelain with high value mixed with In-Nova 1 (1/50 amount) is added, forming full contour. The base color of the crown is formed at this point. After cutback, mamelons (MI-61, 62, and 63), translucency (OT, TI-1, and TI-4,) and hypocalcified areas (PS-2, 3) are formed, and then enamel porcelain is added. Incisal halo (PS-2, 3) is added to emphasize the value contrast.



10a 10b 10c 10d

Figs 10a to 10d *(a)* Black triangles are apparent at prosthesis insertion. *(b)* 10 months posttreatment. *(c and d)* Final pleasing result.

Case 2

Fig 11 Case 2 preoperative situation.

Figs 12a and 12b *(a)* Three different values from the Vita Shade Guide. The image of the target shade guide can be cut and pasted next to the tooth with the designated shade. In this case, it is confirmed that the value of the target shade is higher than that of the shade guide. *(b)* Three different values from the Gradia Shade Guide. It is confirmed that the value of the target shade is lower than that of the shade guide.

11

12a

12b

CASE 2 (FIGS 11 TO 14)

Treatment area: Maxillary left central incisor
Porcelain material: Creation CC, W
Patient: Female/age, 20s
Chief complaint: Esthetics of the maxillary left central incisor

The teeth adjacent to the maxillary left central incisor in this patient had relatively high value. The enamel layer seemed to be relatively translucent. To restore the tooth, a porcelain-fused-to-metal (PFM) crown was selected for longevity because of the patient's relatively young age. There was alignment restriction due to the position of the mandibular incisors (Fig 11).

The author finds it difficult to control the value with PFM crowns. It makes the case more difficult when both high value and translucency are required. In this case, fluorescence was utilized to make the gingiva look brighter to overcome the darkening effect of the metal.

Shade taking was done using three different values from both the Vita and Gradia shade guides (Fig 12). It was determined that the target value was between the Vita shade and Gradia shade. Opacious dentin porcelain and regular dentin porcelain were mixed. In-Nova and Make Up Instant were added to control the hue and chroma.

When the target value is high, as in this case, Intensive opaque porcelain is mainly used as the base shade opaque. The frame is made bright partially using white, sahara, gold, and violet. Value contrast is reproduced from the cervical to incisal direction at this stage (Fig 13a).

Figs 13a to 13l Steps in the porcelain buildup of the maxillary left central incisor.

SP27, which is opaque, and SP21 + 22 + 25, which is translucent, were used for shoulder porcelain (Fig 13b). Since the shoulder porcelain of Creation has high fluorescence, gingiva looks brighter and value does not get lowered by translucency (Fig 13c).[8–10]

Close-up images of the shade guide pasted were used to reproduce the value contrast (Fig 13d). The cervical one-third of many teeth presented a higher value. Even though the area was thickest in labiolingual direction anatomically, the space for porcelain application was limited due to the structure of the PFM crown. OD43 was applied to increase the value (Fig 13e).

Next, ODB1 and DB1 were mixed, and then In-Nova 10 and Make Up Instant 13 were added to control the hue and chroma. It was built up to full contour and then cut back (Figs 13f to 13h). In this process, interdigitation is formed by application of porcelains in different values, not by cutback. In-Nova 7 was applied in the area of lowest value as a base layer. Thus, there are areas of different value within the dentin layer, which makes the prosthesis look natural. The chance of mismatch is minimized by properly conducting these steps.

Layers of porcelain with different values were mixed with universal liquid and applied in the mesiodistal direction. Translucent porcelain was applied on the surface. Opaque shade was selected for the incisal halo to emphasize the translucent layer (Figs 13i to 13l).

The color of the definitive prosthesis (Fig 14) was reproduced satisfactorily by controlling the dentin shade using two different shade guides. The prosthesis appears well balanced in the dentition as a result of its well-controlled value, even with its asymmetric alignment. Reproduction of conflicting colors, brightness, and translucency in the enamel layer was possible by creating the opal effect and translucency by using the value contrast effect.

14a 14b 14c 14d

Figs 14a to 14d *(a)* Immediately after definitive crown placement and *(b to d)* 5 months posttreatment.


15

Fig 15 Case 3 preoperative situation.

Figs 16a to 16c *(a)* Adjacent teeth are bright and *(b)* the abutment is stained, but *(c)* reduction amount is limited (porcelain laminate veneer).

Figs 17a to 17c Translucency and fluorescence of Creation trans-porcelain.


16a


16b


16c

17a


17b


17c

CASE 3 (FIGS 15 TO 19)

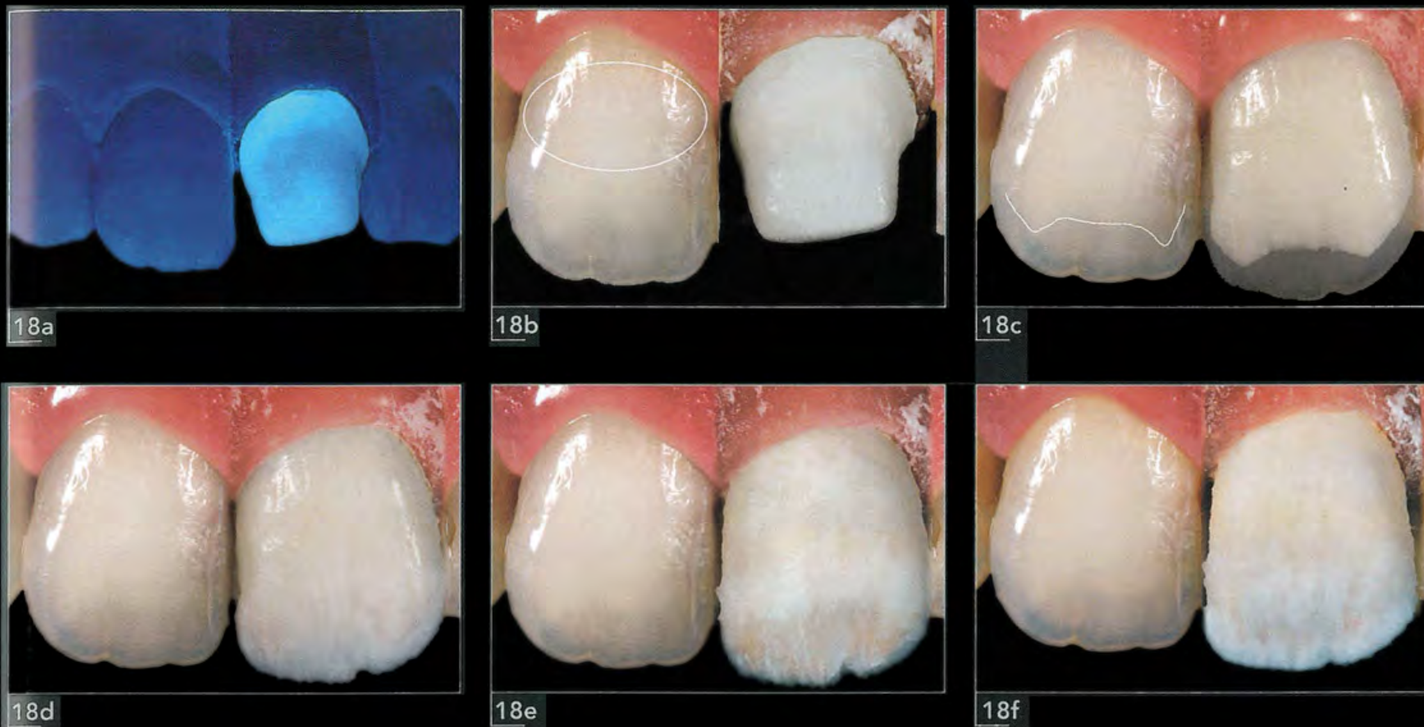
Treatment area: Maxillary left central incisor
Porcelain material: Creation CC, W
Patient: Female/age, 20s
Chief complaint: Discoloration of the maxillary left central incisor

The teeth adjacent to this patient's discolored maxillary left central incisor presented high value in dentin and strong translucency in enamel (Fig 15). The abutment showed heavy staining. The restoration was more labial than the right central incisor due to the position of the mandibular incisors.

In such cases of malalignment it is difficult to match the color to the rest of the dentition. Warm colors tend to make an object look protruded. Cool colors tend to make an object look recessed. White is the expansion color, which makes an object look larger than it is. Cool colors like blue or black are contraction colors, which make an object look smaller. These characteristics of colors are utilized within the range of base shades to balance the restoration in the dentition.

In this case, the designated value of the restored tooth should be within the same range or slightly lower than adjacent teeth, due to the position of the restored tooth in relation to the rest of the dentition. Opacious dentin mixed with Make Up Instant 12 and 13 was selected as the dentin porcelain considering the color of the abutment and available labial space (Fig 16).

HT-51 was wash fired to give the lens effect[11,12] and fluorescence (Fig 17). OD43 was applied to the cervical one-third where the high value was required, and then the dentin porcelain was applied to build full con-



18a 18b 18c 18d 18e 18f

19a

19b

Figs 18a to 18f Porcelain buildup of the maxillary left central incisor.

Figs 19a and 19b Definitive restoration 3 months posttreatment.

tour. The low-value area was replaced by low-value porcelain, and then In-Nova 7 was applied where low value was designated (Fig 18).

In-Nova and Make Up Instant were applied on the dentin layer, which has the value contrast in cervical-incisal direction, giving the value contrast in mesial-distal direction. The contrast effect was created by applying opaque porcelain partially on translucent porcelain. Natural tooth color can be reproduced by applying strong-color porcelain thinly, even within a limited working space.

The translucent layer was created by mixing OT with TI-1 + TI-5 and TI-4. This translucency was emphasized by the contrast effect of the incisal halo using D-a2 + S-58, PS-1, and PS-2 + HT-55.

The definitive restoration is aligned labial to rest of the dentition due to the occlusal relationship of the mandibular incisors. Reproduction of the tooth color with proper translucency was achieved by controlling the value even with the limited working space and malalignment.

CONCLUSION

The PFM crown is considered to be a durable and esthetic restoration. However, the metal framework needs to be well masked to reproduce natural-looking tooth color. It is very important to understand the various color effects and to be familiar with the characteristics of porcelain materials. In this article, it was demonstrated that value is the most important factor in reproduction of natural tooth color. As long as the value is within the acceptable range, esthetics in speaking distance can be achieved predictably by providing proper shape, surface texture, and individualization.

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An Alternative Treatment for an Ankylosed Central Incisor: The Perio-Prosthetic Connection

Eric Van Dooren, DDS[1]
Murilo Calgaro, CDT[2]
Gustavo Giordani, DDS[3]
Victor Clavijo, DDS, MS, PhD[4]

Restoring ankylosed teeth in the anterior region is a highly complex task that often involves invasive surgical treatment. Although the literature describes several options for the replacement of such teeth, most authors agree on the extremely challenging nature of these cases.[1–5] Decoronation, segmental distraction osteogenesis, extraction, and vertical bone and soft tissue augmentation are frequently reported as treatment options; however, these approaches rarely result in satisfactory long-term esthetic outcomes.

Extracting an ankylosed tooth for implant placement can cause severe bone destruction in addition to the surgical difficulties related to this vertical ridge defect.[6–9] Although rare instances of spontaneous reeruption of an ankylosed tooth have been reported, severe vertical discrepancies and esthetic and functional problems are the more likely outcome.[1,10] Unfortunately, few treatment alternatives are available, especially for younger patients with incomplete maxillary growth. This case report describes a conservative approach for esthetic treatment of an ankylosed maxillary central incisor in a young patient.

[1]Private Practice Limited to Periodontics, Fixed Prosthodontics, and Implants, Antwerp, Belgium; Visiting Professor, University of Liege, Belgium, and University of Marseille, France.

[2]Dental Technician, Campinas, Brazil.

[3]Oral and Maxillofacial Surgeon, São Paulo, Brazil.

[4]Professor, Advanced Program in Implantology and Restorative Dentistry, Implante-Perio Institute, São Paulo, Brazil.

Correspondence to: Dr Eric Van Dooren, Tavernierkaai 2, 2000 Antwerp, Belgium. Email: vandoorendent@skynet.be

CASE REPORT

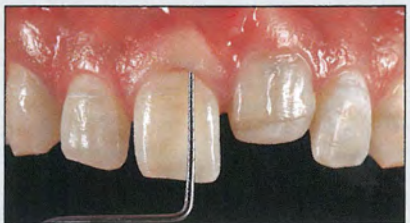
The 17-year-old male patient presented with esthetic concerns related to trauma-induced ankylosis of the maxillary left central incisor (Fig 1). Although periapical radiographs showed severe root resorption, the tooth was stable and firmly anchored in the alveolar bone (Fig 2). Despite that there were no visible signs of gingival inflammation (Fig 3), the patient's oral hygiene

CASE REPORT

1a

1b

2



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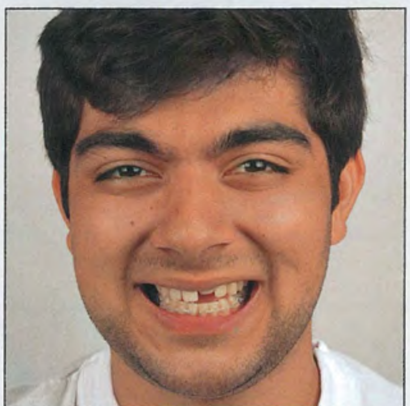

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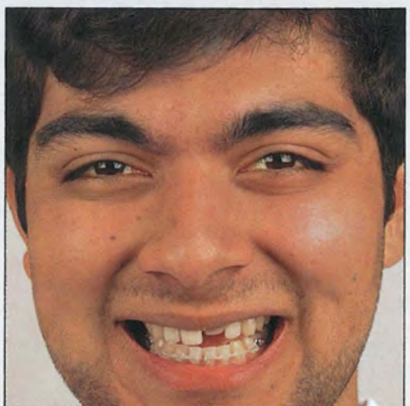

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Figs 1a and 1b Patient presented with trauma-induced ankylosis of the maxillary left central incisor.

Fig 2 Periapical radiograph shows severe root resorption.

Figs 3a to 3c Evaluation of amount/height of keratinized tissue available and probing of CEJ and bone level for proper understanding of the surgical possibilities and limitations.

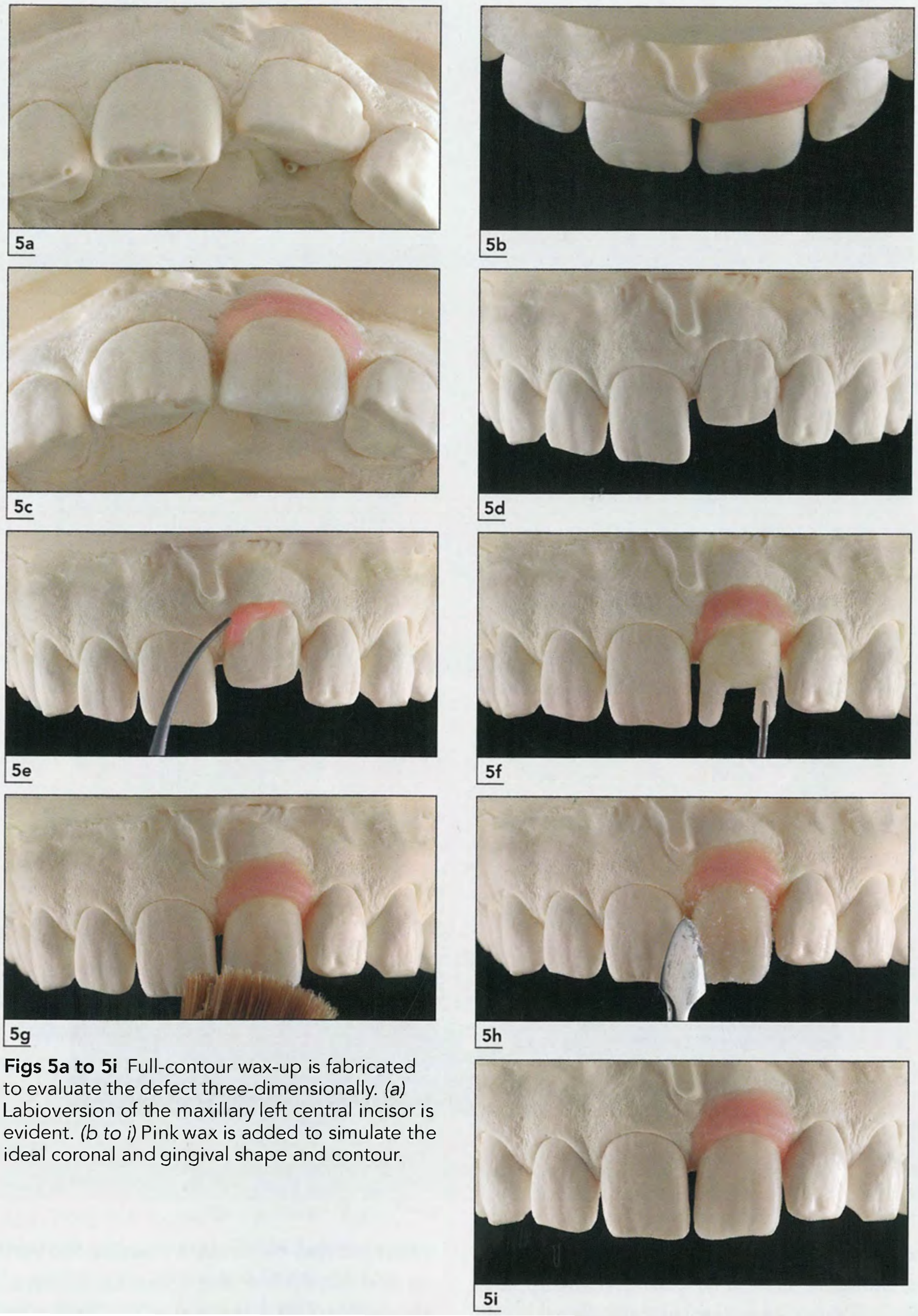
Figs 4a and 4b Preoperative facial photographs.

was less than optimal. The labioversion and partial egression of the mandibular incisors required orthodontic treatment to create space for optimal three-dimensional positioning of a ceramic crown.

Facial photographs of the patient smiling revealed the need for a comprehensive treatment plan (Fig 4). The patient's age prevented extraction and bone and soft tissue regeneration because final maxillary growth had not been attained. Therefore, an alternative but comprehensive treatment plan was proposed to the patient.

Treatment Planning

Vinyl polysiloxane impressions were taken (Virtual, Ivoclar Vivadent, Schaan, Liechtenstein), and two sets of stone casts were fabricated. A full-contour wax-up (after cutback of the stone cast) allowed for three-dimensional evaluation of the defect (Figs 5a to 5i). Since the tooth had been ankylosed for several years, labioversion of the maxillary left central incisor was evident (Fig 5a). Pink wax was added to the gingival portion of the ankylosed tooth to simulate the ideal coronal and gingival shape and contour (Figs 5b to 5i).[11] The distal



Figs 5a to 5i Full-contour wax-up is fabricated to evaluate the defect three-dimensionally. *(a)* Labioversion of the maxillary left central incisor is evident. *(b to i)* Pink wax is added to simulate the ideal coronal and gingival shape and contour.

aspect and diameter of the left central incisor required tooth reduction to create symmetry with the right central incisor in terms of form and gingival contour. Fabrication of an ideal wax-up and thorough knowledge of proper gingival shapes and contours are key factors in planning complex cases.[12,13]

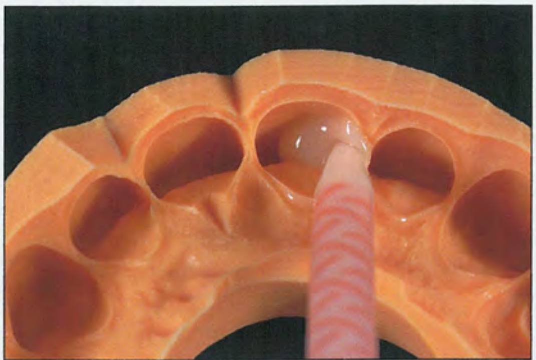


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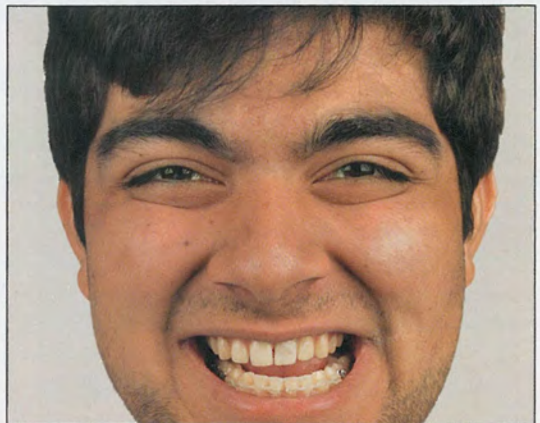
Fig 6 Silicone index is fabricated from the wax-up.

Figs 7a to 7c Try-in of the mock-up indicates the need for distocoronal reshaping.

7a

7b



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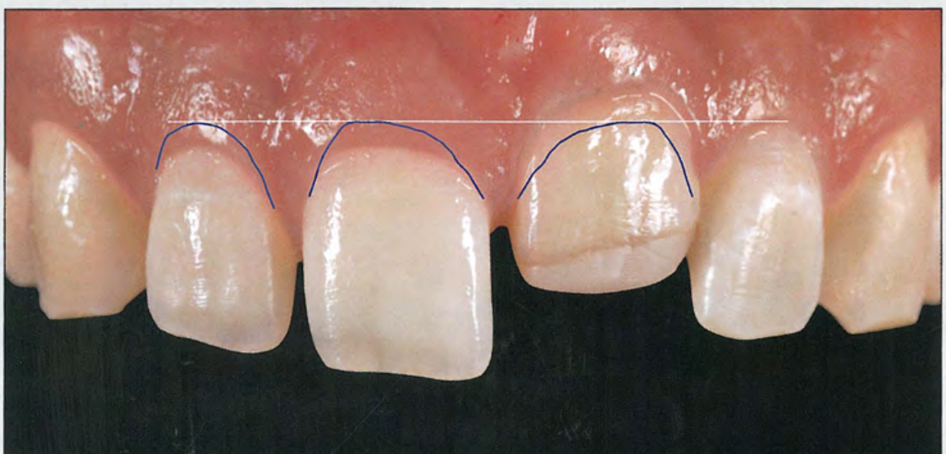

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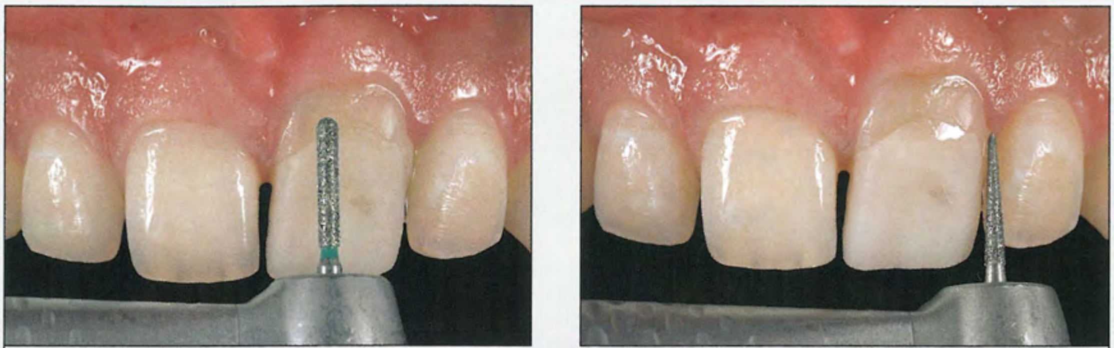
Fig 8 Computer software is used to simulate the new gingival contours.

A silicone index was fabricated (Matrix Form 60, Anaxdent, Stuttgart, Germany) from the wax-up, and a mock-up (Anaxflow, Anaxdent) was used to simulate the tooth form and length (Fig 6). Try-in of the mock-up revealed the need for distocoronal reshaping (Fig 7). The more coronal the preparation, the larger the prosthetic diameter. It became evident that surgical treatment was necessary to resolve the vertical gingival and tooth/form discrepancies; however, it would be unrealistic to expect that any soft tissue grafting procedure would provide complete defect coverage.

In the authors' treatment-planning protocol, it is standard procedure to assess the need for modification of the gingival contour (ie, clinical crown length-



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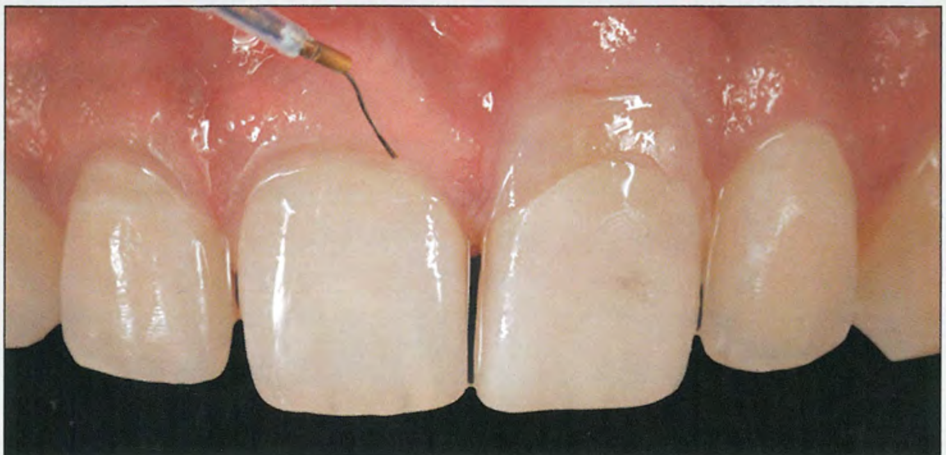

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Figs 9a and 9b Deep chamfer crown preparation is made, followed by substantial distal and buccal reduction to flatten the crown contour.

Fig 10 Electrosurgical crown lengthening is performed.

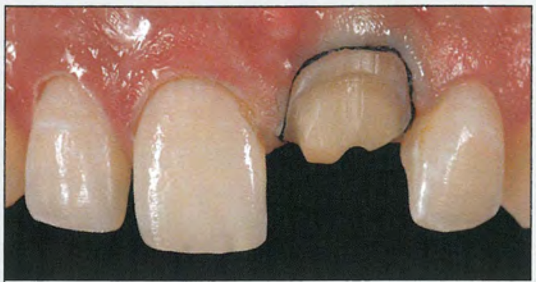
ening) of the adjacent teeth. In many cases, this simple procedure can reduce the amount of vertical augmentation. The use of computer software (Keynote, iWork, Apple, Cupertino, California, USA) to draw horizontal reference lines and simulate future gingival contours can facilitate treatment planning (Fig 8)

Combined resective (right central and lateral incisors) and additive surgical procedures (connective tissue graft on the left central incisor) were the only realistic and conservative treatment options to restore balance, symmetry, and harmony of the maxillary anterior teeth.[12,14,15] Clinical evaluation and probing indicated clinical crown lengthening on the right central and lateral incisors.

A substantial amount of enamel was unexposed (localized modified passive eruption). The cemento-enamel junction and bone levels were determined by probing the sulcus. Next, the amount of possible gingival resection was determined.

Surgical and Restorative Treatment

The diagnostic procedures revealed the need to fabricate and bond the final restoration on the ankylosed tooth before initiating connective tissue grafting. A deep chamfer crown preparation was performed on the left central incisor (Fig 9) to achieve symmetry with the soft tissue contour of the right central incisor after crown lengthening. To establish the final gingival contour of the right central and lateral incisors, electrosurgical clinical crown lengthening was performed (Fig 10). Maximum enamel exposure was obtained for both teeth. Since probing revealed that the biologic space was still maintained (3.0 to 3.5 mm) after tissue resection, no surgical flap procedure was required. It should be noted, however, that this situation is uncommon. In most cases of clinical crown lengthening, bone resection is needed.



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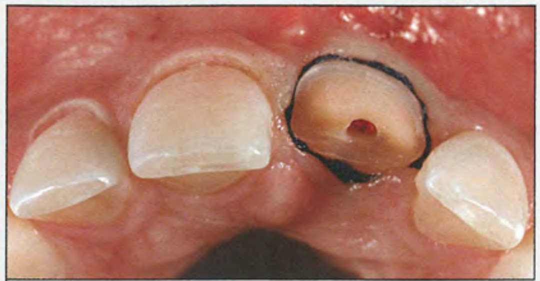

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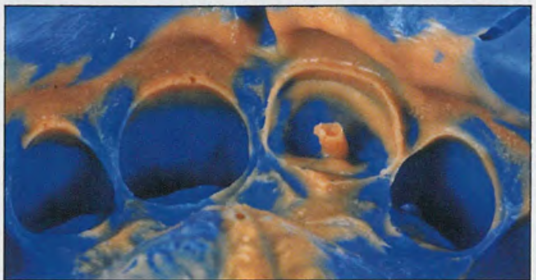

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Figs 11 and 12 The diameter is reduced on both the buccal and distal aspects.

Fig 13 Vinyl polysiloxane impression is made.

Fig 14 Four shade tabs are used for the intraoral shade-taking photograph.

Fig 15 Grayscale image is used to evaluate value.

Fig 16 Oversaturated image for better visualization of tooth details.

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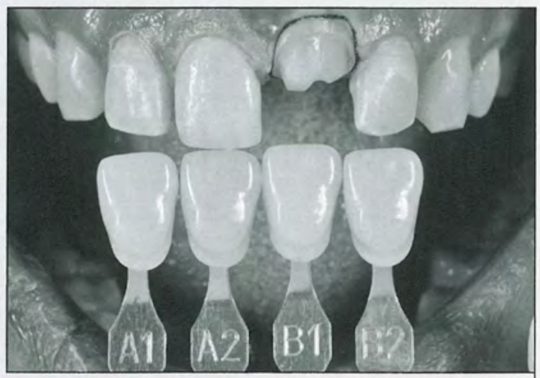

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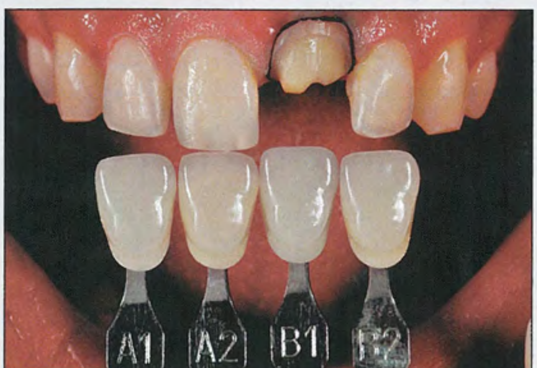

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At the same time, the portion of tooth enamel apical to the deep chamfer preparation was aggressively flattened with a bur up to the most apical part of the sulcus to reduce the facial crown contour and the pressure on facial gingival tissues. On the distal aspect, the diameter was also substantially reduced (Figs 11 and 12). A vinyl polysiloxane impression was made, and stone casts were fabricated (Fig 13).

To determine the exact shade of the tooth, four shade tabs (Classical VITA, VITA Zahnfabrik, Bad Säckingen, Germany) were used for an intraoral shade-taking photograph (A1, A2, B1, B2) (Fig 14). This allowed the tech-


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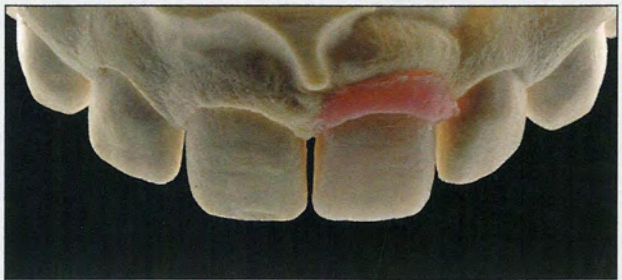
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19a


19b


20

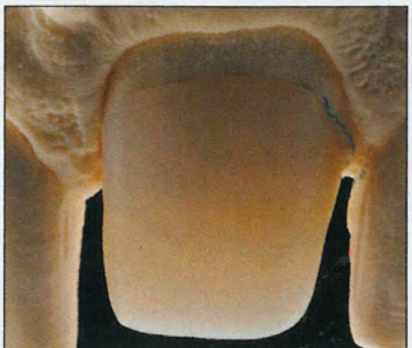
Fig 17 Precise wax-up is made.

Fig 18 Pink wax is added to show missing soft tissue.

Figs 19a and 19b Lithium disilicate coping.

Fig 20 Polishing wheel is used to reduce the contour of the coping.

Figs 21a and 21b Reduction is checked on the solid cast.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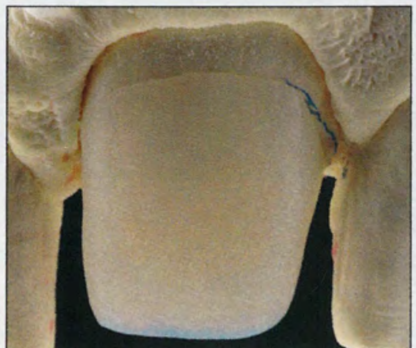

21b

nician to better understand the basic shade to be used. Next, the shade-taking photograph was copied three times side-by-side into computer software (Keynote, Apple). The first image was left intact (Fig 14). In the second image, the saturation was lowered until a grayscale photograph was obtained (Fig 15). Grayscale images make it easier to evaluate the value of the tooth. In the third image, the brightness was lowered and the contrast was increased, resulting in an oversaturated image (Fig 16) that helped the technician visualize details such as mammelons, translucency, and the incisal opalescent layer, all of which are important for the ceramic buildup.

A solid cast and die cast were fabricated, and a precise wax-up was made to obtain optimal tooth form and symmetry with the right central incisor (Fig 17). The missing soft tissue was shaped in pink wax to evaluate the vertical component of the defect (Fig 18). At this stage, it became clear that the distal aspect of the restoration and the diameter of the future crown would not ideally match the diameter of the natural contralateral central incisor, despite the aggressive tooth preparation.

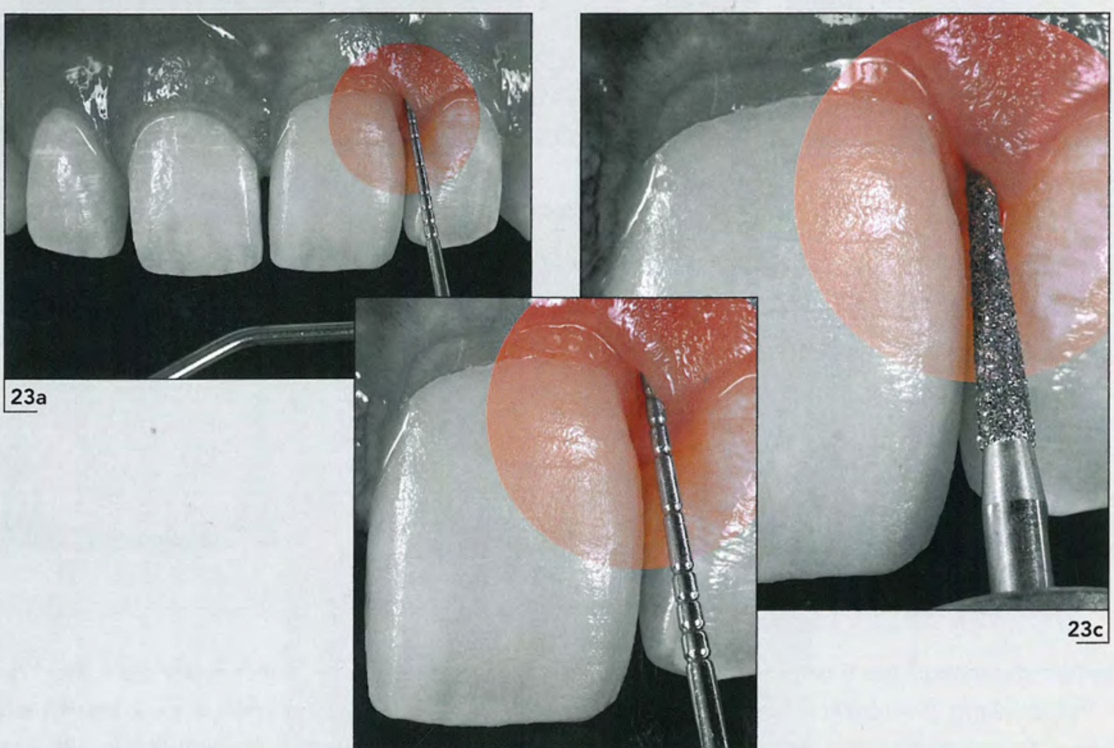
A lithium disilicate coping (IPS e.max Press, MO Ingot, Ivoclar Vivadent) was fabricated (Fig 19). To achieve optimal form and symmetry, it was decided to modify the distal aspect of the crown and reduce the contour of the coping on the die. A polishing wheel was used to reduce both the die and coping distally (Fig 20). The reduction was then checked on the solid cast (Fig 21).

22a

22b

22c

Figs 22a to 22c Coping is layered with porcelain.



23a

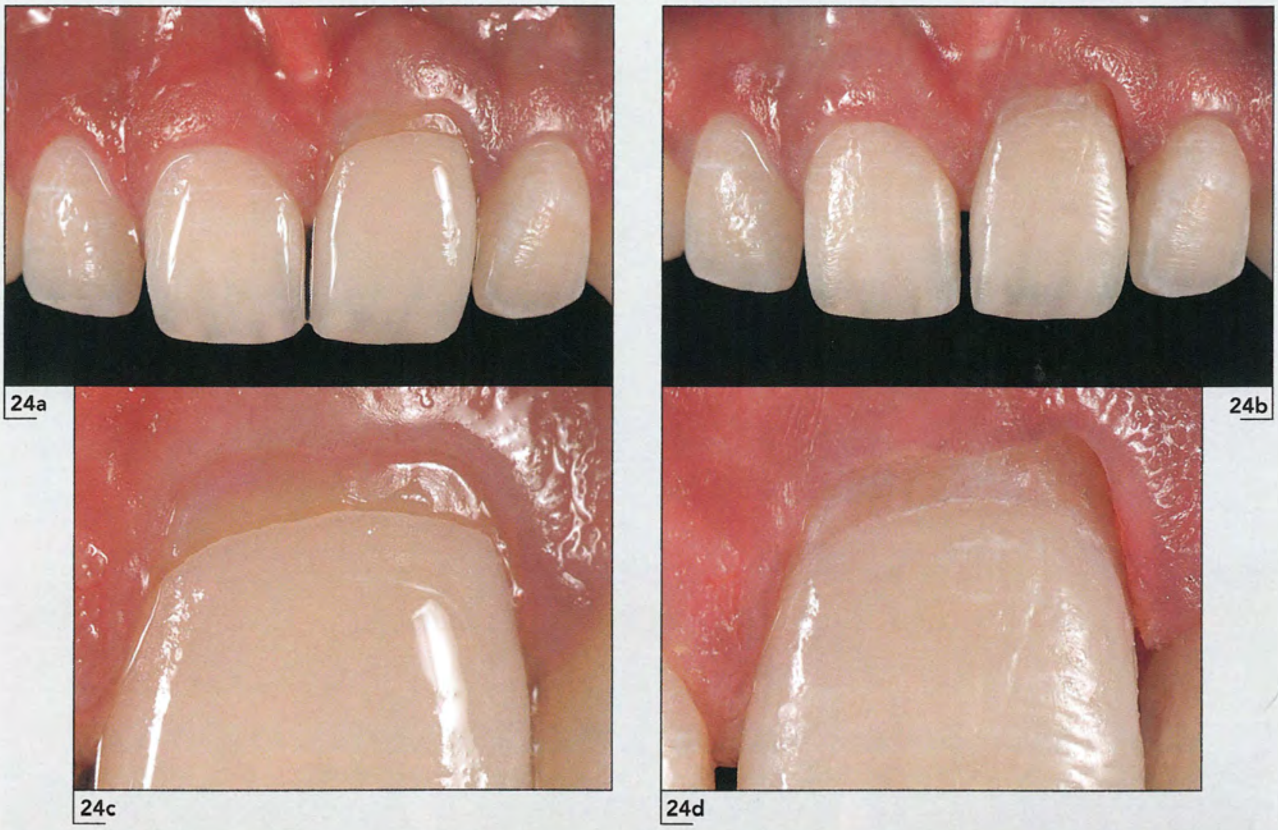
23b

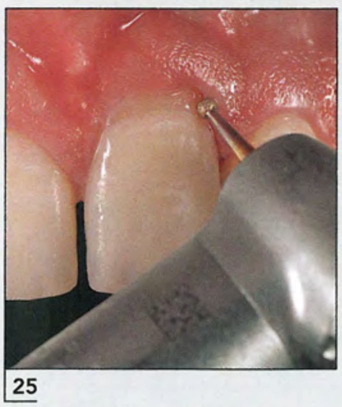
23c

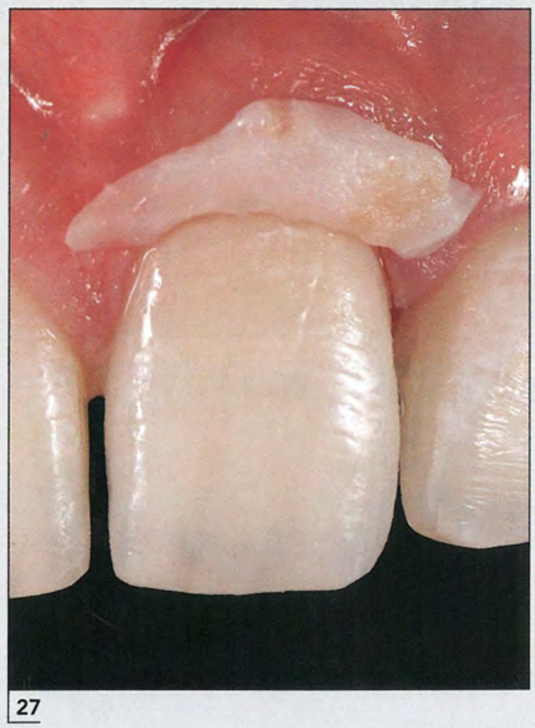
Figs 23a to 23c Diamond bur is used to reduce the distal aspect of the left central incisor.

The coping was layered with porcelain (IPS e.max Ceram, Ivoclar Vivadent) (Fig 22). At the second try-in, the form, texture, color, and line angles were evaluated. The distal aspect of the left central incisor was clinically reduced with a diamond bur (Fig 23) to obtain perfect fit of the restoration on the prepared tooth (Fig 24).

After glazing and finishing, the crown was adhesively cemented (Variolink Veneer Medium, Ivoclar Vivadent). Next, a concavity was created apical to the crown margin with a round high-speed diamond bur (Fig 25). This provided space for the connective tissue graft while simultaneously eliminating enamel and exposing dentin for better attachment of the graft to the tooth surface (Fig 26). The exposed dentin was treated with hypersaturated citric acid for 2 minutes, and a connective tissue graft was harvested from the max-







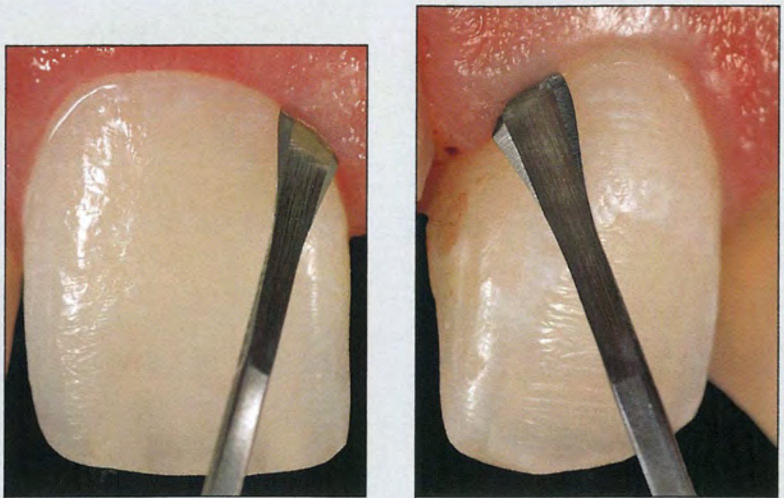
Figs 24a to 24d Ceramic crown in place *(a and b)* before and after bonding and distal enamelplasty reshaping. Close-up *(c and d)* before and after bonding and reshaping.

Fig 25 Concavity is created apical to the crown margin.

Fig 26 Space is now adequate for a connective tissue graft.

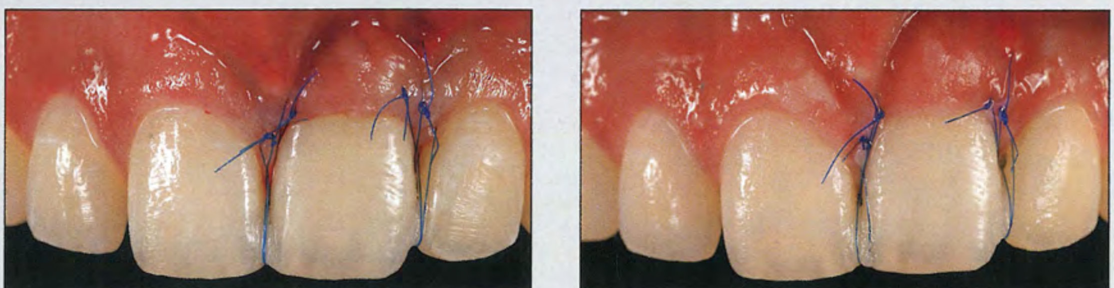
Fig 27 Connective tissue graft in place.

illary tuberosity (Fig 27). To achieve optimal suturing (Seralene 6/0, American Dental Systems, Vaterstetten, Germany) and healing, a split-thickness buccal pouch was carried out beneath the papillae, extending beyond the mucogingival junction with periostal releasing incisions while avoiding vertical incisions.



28a 28b

29a 29b 29c



30a 30b

Microsurgical ophthalmologic tunneling blades were used to ensure minimally invasive surgery (Fig 28). Two composite resin anchorage points were used on the mesial and distal aspects of the restoration to allow for a coronally advanced flap and complete graft coverage (Fig 29). Healing was uneventful (Fig 30) and the final result was satisfactory. The marginal gingival level remained stable over time (Fig 31). The thickness of the connective tissue graft and the slightly concave root shape allowed for mechanical resistance and soft tissue stability (Fig 32), and the patient's smile confirms a successful outcome (Fig 33).

CONCLUSION

The replacement of ankylosed teeth is a clinical challenge that may result in poor long-term outcomes. This article described an alternative approach to the restoration of an ankylosed maxillary central incisor in a young patient. A detailed and comprehensive treatment plan allowed for a more stable and less invasive treatment. Satisfactory functional and esthetic results were achieved.


31a


31b


32a


32b

Figs 28a and 28b Tunneling blades ensure a minimally invasive surgery.

Fig 29a Interproximal phosphoric acid etching.

Fig 29b Application of bonding resin.

Fig 29c Anchorage with flowable composite.

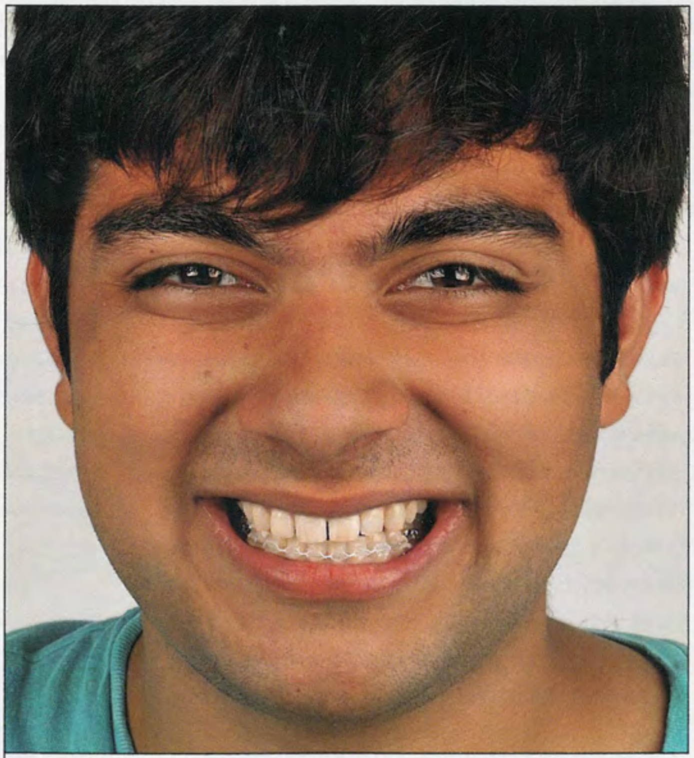
Fig 30a Immediately postoperative.

Fig 30b Healing after 10 days.

Figs 31a and 31b Preoperative and final anterior views.

Figs 32a and 32b Close-up views.

Fig 33 Final smile.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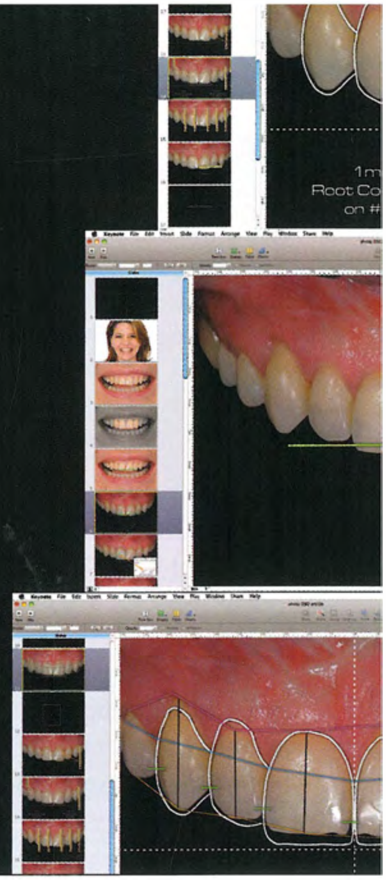

Digital Smile Design: A Tool for Treatment Planning and Communication in Esthetic Dentistry

Christian Coachman, DDS, CDT[1]
Marcelo Calamita, DDS, MS, PhD[1]

To obtain consistent esthetic outcomes, the design of dental restorations should be defined as soon as possible. The importance of gathering diagnostic data from questionnaires and checklists[1–7] cannot be overlooked; however, much of this information may be lost if it is not transferred adequately to the design of the restorations. The diagnostic data must guide the subsequent treatment phases,[8] integrating all of the patient's needs, desires, and functional and biologic issues into an esthetic treatment design.[9,10]

The Digital Smile Design (DSD) is a multi-use conceptual tool that can strengthen diagnostic vision, improve communication, and enhance predictability throughout treatment. The DSD allows for careful analysis of the patient's facial and dental characteristics along with any critical factors that may have been overlooked during clinical, photographic, or diagnostic cast–based evaluation procedures. The drawing of reference lines and shapes over extra- and intraoral digital photographs in a predetermined sequence can widen diagnostic visualization and help the restorative team evaluate the limitations and risk factors of a given case, including asymmetries, disharmonies, and violations of esthetic principles.[1] DSD sketches can be performed in presentation software such as Keynote (iWork, Apple, Cupertino, California, USA) or Microsoft PowerPoint (Microsoft Office, Microsoft, Redmond, Washington, USA). This improved visualization makes it easier to select the ideal restorative technique.

The DSD protocol is characterized by effective communication between the interdisciplinary dental team, including the dental technician. Team members can identify and highlight discrepancies in soft or hard tissue morphology and discuss the best available solutions using the amplified images. Every team member can add information directly on the slides in writing or using voice-over, thus simplifying the process even more. All team members can access this information whenever necessary to review, alter, or add elements during the diagnostic and treatment phases.

[1]Private Practice, São Paulo, Brazil.

Correspondence to: Dr Christian Coachman, Oral Esthetic Rehabilitation, Well Clinic, Rua Bento de Andrade, 116, São Paulo, SP, Brazil, 04503-000. Email: ccoachman@hotmail.com; www.wellclinic.com.br

The adoption of the DSD protocol can make diagnosis more effective and treatment planning more consistent. The efforts required to implement DSD are rewarded by more logical and straightforward treatment sequencing, leading to savings in time, materials, and cost during treatment.

DIGITAL SMILE DESIGN

The DSD protocol offers advantages in the following areas:

- Esthetic diagnosis
- Communication
- Feedback
- Patient management
- Education

Esthetic Diagnosis

When the dentist first evaluates a new patient with esthetic concerns, many critical factors may be overlooked. A digital photography and digital analysis protocol enables the dentist to visualize and analyze issues that he or she may not notice clinically. Drawing of reference lines and shapes over extra- and intraoral digital photographs can easily be performed using presentation software.

Communication

Traditionally, smile design has been instituted by the dental technician. The technician performs the restorative wax-up, creates the tooth shapes and dental arrangements, and follows the instructions and guidelines provided by the dentist in writing or by phone. In many cases, however, insufficient information is given to the dental technician to utilize his or her skills to maximum potential. As a result, the final restoration is less likely to fully satisfy the patient's desires.

When the treatment coordinator or whichever member of the restorative team has developed a personal relationship with the patient takes responsibility for the smile design, the results are likely to be far superior. This individual has the ability to better communicate the patient's personal preferences and/or morphopsychologic features to the technician, elevating the excellence of the restoration from acceptable to exceptional.[7,8,11]

Successful restorative treatment involves controlling the four dimensions of treatment: esthetics, function, structure, and biology. In relation to esthetics, there are four main issues that must be controlled to improve predictability and meet patient expectations: the horizontal reference plane, facial midline, smile design (tooth shape and arrangement), and color. The question is how to precisely transfer this information from the face to the mouth, to the cast, and to the final restoration. The primary goal of the DSD protocol is to facilitate this process.

With this valuable information in hand, the dental technician can fabricate a three-dimensional wax-up more efficiently, focusing on developing anatomical features within the parameters provided, including the planes of reference, facial and dental midlines, recommended incisal edge position, lip dynamics, basic tooth arrangement, and incisal plane.

This information is transferred from the wax-up to the try-in phase through a mock-up or provisional restoration.[4,6,12] The design of the definitive esthetic restorations should be developed and tried-in as soon as possible to guide the treatment sequence. Efficient treatment planning helps the entire dental team identify any challenges and reduce total treatment time.[8]

Feedback

The DSD allows for precise evaluation of the results obtained in every treatment phase. The sequence of treatment is organized on the slides with photographs, videos, notes, graphics, and drawings. At any time, team members can access the slide presentation to track and analyze the treatment provided. With the digital ruler, drawings, and reference lines, easy comparisons can be made between pre- and posttreatment photographs. These comparisons help determine whether the treatment has successfully followed the original plan or if other adjunctive procedures are necessary to improve the final outcome. The dental technician also gains feedback related to tooth shape, arrangement, and color to facilitate any necessary refinements. This constant double-checking ensures the excellence of the final result and provides a great learning tool for the entire interdisciplinary team. The DSD tool also serves as a useful library of treatment procedures. Clinicians can revisit treatments performed years ago and learn from past results.

Patient Management

The DSD can be used as a marketing tool to motivate the patient, an educational tool to help explain issues related to treatment, and an evaluative tool by comparing before and after photographs. Further, the library of slides from past treatments can be used to demonstrate treatment possibilities during patient consultation. The treatment planning presentation will be much more effective because the DSD allows patients to visualize the multiple factors responsible for their orofacial issues. The problems presented in each case can be superimposed in list form directly over the patient's own photographs. The clinician can express the severity of the case, introduce treatment strategies, discuss the prognosis, and make case management recommendations. In addition, DSD aids in patient acceptance by helping them visualize and understand both past and future treatments.

Education

This personal library of clinical cases can also be shared with patients and colleagues, and the most appropriate cases can be transformed into a slideshow for dental presentations and lectures. DSD can increase the visual impact of a lecture by incorporating the slides from clinical cases. The audience can better understand the concepts discussed, and the presenter can minimize the use of a laser pointer.

DSD Workflow

The authors carry out the DSD protocol using Keynote software (iWork); however, similar software such as Microsoft PowerPoint can be used with minor adjustments to the technique. Keynote allows for simple manipulation of the digital images and the addition of lines, shapes, and measurements over the clinical and laboratory images.

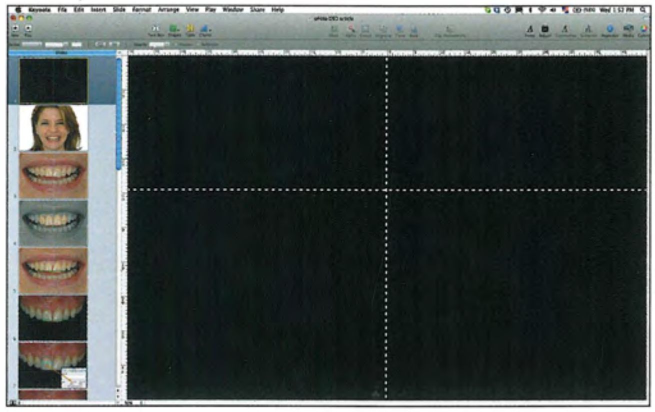

Fig 1 Slide presentation software (Keynote, iWork, Apple) with crossing lines placed on the middle of the slide.

Three basic photographic views are necessary: full face with a wide smile and the teeth apart, full face at rest, and retracted view of the full maxillary arch with teeth apart. A short video is also recommended in which the patient is prompted by the clinician to explain his or her treatment concerns and expectations. Simultaneously, the video should capture all possible dental and smile positions, including 45-degree and profile views. The photographs and videos are downloaded and inserted into the slide presentation. The DSD workflow then proceeds as follows:

1. **The cross:** Two lines must be placed on the center of the slide, forming a cross (Fig 1). The facial photograph with the teeth apart should be positioned behind these lines.
2. **Digital facebow:** Relating the full-face smile image to the horizontal reference line is the most important step in the smile design process. The interpupillary line should be the first reference line to establish the horizontal plane, but it should not be the only one. The face as a whole must be analyzed before determining the best horizontal reference to achieve harmony. After determining the horizontal reference line, the facial midline is outlined according to facial features such as the glabella, nose, and chin (Fig 2).

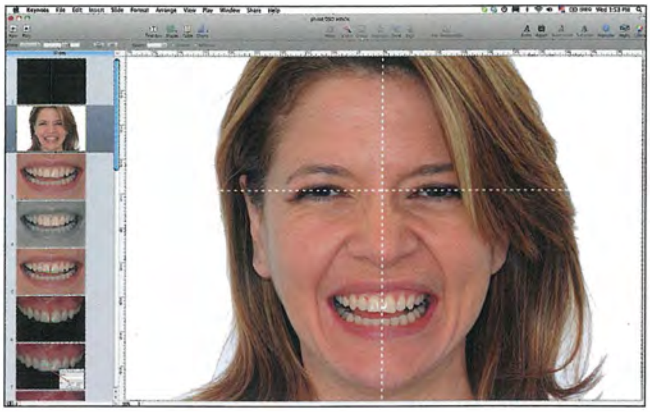

Fig 2 The facial photograph with a wide smile and the teeth apart is moved behind the cross to determine the ideal horizontal plane and vertical midline (ie, the digital facebow).

Fig 3 Transferring the cross to the smile: grouping the lines with the facial photograph and zooming in to analyze the relationship between the facial lines, lips, teeth, and gingiva.

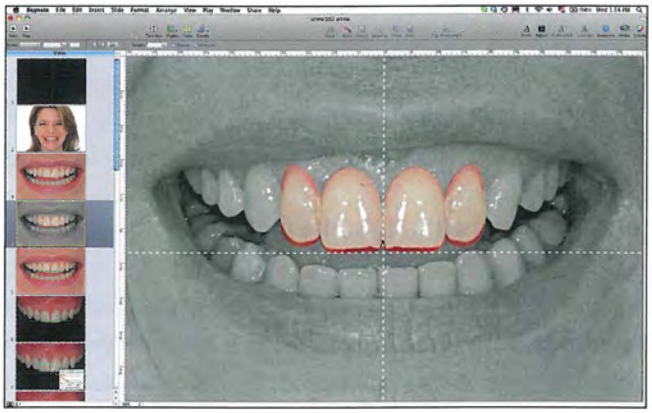

Fig 4 Basic dental simulation performed by cropping the images of the teeth and placing them over the smile photograph, correcting the gingival levels, length, and the canting of the anterior teeth.

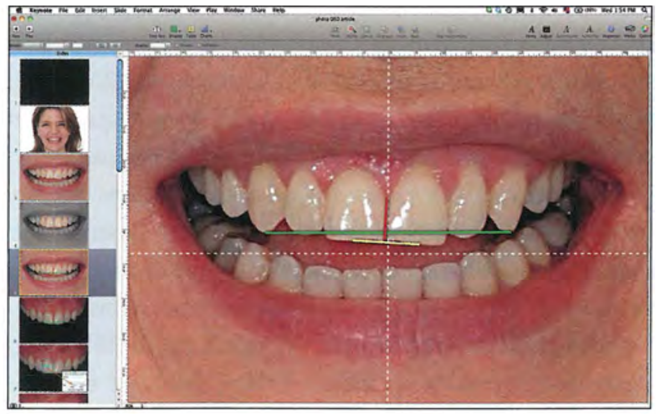

Fig 5 Drawing the three reference lines that will allow for transferring of the cross to the intraoral photograph.

3. **Smile analysis:** Dragging the horizontal line over the mouth will allow for initial evaluation of the relationship of the facial lines with the smile. Grouping the lines and the facial photographs will allow the clinician to zoom in on the image without losing the reference between the lines and photograph. Midline and occlusal plane shifting and canting can be easily detected (Fig 3).
4. **Smile simulation:** Simulations can be performed to fix the incisal edge position, canting, shifting, tooth proportions, and soft tissue outline (Fig 4).
5. **Transferring the cross to the intraoral images:** To analyze the intraoral photographs in accordance with the facial references, the cross must be transferred to the retracted view using three transferring lines drawn over the smile view as follows (Fig 5):
   a) *Line 1:* from the tip of one canine to the tip of the contralateral canine.
   b) *Line 2:* from the middle of the incisal edge of one central incisor to the middle of the incisal edge of the contralateral central incisor.
   c) *Line 3:* over the dental midline, from the tip of the midline interdental papillae to the incisal embrasure.

It is necessary to calibrate four features on the photograph: size, canting, incisal edge position, and midline position. Line 1 will guide the two first aspects (size and canting), line 2 will guide the incisal edge position, and line 3 will guide the midline position (Fig 6).

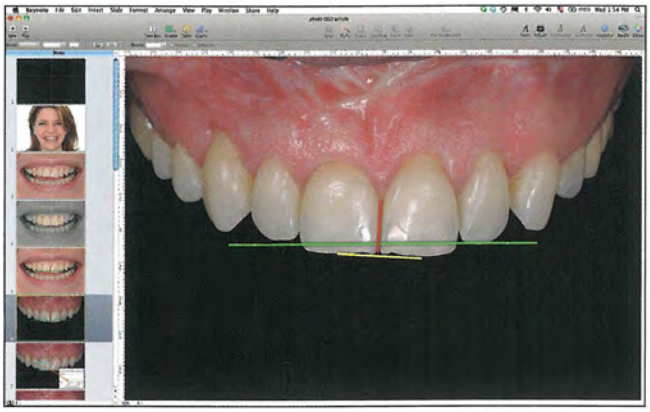

Fig 6 Intraoral photograph adjusted to the three reference lines.

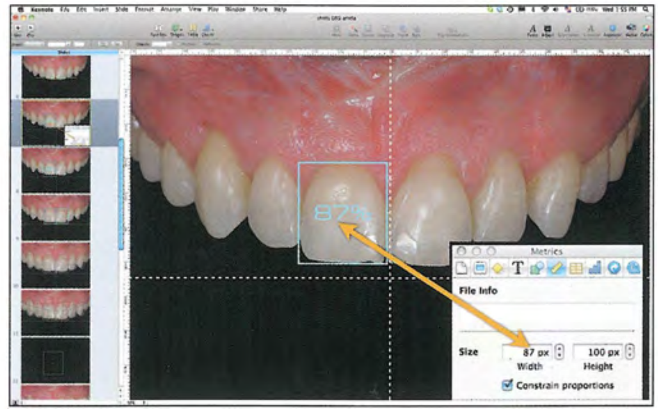

Fig 7 Intraoral photograph with the cross used to measure the actual length/width proportion of the right central incisor.

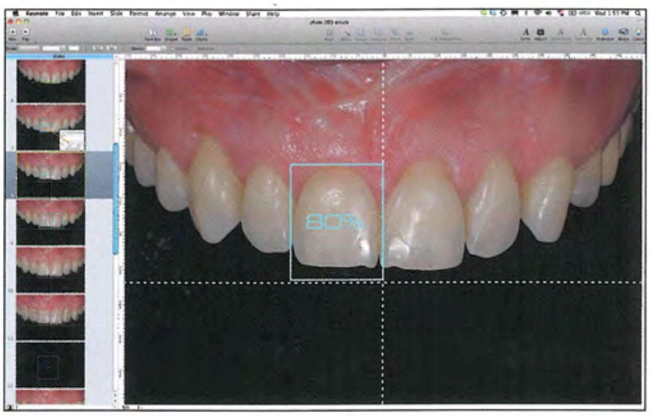

Fig 8 A rectangle with ideal length/width proportion (80%) is placed over the central incisor to compare the actual pretreatment proportion with the ideal one.

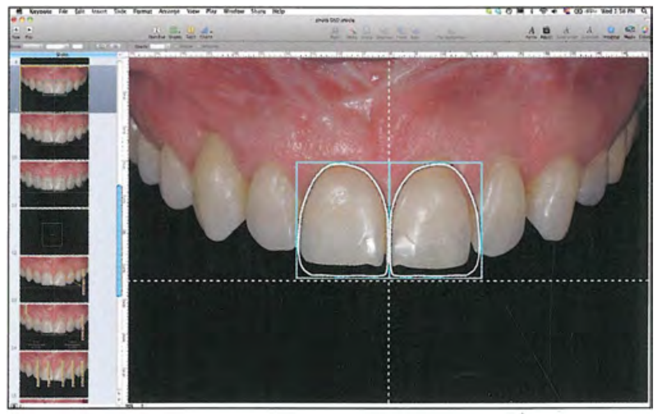

Fig 9 Drawing the tooth outline, as guided by the cross and by the rectangle proportion.

6. **Measuring tooth proportion:** Measuring the width/length proportion of the central incisors is the first step toward understanding how to best redesign the smile. A rectangle is then placed over the edges of both central incisors (Fig 7). The proportions of the patient's central incisors can be compared to the ideal proportions described in the literature (Fig 8).[2–8]
7. **Tooth outline:** From this step on, all drawings may be performed depending on what needs to be visualized or communicated for each specific case. For example, tooth outlines can be drawn over the photograph, or premade tooth outlines can be copied and pasted. The selection of tooth shape will depend on factors such as the morphopsychologic interview and the patient's desires, facial features, and esthetic expectations (Figs 9 and 10).[11,13]

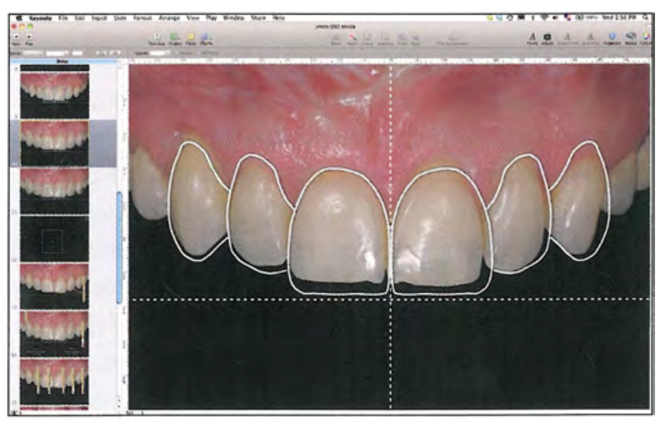

Fig 10 Final teeth outline showing the relationship between the preoperative situation and the ideal design.

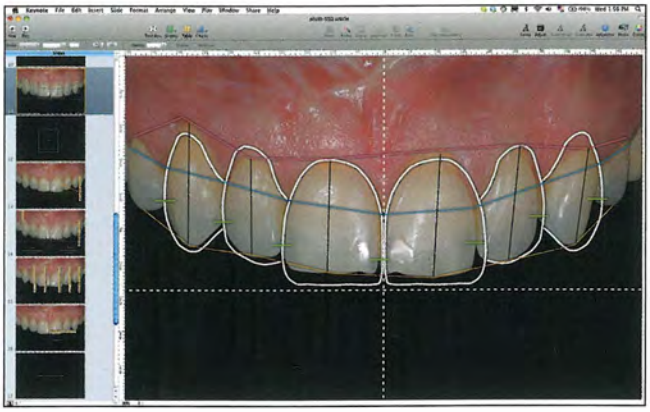

Fig 11 Other drawings and lines can be added as needed to help visualize the esthetic issues and improve the efficiency of communication.

Fig 12 Measuring the length of the left central incisor (10.6 mm) on the cast. This measurement will be transferred to the computer for calibration of the digital ruler.

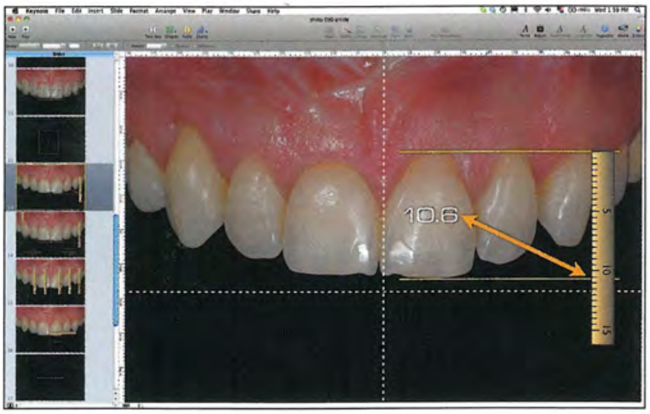

Fig 13 Calibrating the digital ruler on the slide by shrinking/stretching until it matches the measurement done on the cast. The digital ruler is a photograph of a ruler (JPEG file) that is dragged on top of the slide and can be positioned as necessary.

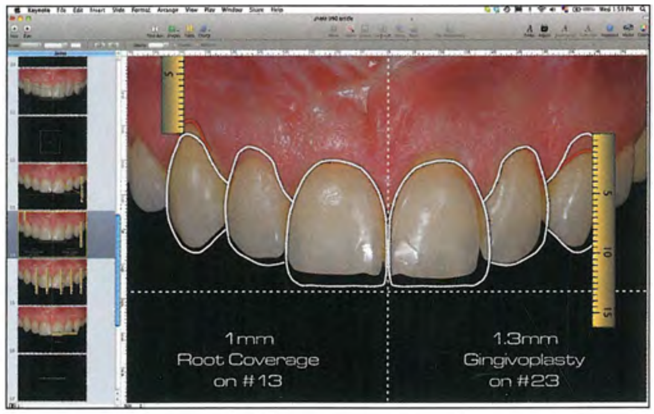

Fig 14 Measurements can be taken of the difference between the preoperative location of the cervical areas of the canines compared to the ideal location. In this case, one maxillary canine needed crown lengthening and the other required root coverage.

8. **White and pink esthetic evaluation:** After all reference lines and drawings have been provided, the clinician should have a clear understanding of the esthetic issues involved in the patient's maxillary arch, including the tooth proportions, interdental relationship, relationship between the teeth and smile line, discrepancy between facial and dental midlines, midline and occlusal plane canting, soft tissue disharmony, relationship between the soft tissues and teeth, papillae heights, gingival margin levels, incisal edge design, and tooth axis (Fig 11).
9. **Digital ruler calibration:** The digital ruler can be calibrated over the intraoral photograph by measuring the length of one of the central incisors on the cast (Fig 12) and transferring this measurement to the computer (Fig 13). Once the digital ruler is calibrated, the clinician can make any measurements needed over the anterior area of the image (Fig 14).
10. **Transferring the cross to the cast:** First, the horizontal line over the intraoral photograph should be moved above the gingival margin of the six anterior teeth. The distance between the horizontal line and the gingival margin of each tooth is measured using the digital ruler, and these measurements are written down on the slide (Fig 15). The measurements are then transferred to the cast with the aid of a caliper. Pencil marks are made on

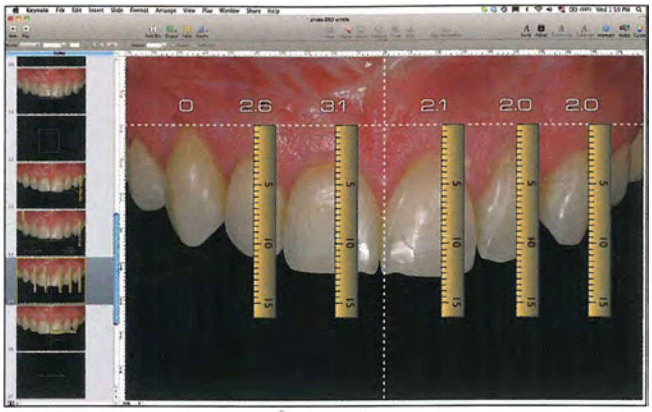

Fig 15 The horizontal line is placed randomly above the gingival margin of the anterior teeth. This distance is then measured and transferred to the stone cast using the digital ruler.

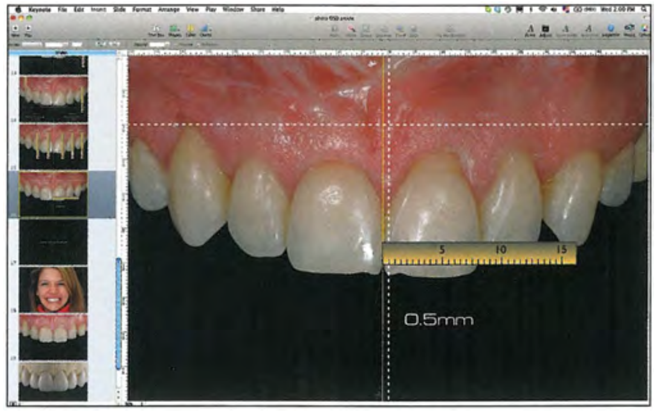

Fig 16 Measuring the discrepancy between the facial midline and dental midline.

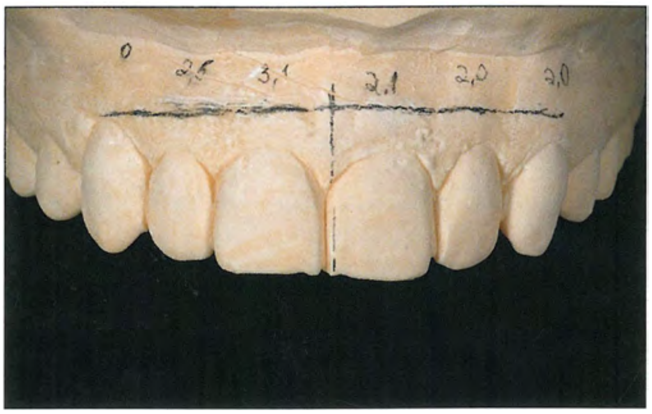

Fig 17 All the measurements are transferred to the cast, and the cross is drawn.

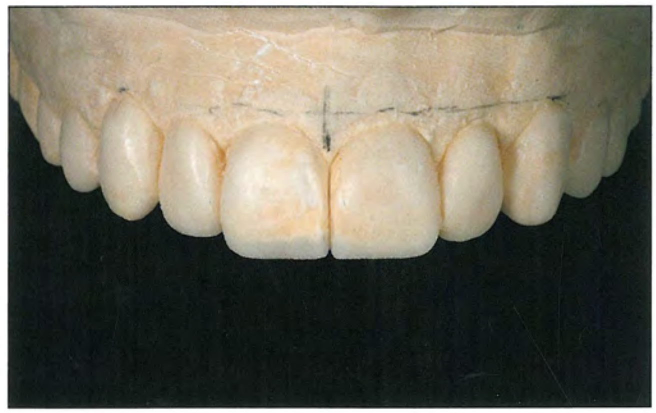

Fig 18 The diagnostic wax-up is fabricated using the cross and morphopsychologic design as guides. The new incisal length is measured on the computer and transferred to the wax-up with a caliper.

the cast at the same distances above the gingival margins as shown on the digital images. Those dots are then connected, creating a horizontal line above the teeth. The next step is to transfer the vertical midline. Because the vertical line must be perpendicular to the horizontal line, only one point is necessary to determine its location. The distance between the dental midline and the facial midline at the incisal edge is measured on the computer, and the distance is then transferred to the cast with the caliper (Fig 16). Subsequently, the line can be drawn perpendicular to the horizontal line passing over this reference point. After drawing the cross on the cast (Fig 17), it is possible to transfer any necessary information, such as gingival margins, root coverage, crown lengthening, incisal edge reduction, and tooth width. At this stage, all information the technician will need to develop a precise wax-up is available on both the slides and cast (Fig 18).

The guided diagnostic wax-up will be an important reference for any surgical, orthodontic, and restorative procedures. Several guides can be produced over this wax-up to control the procedures, such as surgical stents, orthodontic guides, implant guides, crown lengthening guides, and tooth preparation guides. The next important step to evaluate the precision of

Fig 19 Try-in provisional made with bis-acrylic resin is obtained from a silicone index fabricated on top of the diagnostic wax-up.

Fig 20 Final minimally invasive tooth preparation guided by the silicone indexes.

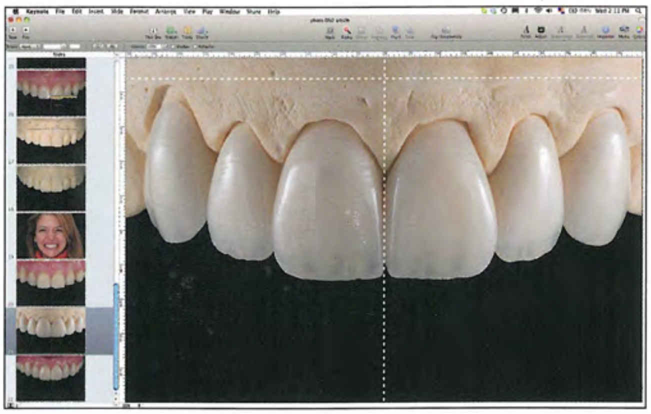

Fig 21 Final ceramic veneers (IPS e.max, Ivoclar Vivadent, Schaan, Liechtenstein) fabricated according to the silicone indexes.

Fig 22 Ceramic veneers after bonding.

Fig 23 Final outcome after 6 months.

the DSD protocol and the wax-up is to perform a clinical try-in (Fig 19). The clinical try-in can be carried out using a direct mock-up or a provisional restoration depending on the complexity of the case. After patient approval, the restorative procedures can be adjusted as necessary. Tooth preparation should be minimally invasive, allowing just enough clearance to create proper space for ceramic restorations (Fig 20). Fabrication of the final restorations should be a controlled process with minimal final adjustments (Fig 21). If all of these steps are carried out properly and carefully, the final result will likely exceed the patient's expectations (Figs 22 and 23).

CONCLUSIONS

The Digital Smile Design is a multi-use tool that can assist the restorative team throughout treatment, improving the dental team's understanding of the esthetic issues and increasing patient acceptance of the final result. The placement of references lines and other shapes over extra- and intraoral digital photographs widens the dental team's diagnostic vision and helps to evaluate the limitations, risk factors, and esthetic principles of a given case. These critical data will lead to improved results in all phases of treatment.

ACKNOWLEDGMENT

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State of the Art

Achieving Excellence in Smile Rehabilitation Using Ultraconservative Esthetic Treatment: A Multidisciplinary Vision

Victor Grover Rene Clavijo, DDS, MS, PhD[1]
Paulo Fernando Mesquita de Carvalho, DDS, MS[2]
Robert Carvalho da Silva, DDS, MS, PhD[2]
Julio Cesar Joly, DDS, MS, PhD[2]
Luis Alves Ferreira, CDT[3]
Victor Humberto Orbegoso Flores, DDS, MS, PhD[4]

Today, esthetic restorative dentistry can offer smile rehabilitations using a conservative approach with minimal removal of sound dental structures. The aim of this article is to demonstrate a multidisciplinary, ultraconservative method of restoring the harmony of the smile.

CASE REPORT

The patient was extremely embarrassed of her smile, resulting in shyness and minimal social interaction. The initial clinical exam revealed diastema, congenitally missing maxillary lateral incisors with the canines located in the lateral incisor positions, and the primary maxillary canines still located in their original positions (Fig 1). These aspects created not only esthetic deficiencies, but also malocclusion.[1] Therefore, a multidisciplinary treatment was suggested to restore both esthetics and function.[2]

[1]Professor, Advanced Program in Implantology and Restorative Dentistry, ImplantePerio Institute, São Paulo, Brazil.

[2]Director, Advanced Program in Implantology, ImplantePerio Institute, São Paulo, Brazil.

[3]Dental Technician, São Paulo, Brazil.

[4]Associate Professor; Restorative Dentistry, Preventive, and Fixed Prosthodontics; Federal University of Alfenas School of Dentistry, Alfenas, Minas Gerais, Brazil.

Correspondence to: Dr Victor Clavijo, Rua Cerqueira Cesar, 1078 Indaiatuba, São Paulo, Brazil 13330-005. Email: clavijovictor@yahoo.com.br; www.implanteperio.com.br

1a

1b

1c

1d

1e

Figs 1a to 1e Preoperative situation showing esthetic deficiencies due to diastema, canine location, and presence of primary teeth. Note the discrepancy in the position of the gingival margin.

Phase 1: Planning

All dental professionals involved in the treatment (orthodontist, periodontist, master ceramist, and operative dentist) evaluated the clinical case individually to decide which noninvasive procedures were indicated. Next, the four professionals discussed the prognosis and limitations of the case. The master ceramist performed a diagnostic wax-up to provide a model of the multidisciplinary treatment. After patient approval, the conservative treatment was then split into three restorative phases: orthodontic, surgical, and restorative.

Phase 2: Orthodontics (Figs 2 to 6)

The orthodontic phase began with the analysis of craniofacial growth, radiographs, and study casts. Primary maxillary canines were extracted, and a fixed orthodontic appliance was used to close the diastema between the maxillary central incisors and redistribute the interdental spaces for esthetic rehabilitation. The orthodontic treatment used the following parameters for evaluation: sagittal relationship between the dental arches; posterior occlusion; location, shape, and size of the canines; amount of remaining interdental space; and profile and facial skeletal pattern of the patient.[3] After orthodontic treatment was finalized, the orthodontic brackets were removed and a removable appliance was used to replace the missing maxillary lateral incisors.

Phase 3: Surgical (Fig 7)

The surgical phase was initiated with esthetic flap surgery to reposition the zenith of the maxillary canines and central incisors. On the same day, open full-flap envelope surgery allowed the placement of two implants to replace the congenitally missing maxillary lateral incisors (3.3 × 14 mm, Straumann Bone Level Narrow CrossFit, Straumann, Basel, Switzerland). After implant placement, conjunctive grafts were performed to increase the gingival volume, and healing caps were placed. These procedures were necessary to restore the harmony of the pink (gingival) and white (dental) architecture.

Phase 4: Restorative (Figs 8 to 36)

After a period of healing and osseointegration, uncovering surgery was performed. The transfer copings were then positioned, and a vinyl polysiloxane (VPS) impression was made to fabricate the working cast. Zirconia abutments and provisional crowns were fabricated to shape the gingival margins to the desired contour.

After the gingival tissues were remodeled and contoured, acrylic resin impression copings (Duralay, Reliance Dental, Worth, Illinois, USA) were fabricated for the implant abutments before the final pickup impression was taken using VPS. Before the impression procedures, an interocclusal bite registration was taken and the shade was selected.

Two lithium disilicate all-ceramic crowns (IPS e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) were made for the implants, and two feldspathic ceramic fragments (IPS d.Sign, Ivoclar Vivadent) were fabricated using the refractory die technique to close the diastema between the maxillary central incisors.

All restorations were checked for fit, marginal adaptation, and interproximal contacts. The final shade was evaluated using glycerin-based try-in paste (Variolink Try-in, Ivoclar Vivadent), which resulted in the selection of clear translucent resin cement. All restorations were adhesively cemented. The fragments were etched with hydrofluoric acid for 90 seconds, rinsed, and dried. To remove any ceramic debris, additional etching was carried out with 35% phosphoric acid for 30 seconds. All fragments were silanated (Monobond, Ivoclar Vivadent). The lithium disilicate crowns were also processed as described above, except that the hydrofluoric acid etching was performed for only 20 seconds.

The ceramic fragments were simultaneously bonded to etched enamel using light-polymerized dental adhesive (Excite, Ivoclar Vivadent) and a clear translucent light-polymerized resin cement (Variolink II, Ivoclar Vivadent). Facial and palatal ceramic overcontouring was removed with a high-speed fine diamond bur, followed by polishing with intraoral ceramic finishing and polishing points. After cementation of the ceramic fragments, the lithium disilicate ceramic crowns were adhesively cemented to the zirconia implant abutment. The zirconia abutments were silanated (Monobond Plus), and dual-cured resin cement was used for bonding (Variolink II). Occlusion was checked, and the patient was dismissed.


2a


2b


3

Fig 2a Orthodontic appliance in place.

Fig 2b After 24 months, note the recovery of space required for prosthetic rehabilitation of the maxillary lateral incisors.

Figs 3 Facial view after completion of orthodontic treatment.

Figs 4a to 4d Extraoral views of the smile after orthodontic treatment.


4a


4b


4c


4d

5a

5b

5c

5d

5e

Figs 5a to 5e Intraoral views of the maxillary anterior teeth after orthodontic treatment. Note the asymmetry of the gingival margins and the diastema between the central incisors.

6a

6b

6c

Figs 6a to 6c Incisal views of the maxillary anterior teeth.

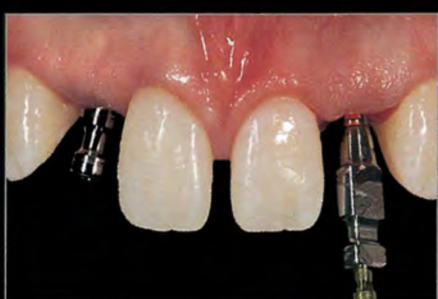
7a

7b

Figs 7a and 7b Clinical appearance 2 months after implant placement at the maxillary lateral incisor sites.

8a

8b



8c

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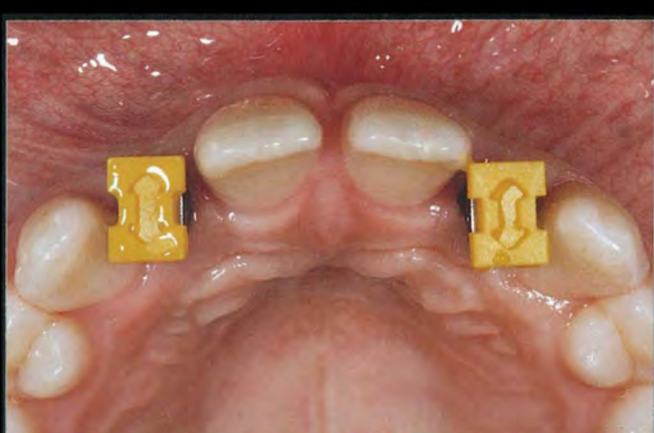
Figs 8a and 8b A minimally invasive surgical procedure was performed to expose the implants.

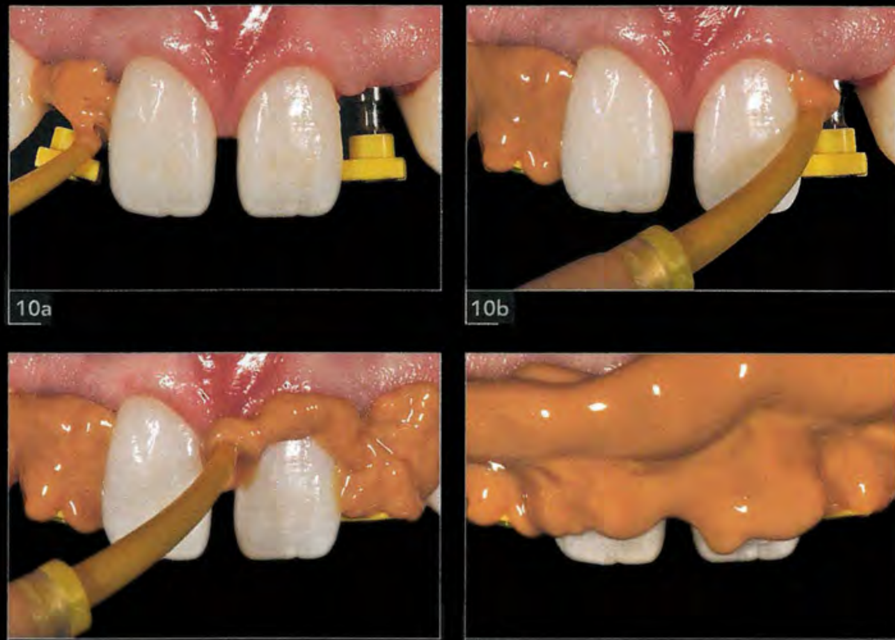
Figs 8c to 8e Placement of the transfer copings.



9a

9b

Figs 9a and 9b Placement of the transfer guides.



10a 10b 10c 10d

Figs 10a to 10d PVS impression procedure.

Fig 11a Transfer copings and analogs.

Fig 11b Insertion of the transfers into the analogs.

Fig 11c Placement of the transfers and analogs on transfer guides captured by the mold.

Fig 12a Anatomical titanium infrastructure and milled zirconia abutment.

Fig 12b Phosphoric acid applied for 60 seconds.

12a

12b

12c

12d

12e

Figs 12c and 12d Application of Metal-Zirconia Primer (Ivoclar Vivadent).

Fig 12e Application of the adhesive (Multilink, Ivoclar Vivadent) into the zirconia abutment.

13a

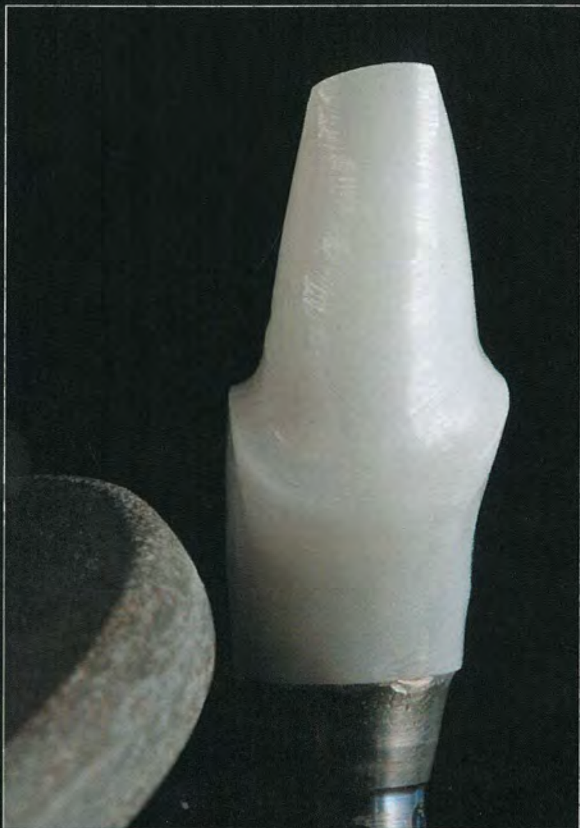
13b

Fig 13a Cementation of the abutment (Multilink).

Fig 13b Removal of excess cement.

Fig 13c Finishing of the bonded interface.

Fig 13d Abutments after cementation (Luiz Alves Ferreira, CDT).



13c

13d

14a

14b

14c

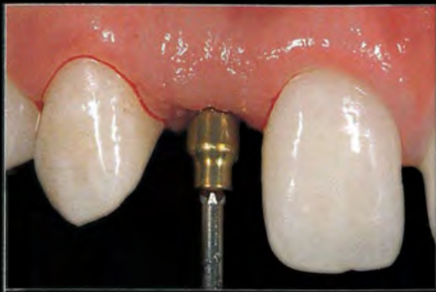
14d

14e

Figs 14a to 14c Provisional restorations and abutments.

Fig 14d Abutments on the cast.

Fig 14e Acrylic resin guide for abutment placement.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15b

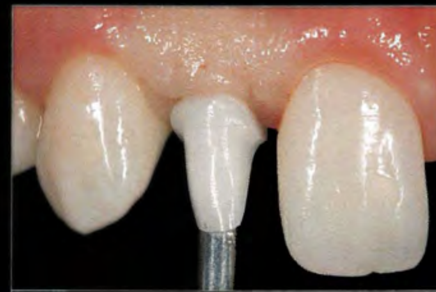

15c

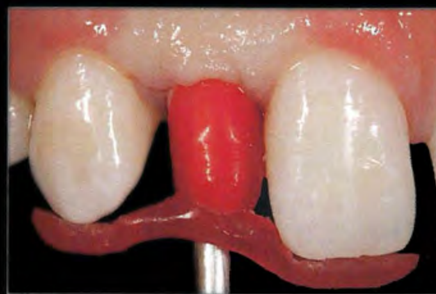
Fig 15a Removal of the healing cap.

Figs 15b to 15e Guided insertion of the abutment.

Fig 16a Soft composite resin sealing of the screw access hole.

Fig 16b Light polymerization.

Fig 16c PVS impression of the abutment.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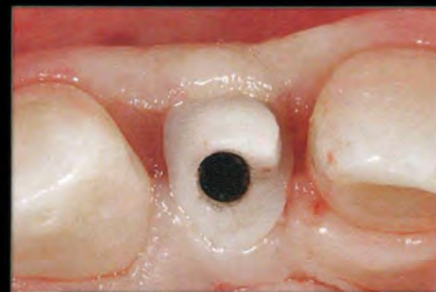
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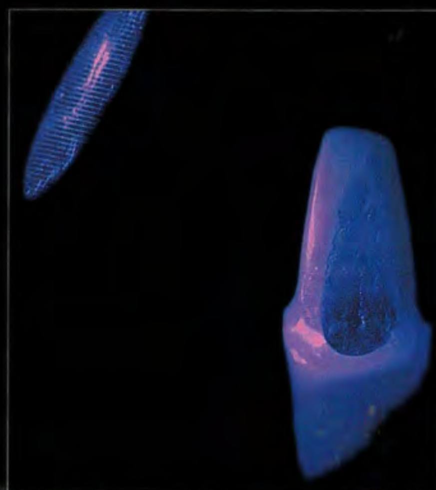
16a


16b


16c


17a


17b


17c

Figs 17a to 17c Provisional restorations 3 months after placement.

18a

18b

18c

18d

Fig 18a After healing, note the condition of the soft tissue prior to final impression procedures.

Figs 18b to 18d Impression copings.

19a

19b

19c

19d

Figs 19a to 19d Shade selection: *(a)* VITA Classical Shade Guide (VITA Zahnfabrik, Bad Säckingen, Germany) with different hues, chromas, and values; *(b)* same image in grayscale; *(c)* detail view of the central incisors; *(d)* detail view of the central incisors with increased saturation.

Fig 20a Clinical try-in of the ceramic fragments (Luiz Alves Ferreira, CDT).

Figs 20b and 20c Interproximal contact verification.

Fig 20d Positioning of the ceramic fragments.

Fig 20e The try-in procedure (Variolink II) resulted in the selection of translucent resin cement.

Fig 21a Ceramic fragments prior to bonding.

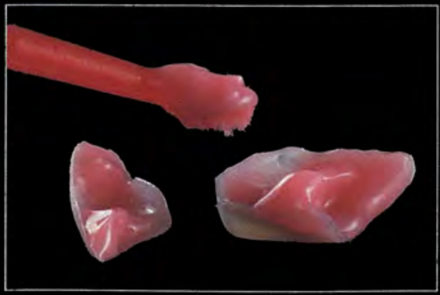


Fig 21b Hydrofluoric acid etching for 90 seconds.

Fig 21c Intaglio aspect after hydrofluoric acid etching.

22a

Fig 22a Application of phosphoric acid for 30 seconds to remove etched ceramic debris.

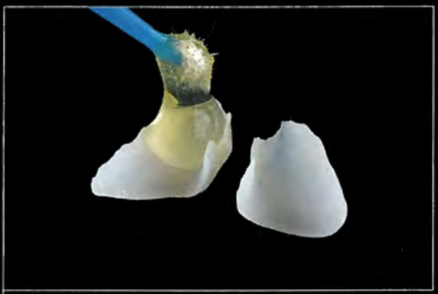
Fig 22b Ceramic fragments after phosphoric acid cleaning.

22b

23a

Fig 23a Application of silane for 60 seconds (Monobond).

Fig 23b Application of bonding agent (Excite).



23b

24a

24b

24c

24d

Fig 24a Prophylaxis of enamel surfaces before bonding with pumice slurry.

Fig 24b Enamel etching for 30 seconds.

Fig 24c Application of a two-step etch-and-rinse adhesive (Excite).

Fig 24d Evaporation of the solvent and thinning of the bonding agent.

Fig 25a Ceramic fragments bonded with transparent resin cement (Variolink II) before light polymerization.

Figs 25b to 25d Removal of excess resin cement with *(b)* an artist brush, *(c)* cotton pellets, and *(d)* dental floss.

Fig 25e Bonded ceramic fragments were light polymerized for 60 seconds per surface.


25a


25b


25c


25d


25e

Fig 26a Demarcation of the line angles and margins.

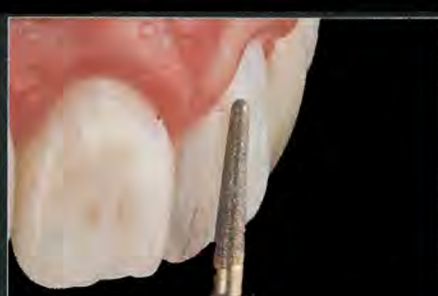
Figs 26b and 26c The ceramic/enamel margins were finished with a fine diamond bur to remove ceramic overcontouring.

Fig 26d Intraoral ceramic polishing cups were used to polish the margins.

Fig 26e Clinical appearance immediately after cementation, finishing, and polishing of the ceramic fragments.


26a


26b

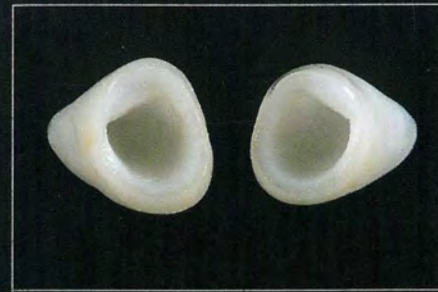

26c


26d


26e

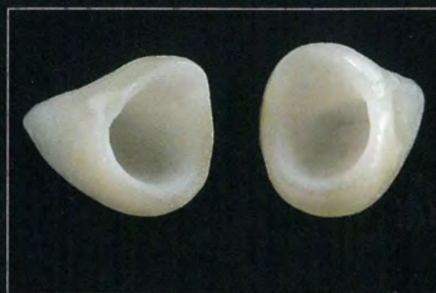
27a

27b



27c

Figs 27a to 27c Lithium disilicate all-ceramic crowns for the maxillary lateral incisors (Luiz Alves Ferreira, CDT).



Figs 28a and 28b Intaglio etching with hydrofluoric acid for 20 seconds, followed by cleaning with phosphoric acid for 30 seconds and silane application.

Fig 28c Application of the bonding agent (Excite) before adhesive cementation with dual-cured transparent resin cement (Variolink II).

Fig 29a Intraoral view after cementation.

Fig 29b Transillumination of the crowns and ceramic fragments.

30a

30b

Figs 30a and 30b Close-up views of the maxillary lateral incisors showing adequate gingival contours and emergence profile around the implants.

31a

31b

31c

Figs 31a to 31c Clinical follow-up after 16 months.

32a

32b

Fig 32a and 32b Proper balance of shade, contour, form, and occlusion was obtained.

33a

33b

34

35

Figs 33 to 36 Final result.

DISCUSSION

Although alternative treatment options were available for this clinical case, the chosen technique guaranteed the preservation of sound dentition. Orthodontic mesialization of the teeth with intrusion and extrusion could also have been performed; however, the final esthetic outcome would not be the most desirable.[4] Conversely, a mesiodistal and facial-palatal alignment of the maxillary canines is completely different from that of the maxillary lateral incisors, which hinders smile esthetics and may contribute to bite overload during chewing.[3] Correct positioning of teeth and maxillary bone allows for better lip support and smile esthetics.[2] The distalization of the maxillary canines ensured restoration of anterior guidance and occlusal function along with the esthetic rehabilitation.[4,5]

Treatment planning is the key to treatment success. Using a combination of three different treatment phases, no reduction or preparation was necessary, and the dental structures remained intact. The diastema was closed using an additive approach via the adhesive cementation of ceramic fragments.[6,7] Recent advances in bonding techniques for both teeth and ceramic guarantee the clinical success of this type of restoration.

After adhesive cementation of the ceramic fragments, minimal facial or palatal overcontouring was observed. This overcontouring must be removed by finishing and polishing at the ceramic-enamel interface. High-speed fine diamond burs under copious water-cooling can be used to adjust the ceramic interface. Next, intraoral ceramic polishing rubber points were used to minimize roughness and restore smoothness until achieving a surface analogous to the glazed ceramic.[6] Ceramic fragments bonded to unprepared enamel present very few disadvantages; nonetheless, communication between the clinician and technician is fundamental to obtain an acceptable result.[6]

CONCLUSION

This article presented the successful multidisciplinary treatment of a patient with severe esthetic and functional deficiencies. Multidisciplinary treatment planning can provide patients with high-quality noninvasive treatment that results in superior esthetics.

ACKNOWLEDGMENTS

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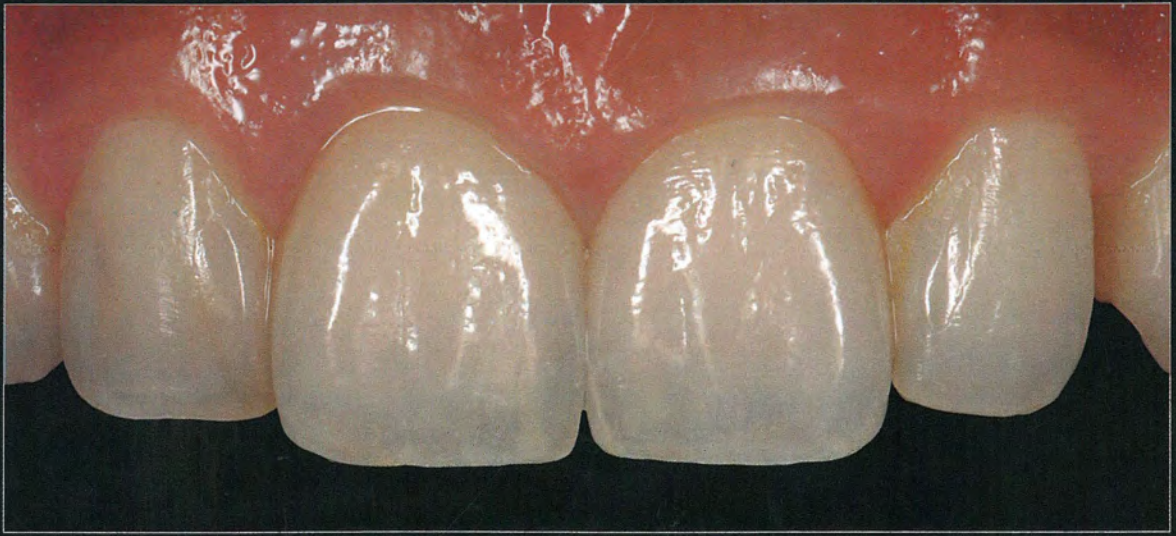
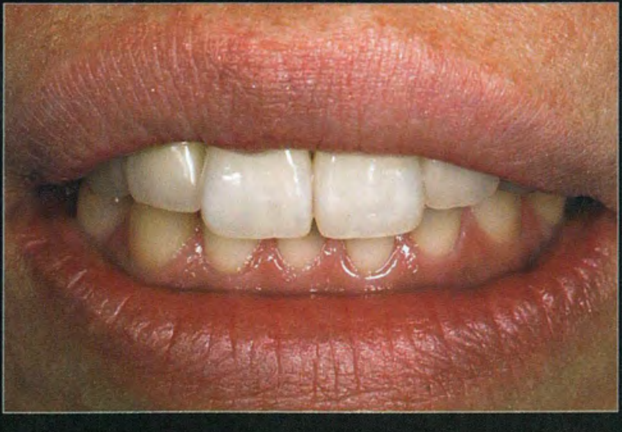
Reproduction of Natural Vivid Appearance in Porcelain Restorations
Part 2: The Essence of the Internal Staining Technique

Naoto Yuasa, RDT
Otani Dental Clinic
2-3-1-1F Shitaya, Taito-ku
Tokyo, Japan 110-0004
Email: naotoyuasa0114@gmail.com

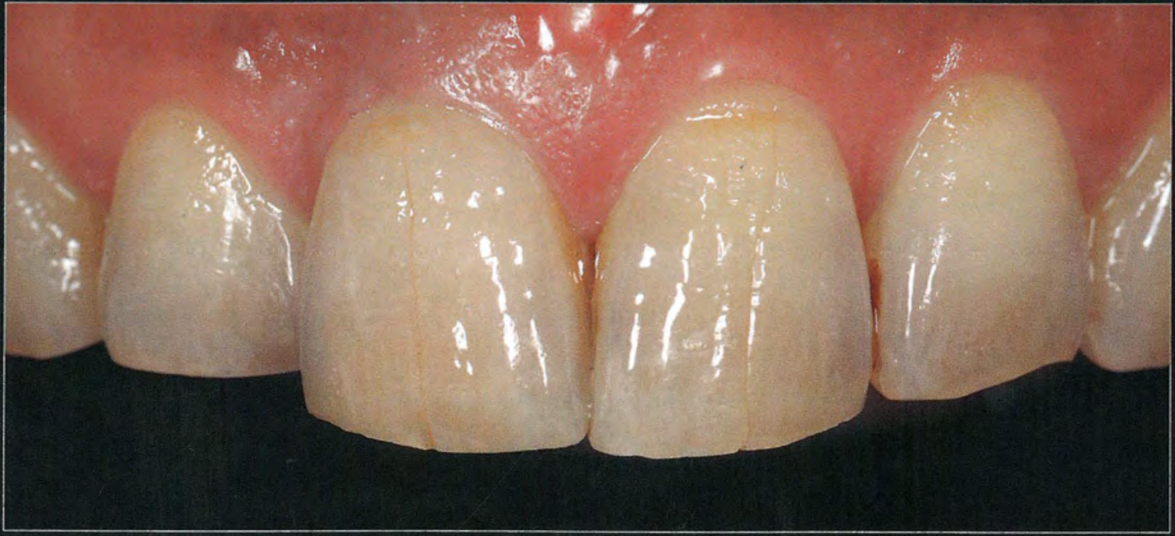
Reproduction of natural tooth color is one of the most important factors in fabricating anterior ceramic restorations, along with reproduction of tooth morphology and surface texture. Restoring a single maxillary central incisor requires exact reproduction of adjacent teeth, which is not an easy task to achieve. Internal staining is a useful technique for color reproduction of anterior restorations. In this article, factors to reproduce tooth color precisely using the internal staining technique are identified and demonstrated through clinical cases.





Case 5

Case 6




A2
A3
A3.5

Case 1

Patient: Female

Restored area: Maxillary lateral and central incisors with porcelain jacket crowns, maxillary canines and mandibular left to right canine with porcelain laminate veneers, mandibular premolars with porcelain onlays, mandibular first molars and right second molar with gold onlays, and mandibular left second molar with a gold crown

Porcelain material: Noritake EX-3 (Noritake Dental Supply, Aichi, Japan)

Figs 1 and 2 First visit. Decreased vertical dimension of occlusion (VDO) and proclination of the maxillary anterior teeth. Occlusal rehabilitation was performed along with increase of the VDO.

Fig 3 Proclination is treated orthodontically after VDO was increased. Twelve maxillary and mandibular anterior teeth were restored with porcelain jacket crowns and porcelain laminate veneers.

Fig 4 Condition of the maxillary anterior abutments.

Fig 5 Working space is checked with silicone core index, which was fabricated from the full-contour wax-up.

Fig 6 Body and enamel porcelains were built up and the surface was smoothed.

Fig 7 Completion of dentin characterization by internal staining. Each tooth was characterized accordingly, resulting in three-dimensional effects of the whole dentition.

Fig 8 One layer of translucent porcelain was added and fired only on the central incisors in an attempt to reproduce the enamel characterization by internal staining; then white spots and crack lines were stained and fired. A second layer of translucent porcelain was then built up and fired.

Fig 9 Condition of the mandibular anterior teeth.

Fig 10 Body and enamel porcelain buildup. Almost identical porcelain was built up in a simple manner.

Fig 11 Typical dentin characterization and color of the mandibular anterior teeth are represented by internal staining.

Fig 12 After refractory material is removed, proximal contact areas and fit are checked on the master cast.

Case 2

Patient: Female
Restored area: Maxillary central incisors with zirconia-based ceramic crowns
Porcelain material: Noritake Katana, Noritake Cerabien ZR

Fig 13 First visit. The patient's chief complaint was unesthetic rotated and discolored maxillary central incisors.

Fig 14 Condition of abutments. The amount of reduction of the maxillary right central incisor is more than that of the left central incisor because of its stronger discoloration.

Fig 15 Try-in of zirconia copings on the soft tissue model, which is used to confirm color during the fabrication process. It was determined that the maxillary right central incisor requires more masking than the left. Due to limited working space, it was decided not to increase the coping thickness. Masking porcelain was layered on the coping as close as possible to the abutment. The translucent layer thickness of the two restorations was kept equal.

Fig 16 Mixture ratio of masking porcelain and opacious body porcelain material and their thickness are adjusted according to the working space and color of each abutment. After the masking procedure, minute color adjustment is performed by internal staining, completing the base layer.

Fig 17 Completed restorations on the master cast. Proper interproximal space is ensured for interdental papillae.

Case 3

Patient: Female
Restored area: Maxillary lateral and central incisors with zirconia all-ceramic crowns
Porcelain material: Noritake Katana, Noritake Cerabien ZR

Fig 18 First visit. The patient desired more natural (more translucency), yet brighter-colored restorations.

Fig 19 Condition of abutments. It is confirmed that the abutment color needs to be masked with masking porcelain.

Fig 20 Zirconia Katana copings on pindexed working cast. The color of the copings is determined based on the color of the abutments, working space, and designated shade of the restoration.

Fig 21 Masking porcelain is applied only cervical to the middle body area, where dentin presents relatively high value. Regardless of the color of the abutment, masking porcelain should never be applied up to the top of the zirconia coping.

Fig 22 Completion after final adjustment on the secondary soft tissue model. Almost identical porcelain buildup is used on the central and lateral incisors. Different characterization of each tooth is made by changing the amount of translucent porcelain and internal staining.

Case 4

Patient: Female
Restored area: Maxillary central incisors and left lateral incisor with porcelain jacket crowns; maxillary left first premolar with PFM crown
Porcelain material: Noritake EX-3, Noritake Katana, Noritake Cerabien ZR

Fig 23 Condition of abutments. Abutments are all vital. Porcelain jacket crowns are ideal for color reproduction and are cost-effective as well.

Fig 24 Porcelain buildup on the refractory cast, after internal stain is fired on the body enamel. Only dentin characterization is stained at this phase. The dark zone often observed at the dentin-enamel junction is reproduced by internal staining after mamelons are stained and fired.

Fig 25 Translucent porcelain is fired, then the white band observed in enamel is stained on the surface.

Fig 26 Completed restorations on the working cast. Final minor adjustment is performed on the solid cast. Mandibular protrusive movement is taken into consideration in the position and shape of restorations.

Case 5

Patient: Female
Restored area: Maxillary right central incisor with zirconia-based ceramic crown
Porcelain material: Noritake Katana, Noritake Cerabien ZR

Figs 27 and 28 Condition of the abutment. Change in the enamel surface after bleaching is observed. The shade of the target tooth (maxillary left central incisor) is NW0. The value of the target tooth is in the range of 5~A1. The key to this restoration is the reproduction of this bright enamel color.

Fig 29 Completed restoration. In color representation of a bleached tooth, the most difficult area to reproduce is the midcoronal to incisal edge, where the enamel becomes thicker. In this case, value was increased by layering white with internal stain at the dentin-enamel junction area, and then applying slightly high-value translucent porcelain on the white layer. High value and translucency coexist using this porcelain application technique mimicking the bleached enamel (technique of Mr Kazunobu Yamada).

Fig 30 Completed restoration just before cementation. Since fit and subgingival contour of the provisional restoration is well controlled, the soft tissue is stable at the time of insertion.

Case 6

Patient: Male
Restored area: Maxillary central incisors and right lateral incisor with zirconia-based ceramic crowns
Porcelain material: Noritake Katana, Noritake Cerabien ZR

Fig 31 Dentin characterization is stained on body enamel. The base dentin color, mamelons, and dark zones are reproduced. The characterization of dark zones by internal stain is done in multiple layers (weaker on the outer layer) to maintain the look of a natural tooth.

Fig 32 Translucent porcelain is applied and fired as a base for enamel characterization by internal stain.

Fig 33 White bands and crack lines are stained and fired separately on the translucent layer. Enamel crack lines are stained close to the external surface (still internal staining).

Fig 34 Completed restoration. It is important that dentin and enamel characterization is stained and fired separately to mimic the layering of natural teeth.

Case 7

Patient: Male
Restored area: Maxillary right central incisor with zirconia-based ceramic crown
Porcelain material: Noritake Katana, Noritake Cerabien ZR

Fig 35 First visit. Discoloration due to necrosis and palatal malposition of the tooth needs to be treated. In this case, gingival contour was improved first by the provisional restoration.

Fig 36 Completed restoration. Exakto-Form (Bredent, Senden, Germany) is used as the model material in order to observe the detailed surface texture.

Fig 37 Final color check on the soft tissue model. In this case, special attention was paid to the cervical area. Alignment was balanced with the adjacent tooth (maxillary left central incisor) by labially projected subgingival contour. To prevent lowering the value, more than the usual amount of opacious body porcelain was applied. The reflected gingival color after insertion of the restoration is estimated with this model.

Fig 38 Intraoral view just before the restoration is inserted. As mentioned previously, three-dimensional effects in color are reproduced by performing internal staining separately in dentin and enamel.

Case 8

Patient: Female
Restored area: Maxillary left lateral incisor with PFM crown
Porcelain material: Noritake EX-3

Fig 39 After tooth preparation. Note the ideal preparation for the PFM crown. To prevent any metal effect after insertion, adequate reduction at the cervical area is important.

Fig 40 Color control of the PFM crown is possible with the proper amount of tooth reduction and a porcelain butt joint margin.

Fig 41 Dentin characterization by internal staining on the body enamel.

Fig 42 Lateral incisor presents mamelon area of low translucency. Hence, the amount of staining could be minimum. Shown is application of translucent porcelain in one attempt. After firing, the shape is adjusted.

Fig 43 Completed restoration. Lateral incisors generally require less complicated porcelain application than central incisors.

CONCLUSION

The internal staining technique developed by Mr Hitoshi Aoshima is one of the standard porcelain application techniques. The popularity of this technique lies in the fact that it is relatively reproducible. However, if the stain layer or its intensity is not carefully considered, the restoration could easily appear flat. More understanding of this technique will lead to more natural-looking restorations. The most important concepts are *capture of the color in three-dimensional space* and *reproduction of tooth morphology*. Color is not the only factor involved in achieving natural-looking restorations.

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My deepest appreciation to Mr Hitoshi Aoshima, developer of the internal staining technique, for giving me advice and many opportunities, and to Mr Kohei Ono (Cusp Dental Supply/Kanare Technical Center), who fabricated all of the zirconia copings of the cases presented in this article. I also thank Dr Kazunori Otani, the dentist who treated all of the cases in this article. The results shown would not have been possible without Dr Otani's exceptional clinical skill and ability to convey all vital information.

Fluorescence: Clinical Evaluation of New Composite Resins

Fernando Rey Duro, DDS, MS[1]
Joana Souza Andrade, DDS, MS[1]
Sillas Duarte, Jr, DDS, MS, PhD[2]

Dental fluorescence has been the subject of great interest and study.[1–9] In 1928, Benedict[1] observed that teeth show fluorescence in a bluish range (Fig 1). He also noted that dentin is more fluorescent than enamel (Fig 2). Subsequent investigations focused on the nature of dental fluorescence and the potential causes of this optical phenomenon.[2–8]

Fluorescence can be defined as the absorption of light by an object and the spontaneous emission of light after stimulation by a large-wavelength light source for at least 10^{-8} seconds. A fluorescent object irradiates a larger quantity of light than it receives, making it brighter than a nonfluorescent object.[9]

A more life-like dental restoration can be attained if optical properties such as hue, translucency, opacity, chromaticity, saturation, value, and opalescence are restored.[10] The importance of reproducing fluorescence during restoration lies in the inherent optical characteristics of the natural tooth. Restoring dental fluorescence in esthetic oral rehabilitation is especially crucial for patients whose profession or social environment contains a high quantity of UV light, eg, involving locations such as movie theaters, fashion shows, dance clubs, or the beach.[11] Fluorescence provides the tooth with a brighter and more dynamic appearance. Further, in clinical situations where it is necessary to hide the background color, such as because of a discolored abutment, fluorescence play an important role without affecting the translucency.[12,13]

Several fluorescence classifications of dental materials are available.[14] However, fluorescence of composite resins is still inconsistent. Therefore, a standardized optical evaluation of novel composite resins that includes discrepancies in intensity and hue is still needed.

[1]Professor, Endodontics and Restorative Dentistry Postgraduate Program, Department of Conservative Dentistry, School of Dentistry, Rey Juan Carlos I University, Alcorcón, Madrid, Spain.
[2]Associate Professor and Chair, Division of Restorative Sciences, Director of the Advanced Program in Operative Dentistry, Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA.

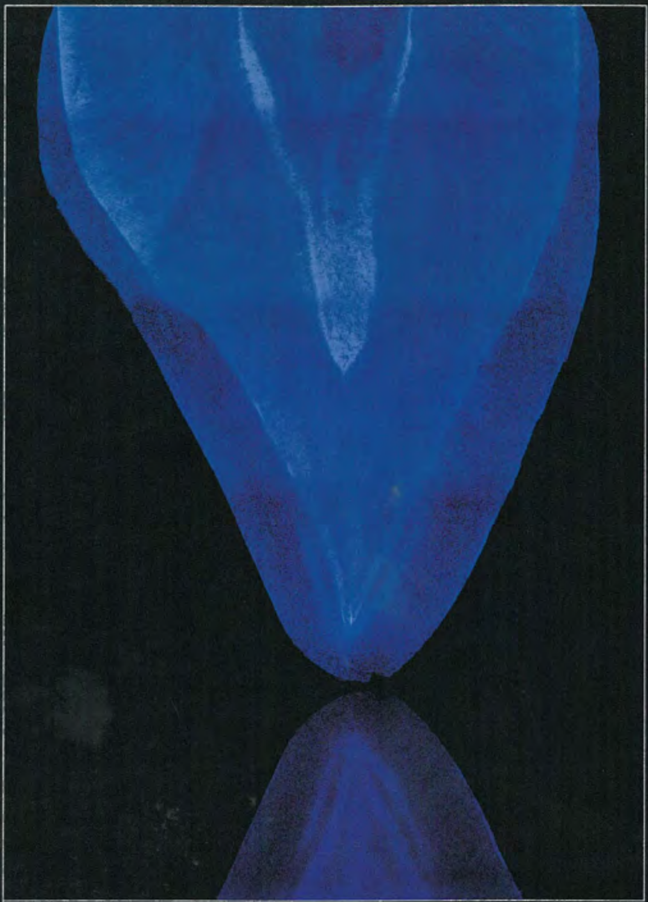
Correspondence to: Dr Fernando Rey Duro, C/ Morrones 4, 1A, 28220 Majadahonda, Madrid, Spain. Email: fernandoreyduro@yahoo.es

Fig 1 Cross section of a maxillary central incisor displaying fluorescence.

Photography has become a vital tool in dentistry. The primary advantage of photography is that it can be used to record teeth-lighting interactions.[15] In the case of fluorescence, however, generating a standardized method of photographic evaluation is not easy. The aim of this study was to analyze the fluorescence of the natural tooth in vivo and to compare a variety of composite resins using a standardized photographic procedure.

MATERIALS AND METHODS

A volunteer patient was selected for the clinical evaluation. Inclusion criteria were as follows: all teeth perfectly aligned, nonsmoking, adequate oral hygiene, and no dental restorations present. Contrary to natural teeth, in which dentin is the main source of the fluorescence, the enamel composite resin layer (the final layer) is the main source of fluorescence in a dental


2a


2b

Figs 2a and 2b Fluorescence of a maxillary central incisor observed under a fluorescent microscope: *(a)* Cross section revealing the differences in fluorescence between enamel and dentin (dentin is more fluorescent than enamel); *(b)* higher magnification of the incisal edge showing increased fluorescence at the dentinoenamel junction.

restoration. It has been shown that including a thin nonfluorescent composite resin layer as the final layer[14] or applying a resin sealer with a width of approximately 70 µm[16] can completely block the fluorescence of a restoration. Therefore, only enamel-shade composite resins were used in the present study.

A vinyl polysiloxane impression of the patient's maxillary arch was made, and multiple casts were poured in type IV stone (Velmix Stone White, Kerr, Orange, California, USA). Fifty-two indirect composite resin veneers with a uniform thickness of 0.5 mm were fabricated for the maxillary right central incisor (Table 1). The casts were isolated with die separator, and the composite resin veneers were fabricated and light-polymerized for 90 seconds at an output of 800 mW/cm^2 under constant monitoring.

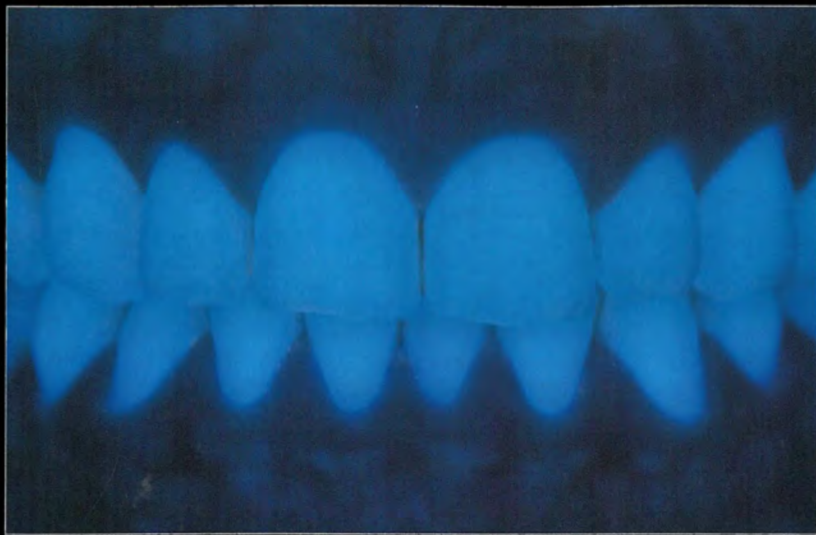
A darkroom was specially prepared for fluorescence photography. A lighting device consisting of two ultra-

Table 1 Composite Resins Tested

Composite Resin	Shades	Composition	Manufacturer
Filtek Supreme Plus	A2B, A2E	Resin matrix: bis-GMA, bis-EMA(6), UDMA, TEGDMA Fillers: combination of non-agglomerated/non-aggregated 20-nm nanosilica filler and loosely bound agglomerated zirconia/silica nanocluster, consisting of agglomerates of primary zirconia/silica particles with 5- to 20-nm fillers	3M ESPE, St Paul, MN, USA
Filtek Supreme Ultra	A1E, A2E, A2B, A2D, A3D, A4E, A4B, B1B, B1E, AT	Resin matrix: bis-GMA, UDMA, TEGDMA, bis-EMA(6) Fillers: combination of non-agglomerated/non-aggregated 20-nm silica filler, non-agglomerated/non-aggregated 4- to 11-nm zirconia filler, and aggregated zirconia/silica cluster filler	3M ESPE
Empress Direct	A1E, A2E, A3E, A4E, B1E, Opal, A2D	Resin matrix: dimethacrylates Fillers: barium glass, Ba-Al-fluorosilicate glass, ytterbium trifluoride, mixed oxide, silicon dioxide, copolymer	Ivoclar Vivadent, Schaan, Liechtenstein
Enamel Plus HFO	GE2	Resin matrix: bis-GMA, UDMA, butandioldimeth-acrylate, pigments Fillers: glass filler silanized, silicium oxide silanized	Micerium, Avegno, Italy
Enamel Plus HRi	UE2	Resin matrix: diurethandimethacrylate, Iso-propyliden-bis (2(3)-hydroxy-3(2)-4(phenoxy) propyl-bis(methacrylate) (Bis-GMA), 1,4- Butan-dioldimethacrylate. Fillers: silium bioxide	Micerium
Miris 2	NR, WR, IR, WR, NT	Resin matrix: bis-GMA, TEGDMA, UDMA Fillers: Barium glass, silanized amorphous silica	Coltène/Whaledent, Altstätten, Germany
Renamel Microfill	Incisal Light, A2	Resin matrix: bis-GMA, UDMA, butanediol dimethacrylate Fillers: strontium aluminum boron silicate, silicon dioxide	Cosmedent, Chicago, IL, USA
Herculite HRV Ultra	A2E	Resin matrix: bis-GMA, ethoxylated bisphenol-A-dimethacrylate, TEGDMA Fillers: barium aluminoborosilicate glass with fumed silica	Kerr, Orange, CA, USA
Premise	A2E	Resin matrix: bis-GMA, ethoxylated bisphenol-A-dimethacrylate, TEGDMA Fillers: barium aluminoborosilicate glass, silica nanofiller, proprietary prepolymerized filler (blend of low-shrinkage resin and barium glass)	Kerr

Composite Resin	Shades	Composition	Manufacturer
Esthet-X HD	A2	Resin matrix: bis-GMA-adduct, ethoxylated bisphenol-A-dimethacrylate, TEGDMA Fillers: barium aluminofluoroborosilicate glass with silicon dioxide particles	Dentsply, York, PA, USA
Gradia Direct	A2	Resin matrix: UDMA, dimethacrylate comonomers Fillers: silica and prepolymerized filler	GC EUROPE, Leuven, Belgium
Kalore	A2	Resin matrix: UDMA, DX-511 comonomers Fillers: Dimethacrylate, fluoroaluminosilicate glass, prepolymerized filler, silicon dioxide	GC EUROPE
G-aenial Anterior	JE	Resin matrix: UDMA, dimethacrylate comonomers Fillers: prepolymerized fillers (16–17 μ; silica, strontium and lanthanoid fluoride), silica, and fumed silica	GC EUROPE
Estelite ∑ Quick	A2E	Resin matrix: bis-GMA, TEGDMA Fillers: silica-zirconia, composite resin filler	Tokuyama, Tokyo, Japan
Estelite Omega	A1E, A2E, B1E, MW, Trans	Resin matrix: bis-GMA, TEGDMA, dibutyl hydroxy toluene, mequinol Fillers: silica-zirconia	Tokuyama
Durafill	A2	Resin matrix: bis-GMA, UDMA, TEGDMA Fillers: prepolymerized particles, disperse silicon dioxide, quartz, amorphous fused silica	Heraeus Kulzer, South Bend, IN, USA
Durafill VS	A1, A2, A4, B1	Resin matrix: bis-GMA/TEGDMA, UDMA Fillers: silicon dioxide, prepolymerized filler	Heraeus Kulzer
Venus Diamond	A2	Resin matrix: bis-GMA, TEGDMA Fillers: barium aluminum boron fluoride silica glass with silicon dioxide particles	Heraeus Kulzer
Opallis	A2E	Resin matrix: bis-GMA, bis-EMA TEGDMA, UDMA Fillers: barium aluminum boron fluoride silica glass	FGM, Joinville, Brazil
Amaris	TN	Resin matrix: bis-GMA, UDMA, TEGDMA Filler: silica glass	VOCO, Cuxhaven, Germany
Clearfil Majesty Esthetic	A2E	Resin matrix: bis-GMA, TEGDMA Filler: barium glass	Kuraray, Okayama, Japan
Amelogen Plus	EN	Resin matrix: bis-GMA-adduct, UDMA Fillers: strontium boroaluminasilicate glass silicon dioxide particles	Ultradent, South Jordan, UT, USA
Tetric Evo-Ceram	A2E	Resin matrix: bis-GMA, UDMA, ethoxylated bis-EMA Fillers: filler ytterbium trifluoride, barium glass fillers, mixed oxides	Ivoclar Vivadent

bis-GMA = bisphenol glycidyl methacrylate; TEGDMA = triethylene glycol dimethacrylate; UDMA = urethane dimethacrylate; bis-EMA = bisphenol A polyethylene glycol diether dimethacrylate.



3

Fig 3 Fluorescence of the patient's teeth.

Table 2 Standardized Photographic Settings for Clinical Evaluation of Fluorescence

Magnification	1:2
Speed	1/4
Aperture	9
ISO	400
White balance	4,000 K
Size	Large (3,888 × 2,592 pixels)
Image quality	RAW

violet (UV) lamps (Sylvania S18W/BLB, Danvers, Massachusetts, USA) was fabricated and positioned over the patient. A digital single-lens reflex camera (Canon EOS 400D with a 100-mm/f.28 USM macro lens, Canon, Tokyo, Japan) was used for the photographic evaluation. The equipment was attached to a sturdy tripod (Manfrotto, Cassola, Italy), and the location and distance of the camera from the patient's mouth were standardized. All photographs were taken wirelessly to avoid any vibration.

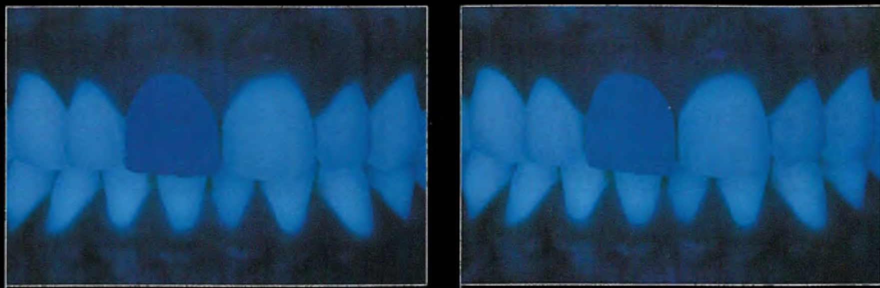
Bilateral cheek retractors were placed on the patient, and each light source was positioned 20 cm from the camera, the patient's teeth, and the other light source. This distance was selected based on the distance of a typical social conversation. After numerous attempts to accurately capture the patient's teeth, the camera settings were calibrated according to the parameters shown in Table 2. Each composite resin veneer was placed over the right maxillary central incisor using the patient's saliva as the connecting agent. No dental adhesive was used to avoid optical interference. The patient was instructed to occlude carefully, and photographs were taken according to the standardized method described above. All photographs of the individual veneers were taken at intervals of 10 minutes to avoid dehydration of the teeth and possible changes in fluorescence. The images were evaluated for composite resin veneer fluorescence according to composite resin type, shade, and translucency in comparison to the natural dentition (Fig 3).

Table 3 Classification of Composite Resin Fluorescence

Composite resin	Fluorescence			
	Low	Optimal	Exaggerated	Incorrect
Durafill	X			
Filtek Supreme Plus	X			
Empress Direct		X		
Enamel Plus HFO		X		
Renamel Microfill		X		
Esthet-X HD		X		
Estelite ∑ Quick		X		
Durafill VS		X		
Opallis		X		
Amaris		X		
Clearfil Majestic		X		
Filtek Supreme Ultra		X		
Estelite Omega		X		
G-aenial anterior		X		
Tetric EvoCeram		X		
Kalore			X	
Venus			X	
Amelogen Plus			X	
Miris 2			X	
Gradia			X	
Venus Diamond			X	
Enamel Plus HRi				X
Herculite HRV Ultra				X
Premise				X

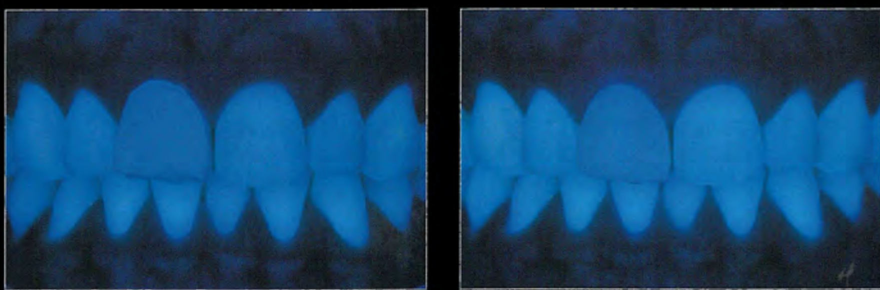
RESULTS

Significant differences were found in the clinical fluorescence of the tested composite resins compared to natural teeth. The results were classified in terms of fluorescence as follows: low, optimal, exaggerated, and incorrect (Table 3). Low fluorescent composite resin displayed low value and a dark bluish aspect. Low florescence was found only in older generations of composite resins (Fig 4). Many composite resins ex-



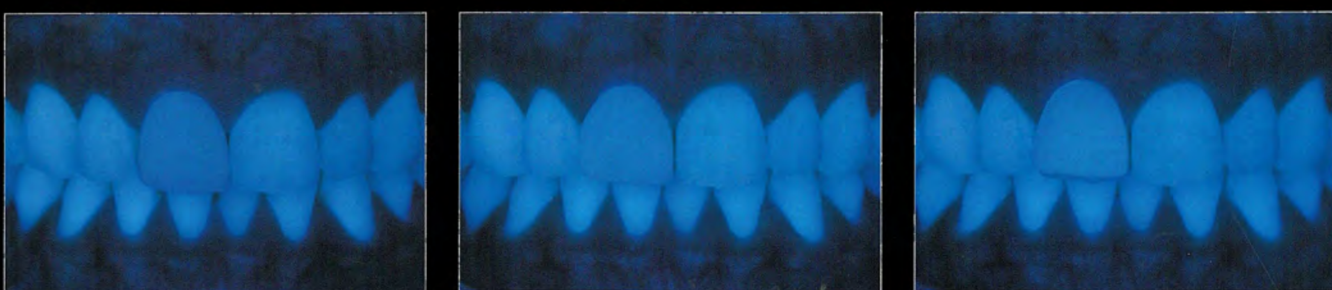
4a 4b

Figs 4a and 4b Low fluorescence: Composite resin veneers fabricated with *(a)* Durafill and *(b)* Filtek Supreme Plus.



5a 5b

Figs 5a to 5e Low-optimal fluorescence: Composite resin veneers fabricated with *(a)* Renamel Microfill, *(b)* Clearfil Majestic, *(c)* Filtek Supreme Ultra, *(d)* Opallis, and *(e)* Enamel Plus HFO.



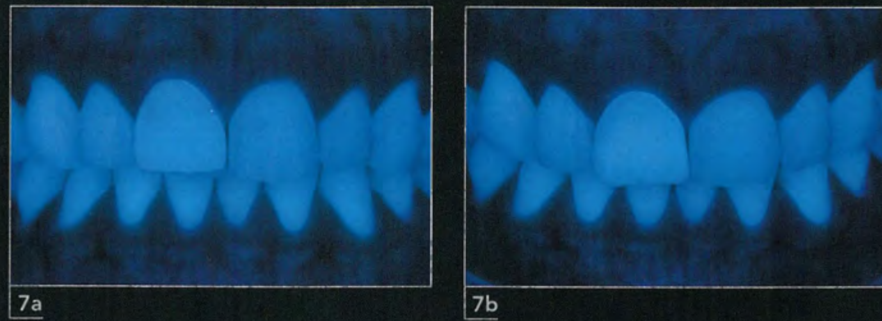
5c 5d 5e

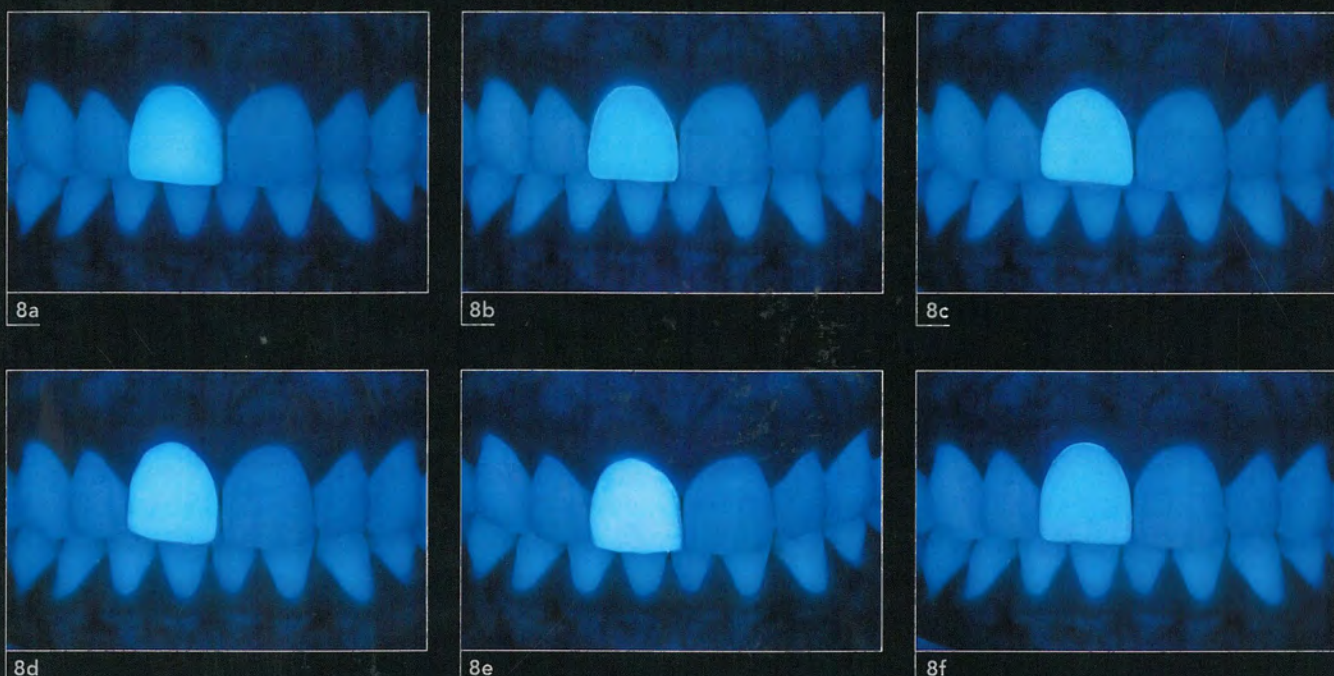
6a 6b 6c

Figs 6a to 6c Optimal fluorescence: Composite resin veneers fabricated with *(a)* Esthet-X, *(b)* Durafill VS, and *(c)* Estelite ∑ Quick.

hibited fluorescence close to that of natural teeth (Figs 5 to 7). However, within the acceptable fluorescence, a range of hues and luminosities was observed. Thus, optimal fluorescence could be subcategorized as low-optimal (Fig 5), optimal (Fig 6), and high-optimal (Fig 7) depending on the composite resin's composition, luminophore dyes, chroma, and translucency. Some of the composite resins revealed exaggerated fluores-

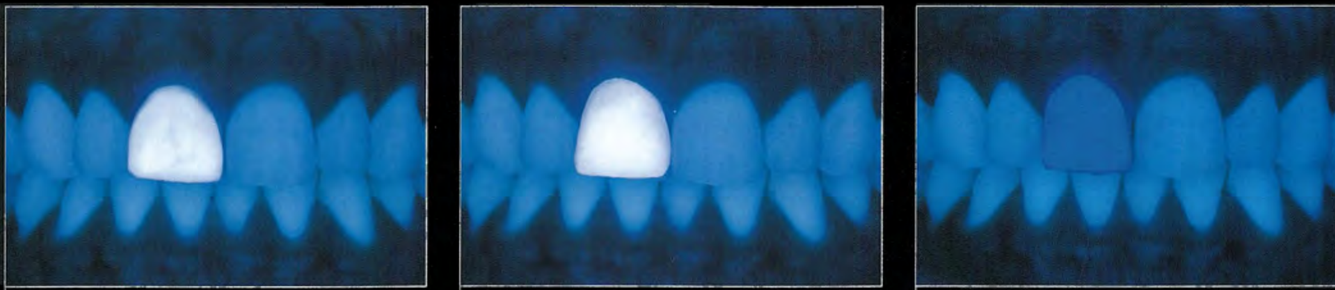
Figs 7a to 7e High-optimal fluorescence: Composite resin veneers fabricated with *(a)* Amaris, *(b)* Estelite Omega, *(c)* Empress Direct, *(d)* G-aenial Anterior, and *(e)* Tetric EvoCeram.





Figs 8a to 8f Exaggerated fluorescence: Composite resin veneers fabricated with *(a)* Amelogen, *(b)* Miris 2, *(c)* Gradia, *(d)* Venus, *(e)* Venus Diamond, and *(f)* Kalore.

cence (Fig 8). Composite resins with exaggerated fluorescence exhibited higher fluorescence than natural teeth, with a white-bluish hue and significant increase in value. Finally, a few composite resins showed incorrect fluorescence, meaning that the fluorescent hue was discrepant from the natural tooth (Fig 9). Herculite XRV Ultra and Premise exhibited a strong whitish-blue fluorescent hue, whereas Enamel Plus HRi (Micerum)


9a 9b 9c

Figs 9a to 9c Incorrect fluorescence: Composite resin veneers fabricated with *(a)* Herculite XVR Ultra, *(b)* Premise, and *(c)* Enamel Plus HRi.


10a 10b 10c


10d

Figs 10a to 10d Difference in fluorescence among different translucencies within the same composite resin brand (Estelite Omega): *(a)* Dentin (shade A2D), *(b)* enamel (shade A1E), *(c)* achromatic high value (shade MW), and *(d)* highly translucent and opalescent (shade Trans).

exhibited a vivid azure bluish fluorescent hue, both of which are unlike the fluorescent hue of natural teeth.

Fluorescence was highly dependent on the composition and manufacturer of the composite resins tested (Figs 4 to 9). Newer generations of composite resin exhibited substantial improvements in fluorescence compared to older generations. Significant differences in fluorescence were observed within the same manufacturer and within the same brand (Fig 10).

The fluorescence of composite resins is also greatly influenced by translucency, chroma, and value. Translucency played a major role in fluorescence (Fig 10). Within the same composite resin system, highly translucent shades showed increased fluorescence, causing changes in the fluorescence rating from optimal to exaggerated or even to incorrect. Current dentin-shade composite resins were less fluorescent than enamel or translucent shades. Chroma negatively affected the fluorescence of composite resins; as chroma increased, the fluorescence decreased (Fig 11). For instance, an A1 shade composite is more fluorescent than an A4 shade composite from the same manufacturer, irrespective of the composite's translucency. The fluorescence of achromatic enamel composites is dependent of their composition, which can range from low optimal (see Fig 5e), to exaggerated (see Fig 8b), to incorrect fluorescence (see Fig 9c). In addition, value affects the fluorescence of most tested composites. Our findings showed that the higher the value, the more fluorescent is the composite.

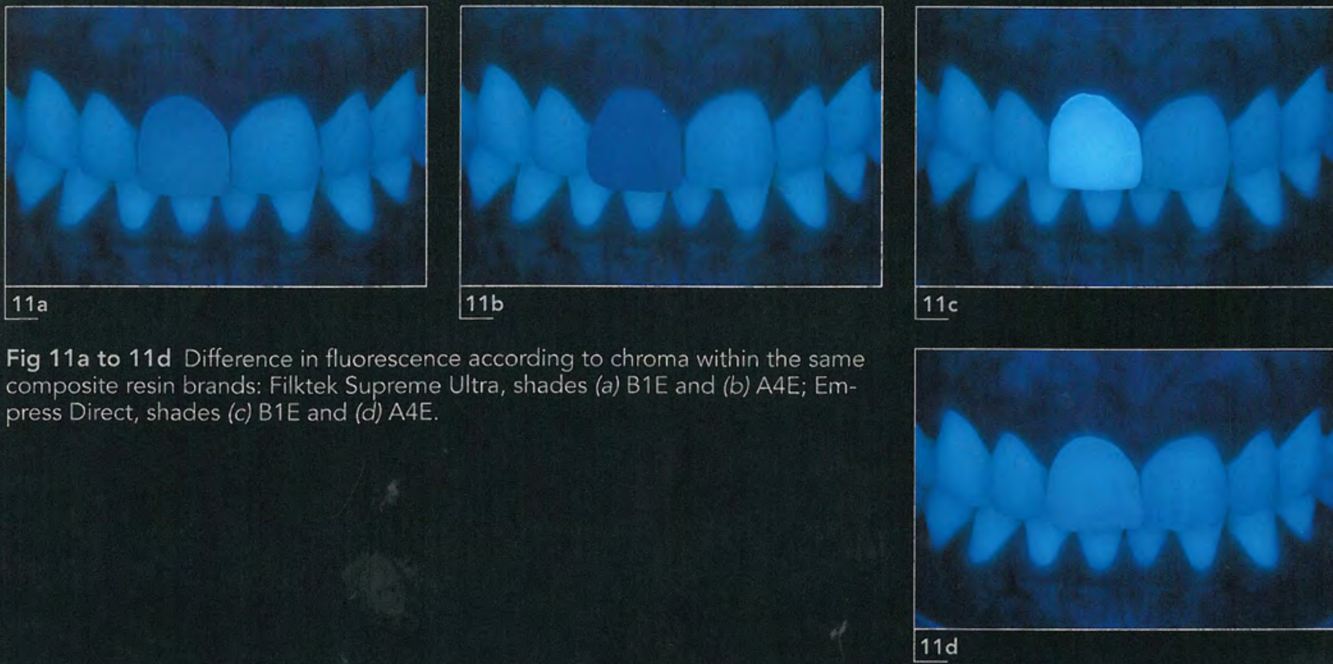


Fig 11a to 11d Difference in fluorescence according to chroma within the same composite resin brands: Filktek Supreme Ultra, shades *(a)* B1E and *(b)* A4E; Empress Direct, shades *(c)* B1E and *(d)* A4E.

DISCUSSION

The ideal esthetic restorative material must have characteristics similar to the reflection and fluorescent light dispersion found in the natural tooth. This clinical evaluation showed a lack of standardization of fluorescence for different composite resins. Only a few composite resins showed acceptable fluorescence. The results of this investigation allow for the classification of composite resins based on their fluorescence.

All vital teeth show bluish-whitish fluorescence.[17] Fluorophores are responsible for the fluorescence in natural teeth. The chemical nature of fluorophores varies widely in both organic and inorganic components.[8] Dentin fluorescence is three times more fluorescent than that of enamel.[18] The higher organic content of the dentin (especially the collagen fibers) is responsible for this optical phenomenon.[19]

Studying fluorescence is a complex task because fluorescence is lost after extraction unless fixation procedures are performed. Fixation of the collagen proteins and their components is technique-sensitive but essential to study fluorescence.[20,21] Moreover, other dentinal components are responsible for dental fluorescence, including minerals, pyrimidine, tryptophan,[4,5] pyridinoline, and hydroxylapatite-pyridinoline complex.[8] Therefore, fluorescence is a multifactorial phenomenon based on multiple organic and inorganic components, age, and biotype. These many factors make fluorescence one of the most difficult optical properties to replicate artificially.

The fluorescence found in composite resins is attained by incorporation of fluorescent (luminophore) dyes.[11,22] However, it is very difficult to correctly reproduce the luminescent spectrum of enamel and dentin in terms of color and intensity. Rare elements are often used as luminiferous, including terbium, cerium, ytterbium, and europium; however, none of these can truly reproduce the blue-mauve fluorescence of natural teeth. Thus, adjustment of the amount of fluorophores is necessary to achieve fluorescence similar to that of the natural dentin.[23] Generally, when the saturation and/or chromaticity of the color increase, the fluorescence decreases.[24] Fluorescence is highly dependent on the type of pigments and opacifying agents used to mimic the optical characteristics of natural teeth.

Fluorescent UV tubes covered with special phosphorus (Wood's coating) absorb the larger portion of visible light and emit UV rays over a long distance. These tubes are violet in color, and the light they produce is commonly known as "black light." Fluorescent UV tubes are a useful source of UV radiation for studies of fluorescence.[25]

A fluorescent composite resin will exhibit higher luminosity than nonfluorescent or low-fluorescent composite resins of the same color.[13] Lee[26] showed that UV light emitted from a light source influences the color not only of the composite resin, but also of the tooth. When fluorescence is absent, the restoration will show decreased luminosity.[9] Therefore, it is desirable that composite resins emulate the fluorescent behavior of the natural tooth and minimize metamerism.[11,27]

Matching the fluorescence of composite resins with that of natural teeth is complicated because each tooth has its own fluorescence and each restorative system has a determined level of fluorescent pigments. Therefore, the clinician must have thorough knowledge of the fluorescent characteristics of the restorative system used.[14]

Esthetic restorative materials should perfectly simulate the optical properties of the natural tooth. This optical behavior is highly influenced by the interaction of light with the dental components and soft tissues.[17,22,24,28] Fortunately, the importance of fluorescence in esthetic dental materials is becoming more recognized, particularly because of its effect on the luminosity of a restoration.

CONCLUSIONS

Few of the available composite resins can perfectly match the fluorescence of a natural tooth. Fluorescence is significantly affected by composite type, shade, translucency, chroma, and value. A standardized photographic procedure is fundamental to study and critically analyze the fluorescence of different restorative materials in vivo. Manufacturers of esthetic composite resins must find a way to better reproduce the fluorescence of natural teeth to facilitate their selection and use.

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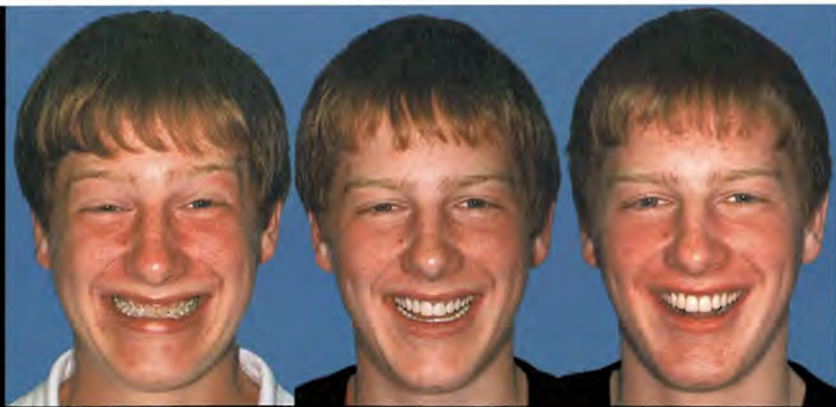


Smile Reconstruction: Esthetic and Functional Rehabilitation of a Patient with Dentinogenesis Imperfecta Using Lithium Disilicate Glass-Ceramic

Oliver Brix, MDT[1]
Daniel Edelhoff, CDT, Dr Med Dent, PhD[2]

Modern dental technology and materials have promoted new treatment strategies, including the use of an extended provisional phase to better determine the functional and esthetic aspects of a specific case. This case report illustrates the complex rehabilitation of a generalized hard tissue defect of a young patient using lithium disilicate glass-ceramic. Computer-aided design/computer-assisted manufacture (CAD/CAM)-fabricated long-term provisional restorations made of high-performance polymer (Vita CAD-Temp, a high-molecular, cross-linked acrylic polymer containing 14 wt% microfillers, Vita Zahnfabrik, Bad Säckingen, Germany) were used during the patient's growth phase to allow for long-term verification of the restorative plan. This strategy enhanced the predictability of the definitive lithium disilicate glass-ceramic restorations.

[1]Dental Technician, Innovative Dentaldesign Oliver Brix, Wiesbaden, Germany.

[2]Tenured Associate Professor, Department of Prosthodontics, Dental School, Ludwig-Maximilians-University, Munich, Germany.

Correspondence to: Oliver Brix, Innovative Dentaldesign Oliver Brix, Dwight-D. Eisenhowerstrasse 9, 65197 Wiesbaden, Germany. Email: Oliver-Brix@t-online.de

CASE REPORT

A 16-year-old patient diagnosed with dentinogenesis imperfecta type II was seen at the Department of Prosthodontics, Ludwig-Maximilians-University, Munich, Germany (Figs 1a to 1f). Dentinogenesis imperfecta is an autosomal dominant genetic trait that affects both primary and permanent teeth[1,2]; it is characterized by yellow-brown or bluish-gray hard tissue discoloration. The dentin malformation is caused by a defect in the dentin sialophosphoprotein (DSPP) gene. DSPP is involved in the formation of noncollagen proteins in dentin.[3,4] Afflicted patients tend to have enamel defects that lead to dentin exposure and accelerated attrition.[5] Radiographs show bulbous crowns, short roots, and progressive obliteration of the root canal system.[3,6]

This case presented a particular challenge because of the young age of the patient, who had not finished the growth stage. Therefore, the planned treatment involved two phases. The first phase aimed to quickly improve esthetics, provide adequate functional morphology, adjust the vertical dimension of occlusion (VDO), and obtain canine/anterior guidance. The second phase aimed to provide adhesively bonded definitive restorations for the compromised hard tissues.

CASE REPORT

1a

Figs 1a to 1f Initial presentation: dentinogenesis imperfecta type II with significant hard tissue damage and an obvious need to restore the vertical dimension of occlusion.

1b

1c

1d

1e

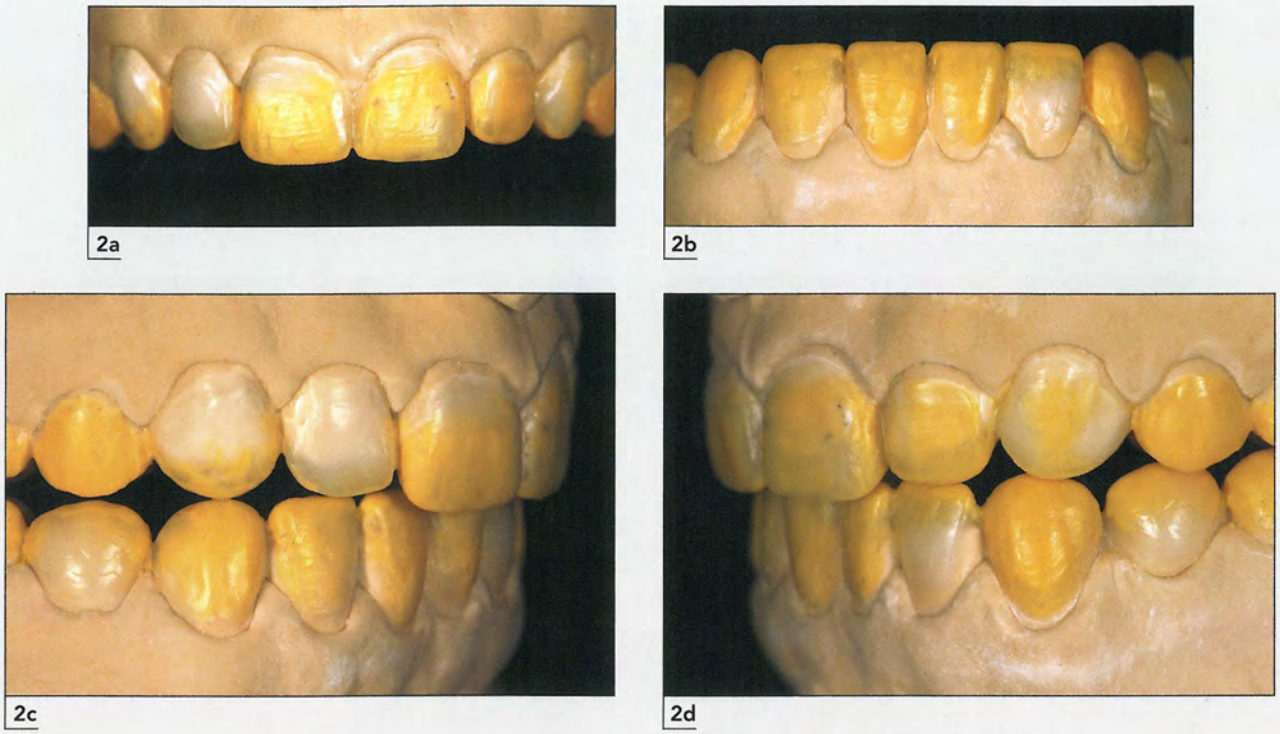
1f

Treatment Planning

The connection between enamel and dentin was compromised due to dentin malformation. Therefore, noninvasive bonded restorations were not feasible. The IPS e.max system (Ivoclar Vivadent, Schaan, Liechtenstein) was selected because of its material toughness, flexible luting possibilities, and esthetic potential. The posterior teeth received full crowns using IPS e.max Press LT, while the anterior teeth received IPS e.max Press copings (shade MO 0) veneered with IPS e.max Ceram veneering porcelain.

Detailed planning and execution are essential for complex restorations with significant modifications of functional and esthetic conditions. The following clinical sequence was planned:

- Photographic records and arbitrarily mounted casts
- Diagnostic wax-up/thermoformed template
- Mock-up using the thermoformed template



Figs 2a to 2d Diagnostic wax-up to determine functional and esthetic parameters and establish canine-guided occlusion at 47 degrees for clear disocclusion.

- Transfer of the wax-up with increased VDO to a modified Michigan splint for 8-week functional evaluation
- Tooth preparation guided by the diagnostic template
- Precision impression and alternating bite registration according to the separated Michigan splint
- Scanning of the wax-up and fabrication of identical CAD/CAM long-term provisionals
- Twelve-month clinical trial of the long-term provisionals
- Definitive maxillary restorations mounted against the mandibular provisionals
- Fabrication of definitive maxillary restorations
- Adhesive insertion of the definitive maxillary restorations
- Similar procedure for mandibular restorations

Clinical and Laboratory Procedures

The photographic records were sent to the dental technician for analysis. The casts were arbitrarily mounted, and the VDO was increased by 2.5 mm. The diagnostic wax-up included all teeth to better clarify the esthetic requirements and possibilities. The desired dynamic occlusion with canine/anterior guidance was included in the wax-up (Fig 2). This step is the cornerstone of such a treatment because only the wax-up can enable a preview of all parameters.

An impression of the wax-up was made, and casts of the arches were fabricated to duplicate the wax-up. Hard and highly translucent thermoplastic sheets (Duran 0.5 mm, hard-transparent, Scheu-Dental, Iserlohn, Germany) were thermoformed on the duplicate casts. These patterns are ideal for a mock-up to assess the preparation and the fabrication of provisionals.


3a


3b


4a


4b


4c


5

Figs 3a and 3b Reproduction of the wax-up using thermoplastic splints to visualize the desired treatment.

Figs 4a to 4c CAD/CAM-produced long-term provisionals.

Fig 5 Identical duplication of the wax-up into the provisionals via scanning. (Dental technician: Josef Schweiger, LMU, Munich, Germany.)

To visualize the wax-up, templates were filled with a bisphenol glycidyl methacrylate (bis-GMA)-based provisional restoration material and placed into position in the mouth (Fig 3). This step helps to assess the esthetic demands of all parties involved.

After preparation and soft tissue healing, impressions were taken in both arches, facebow records were transferred, and the vertical relation was recorded using a segmented Michigan splint. The in-house dental laboratory fabricated CAD/CAM long-term provisionals from high-performance polymer plastic (Figs 4 and 5). The provisionals were made identical to the wax-up via scanning procedures. The crowns of the long-term provisionals were splinted into segments of three to

6

7a

7b

7c

Fig 6 Atraumatic preparation of the heavily discolored abutments.

Figs 7a and 7b Sequential bite registration using a bis-GMA–based material.

Fig 7c Crown lengthening procedure with an oscillating instrument to adjust the gingival contour.

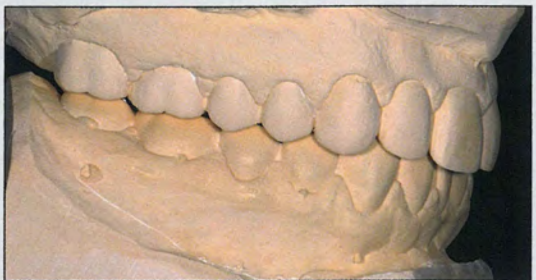
four units and luted with glass-ionomer cement to prevent loosening of the provisionals from the relatively short abutment teeth.

The long-term provisionals allowed the patient to evaluate the esthetics and function. The provisionals were left in place for 1 year, during which time they were initially checked monthly and then in intervals of 3 months. Small corrections were performed as needed, eg, minimally invasive crown lengthening for the maxillary left central incisor using oscillating instruments.

At the conclusion of the provisional phase, a new set of study casts was made and mounted as a first step toward definitive restoration. The maxillary provisionals were removed in segments. Figure 6 shows the prepared anterior teeth, the perfectly conditioned gingiva, and the severely discolored abutment teeth. Maxillomandibular registration records were fabricated to determine the position of the prepared teeth against the mandibular provisionals (Fig 7).

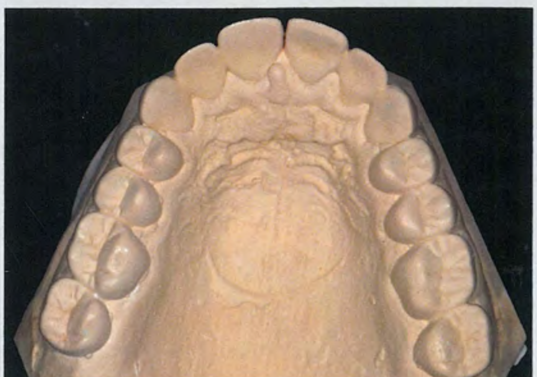
Master casts were mounted using a facebow (Figs 8 and 9), and a so-called cross-mounting was performed:

8a

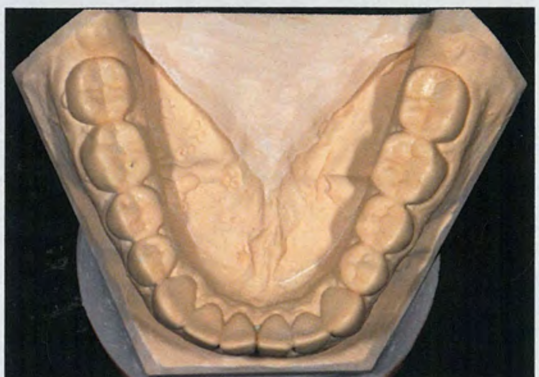


8b

8c



9a



9b

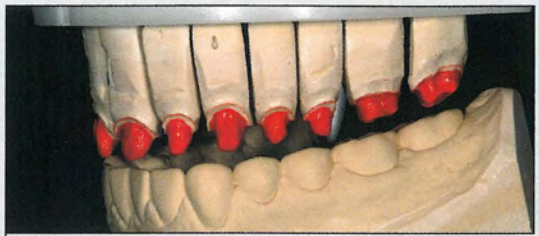
Figs 8a to 8c Mounted casts of the provisionals.

Figs 9a and 9b The occlusal surfaces do not show any abrasion marks, which is a testament to the precision and quality of the material used.

the master cast of the prepared maxillary teeth was mounted against a cast of the mandibular provisionals, followed by mounting of the maxillary provisionals against the mandibular provisionals (Fig 10).

The relationship of the mounted provisionals was recorded with a silicone bite record. This record was used again to orient the maxillary master cast (Figs 11 and 12). Molten casting wax was drawn into a syringe and injected into the lubricated silicone registration. The hardened wax forms a perfect copy of the provisionals (Fig 13). The benefits of this method are a significant time savings and the exact conversion of the already tried-in morphology and occlusion of the provisionals. Figure 14 shows the adjusted posterior teeth and wax copings of the anterior teeth. Due to lack of retention, the individual crowns were splinted in pairs


10a


10b

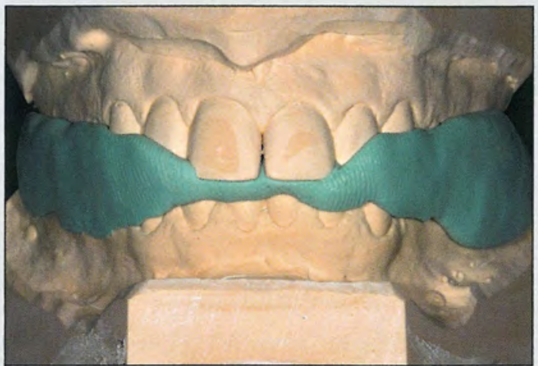
Figs 10a and 10b Master casts mounted using the cross-mounting approach.

Fig 11 Occlusal surface of the provisionals registered with a silicone key.

Figs 12a and 12b The maxillary master cast and silicone key before application of liquid wax.

Figs 13a and 13b After removal of the silicone key, the wax accurately reproduced the occlusal morphology of the provisionals.

Figs 14a and 14b The previously tested morphology was exactly duplicated.


11

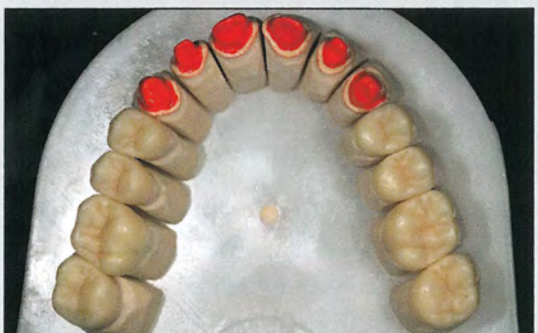

12a


12b


13a


13b


14a


14b

15

16

17a

17b

Fig 15 After placement of the copings on the master cast, only small details need to be corrected.

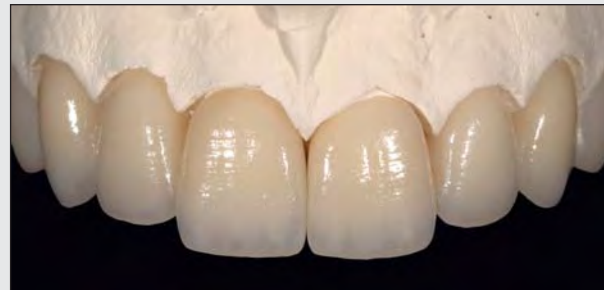
Fig 16 The posterior restorations were pressed with IPS e.max Press LT, and the anterior copings with IPS e.max Press MO 0.

Figs 17a and 17b Homogenous and accurate results after pressing.

and in groups of three in the posterior and anterior regions, respectively. All wax copings were pressed according to the manufacturer's guidelines. Anterior copings were pressed with IPS e.max Press MO 0, while posterior teeth were pressed with IPS e.max Press LT A2. After pressing, divesting, and trial placement on the master cast (Fig 15), the material's precise rendering of esthetic details and homogeneity are evident.

The anterior copings were shaped similarly to the provisionals by using a silicone key and individually layered IPS e.max Ceram (Fig 16). Figure 17 shows the finished, as yet unpolished anterior crowns in an

18



19

20

Fig 18 Predictable results for the anterior restorations were facilitated by the silicone key.

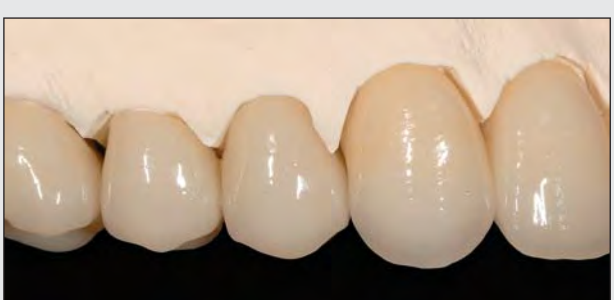
Fig 19 The anterior crowns before final glaze firing.

Fig 20 A clear advantage of the IPS e.max system is the potential for corrections of the pressed crowns by adding incisal porcelain mass.

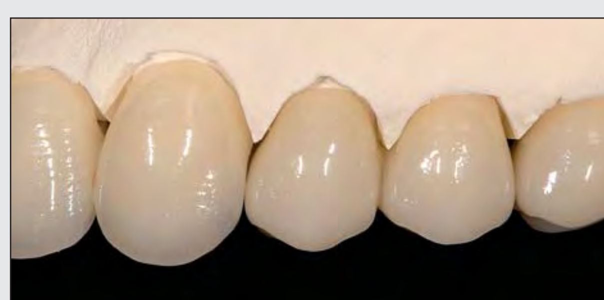
Fig 21 Double-stacked honeycomb sagger trays allow for higher placement in the oven and thus better control during firing.

Figs 22a and 22b The finished restorations on the cast demonstrating perfect shade match.

21



22a



22b

unsectioned solid cast. Incisal mass was added to the buccal surfaces of the premolars to create a smooth transition from canines to molars (Figs 18 to 21). The ability to apply corrections to all components using layering porcelain makes the IPS e.max system very user friendly (Fig 22).

23

Fig 23 Manual polishing.

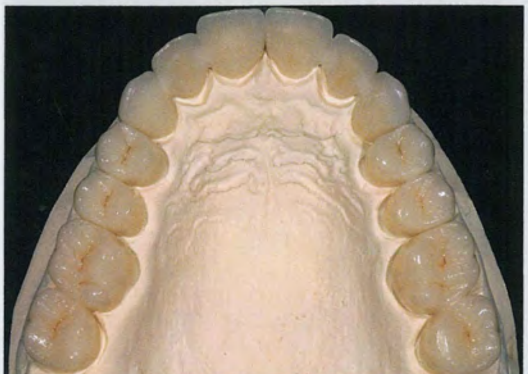
Figs 24a to 24c Anatomically pressed posterior crowns after glaze firing and polishing.

Fig 25 Maxillary restorations.

Figs 26a to 26c Maxillary restorations mounted in an articulator against the long-term mandibular provisionals. This concludes the first phase of the rehabilitation.

24a

24b

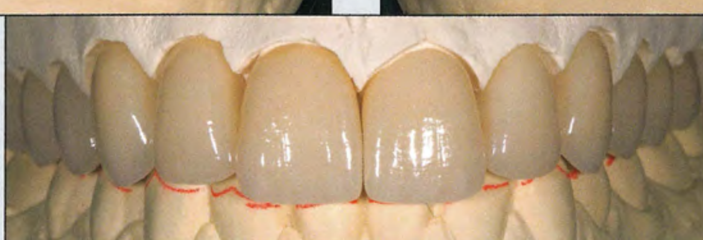


24c

25

26a

26b



26c

Final Restorations

While the anterior restorations were polished for a natural glaze (Fig 23), the posterior restorations were fired for coloring and glazing (Figs 24 and 25). Figure 26 shows the finished maxillary restorations in relation to the mandibular provisionals. All restorations were adhesively luted with Variolink II (Ivoclar Vivadent) without further adjustments.

After several weeks, the restorations for the mandibular teeth were fabricated in a similar fashion and inserted (Figs 27 to 29). Figures 30 to 32 show the

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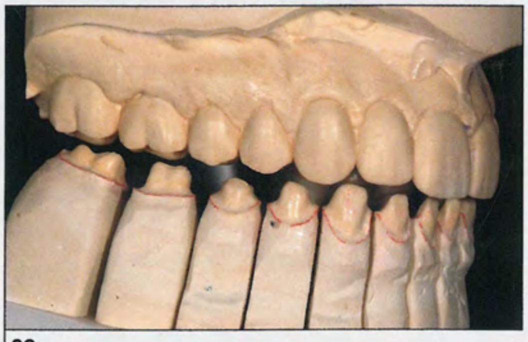
28a

28b

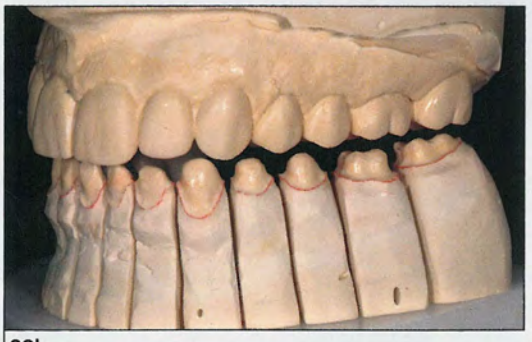
28c

28d

28e



29a

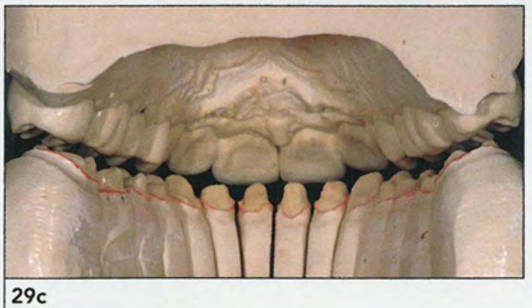


29b

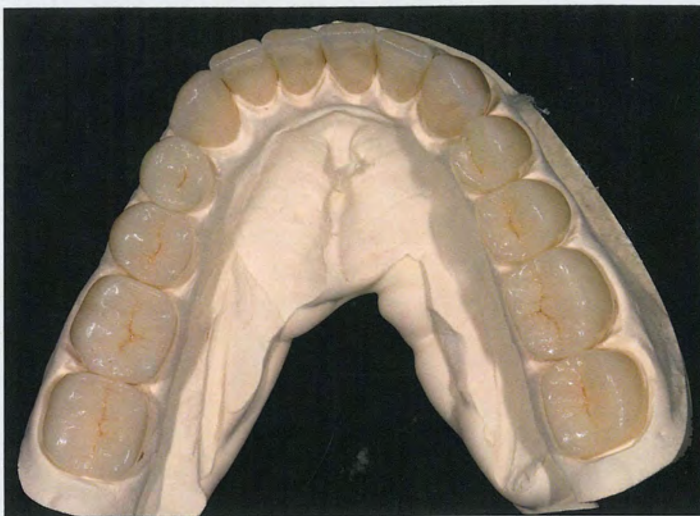
Fig 27 The second phase begins with the sectional mandibular cast and additional cross-mounting.

Figs 28a to 28e After impression-taking of the maxilla, the cast reveals all relevant details and provides a perfect foundation for the mandibular restorations.

Figs 29a to 29c The mounted casts.



29c



30b

30a

30c

31

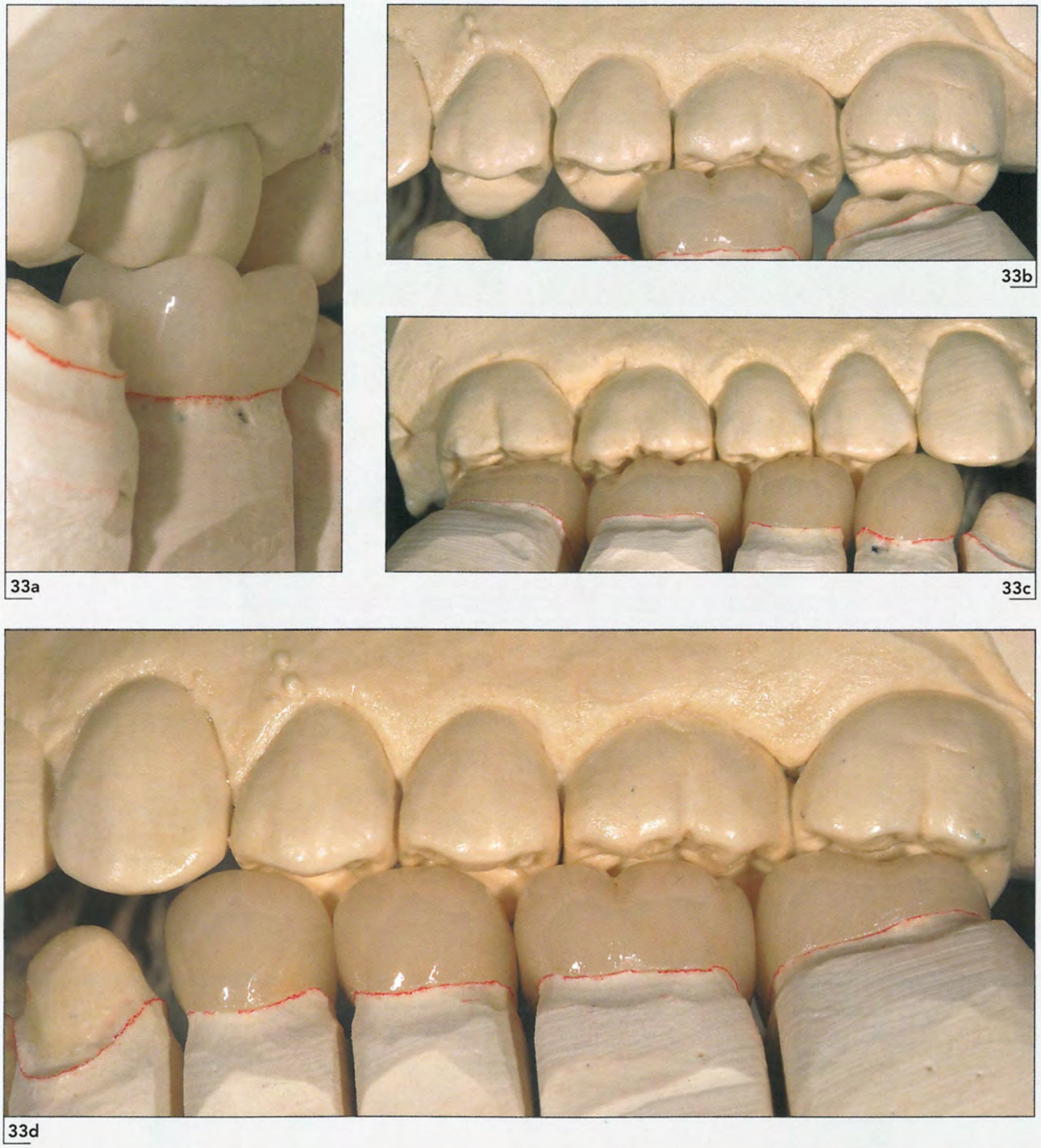
32a

32b

32c

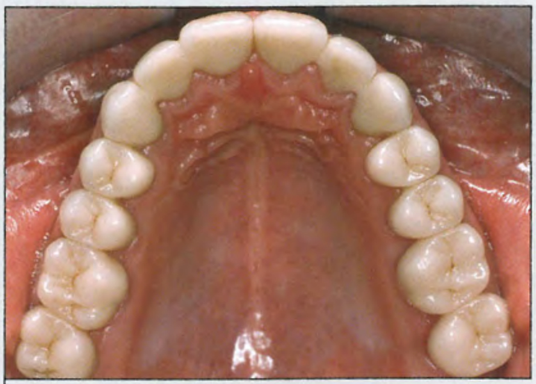
Figs 30 and 31 Finished mandibular restorations. Note the dynamic optical effects.

Figs 32a to 32c Final check in the articulator.



Figs 33a to 33d Close-up view of the functional concept, highlighting the collaboration between the dentist and technician.

complete mandibular restorations. All crowns for the mandible were fabricated in the same way as described earlier to complete the case (Fig 33). The mandibular crowns were inserted without any need for adjustment, and the patient was immediately placed into a recall program. Figures 34 to 37 show the final result.



34a

34b

35a

35b

35c

Figs 34a and 34b Finished and bonded maxillary and mandibular restorations.

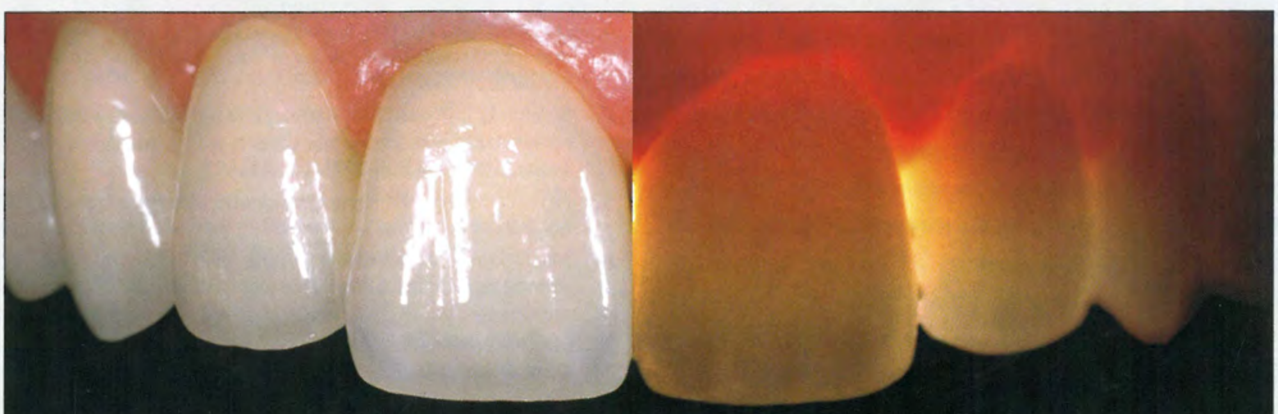
Figs 35a to 35h Definitively luted restorations.

35d

35e

35f

35g



35h

36a

36b

36c

37

Figs 36a to 36c Sequence of treatment: *(a)* initial situation, *(b)* provisional phase, *(c)* definitive restoration.

Fig 37 Extraoral view with the lips partly open showing the excellent esthetic result.

CONCLUSION

The successful result of this unusual clinical case is a testament to the collaboration and disciplined group effort of the dental team. Lithium disilicate glass-ceramic, which has a flexural strength of 400 MPa, provided the foundation for long-term success. Both the esthetics and function were successfully restored.

ACKNOWLEDGMENT

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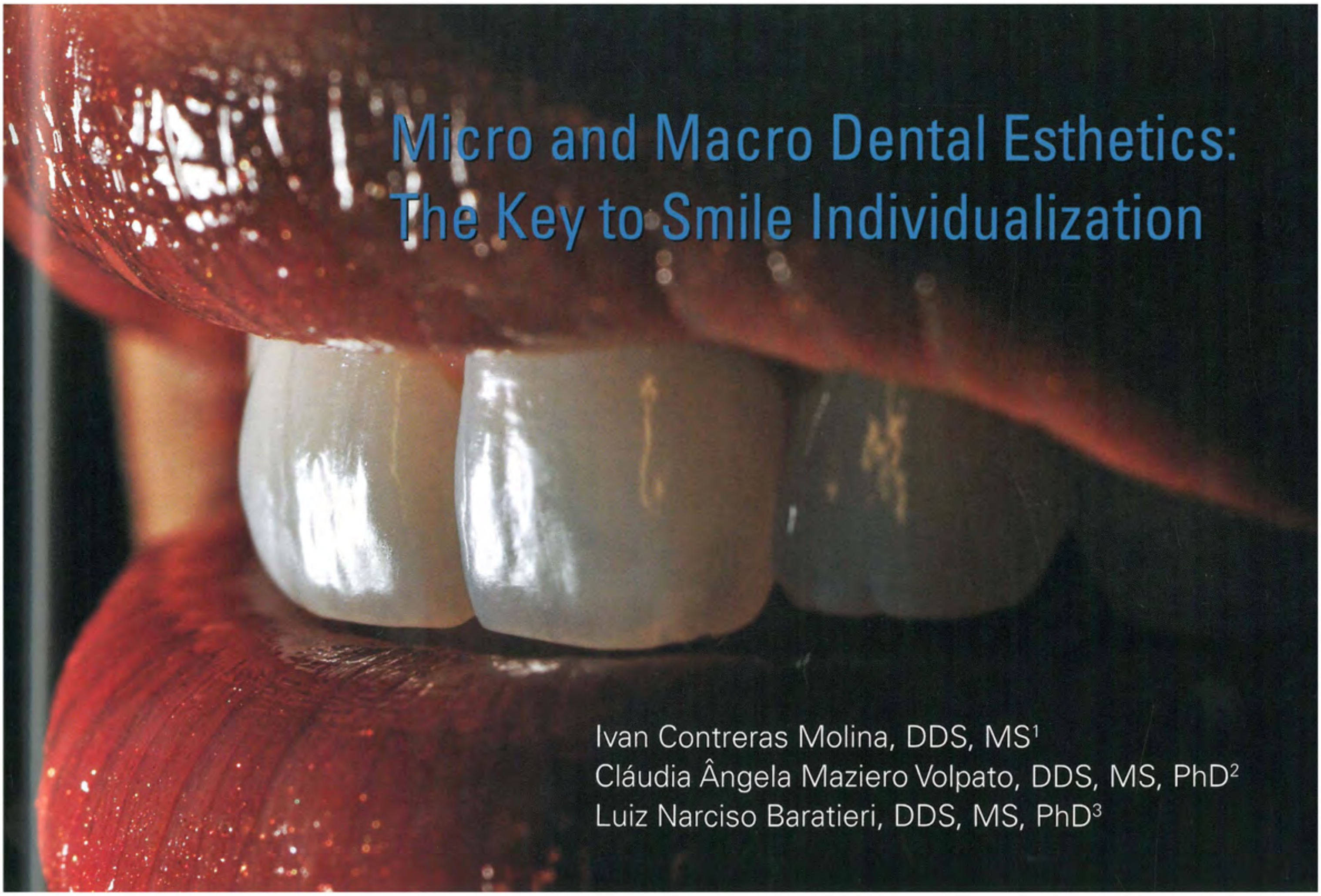

Micro and Macro Dental Esthetics: The Key to Smile Individualization

Ivan Contreras Molina, DDS, MS[1]
Cláudia Ângela Maziero Volpato, DDS, MS, PhD[2]
Luiz Narciso Baratieri, DDS, MS, PhD[3]

The smile is undoubtedly a great means of communication. Its impact on an individual's appearance is immeasurable; it can directly affect one's social life and psychological well-being.[1,2] Through cosmetic dentistry we can help deliver a beautiful smile by reproducing and integrating restorations so that our work becomes imperceptible.

The construction of a beautiful, natural smile depends on how the dental professional identifies the esthetic problems and understands the patient's expectations. Accurately diagnosing these problems, applying the principles of esthetics, and developing artistic sensibility are essential for clinical success.[3] But the greatest challenge is to meet all of these requirements with ease and functionality.

An esthetic resolution is accomplished only through the use of effective parameters based on clinical observations. The dental professional can minimize the subjectivity of esthetics by observing the shape, texture, and color of teeth in detail (microesthetics) and correlating these features to the whole in a broader view (macroesthetics), which includes factors related to the harmony of the teeth as a whole, gingival architecture, and esthetics of the periodontium.[4]

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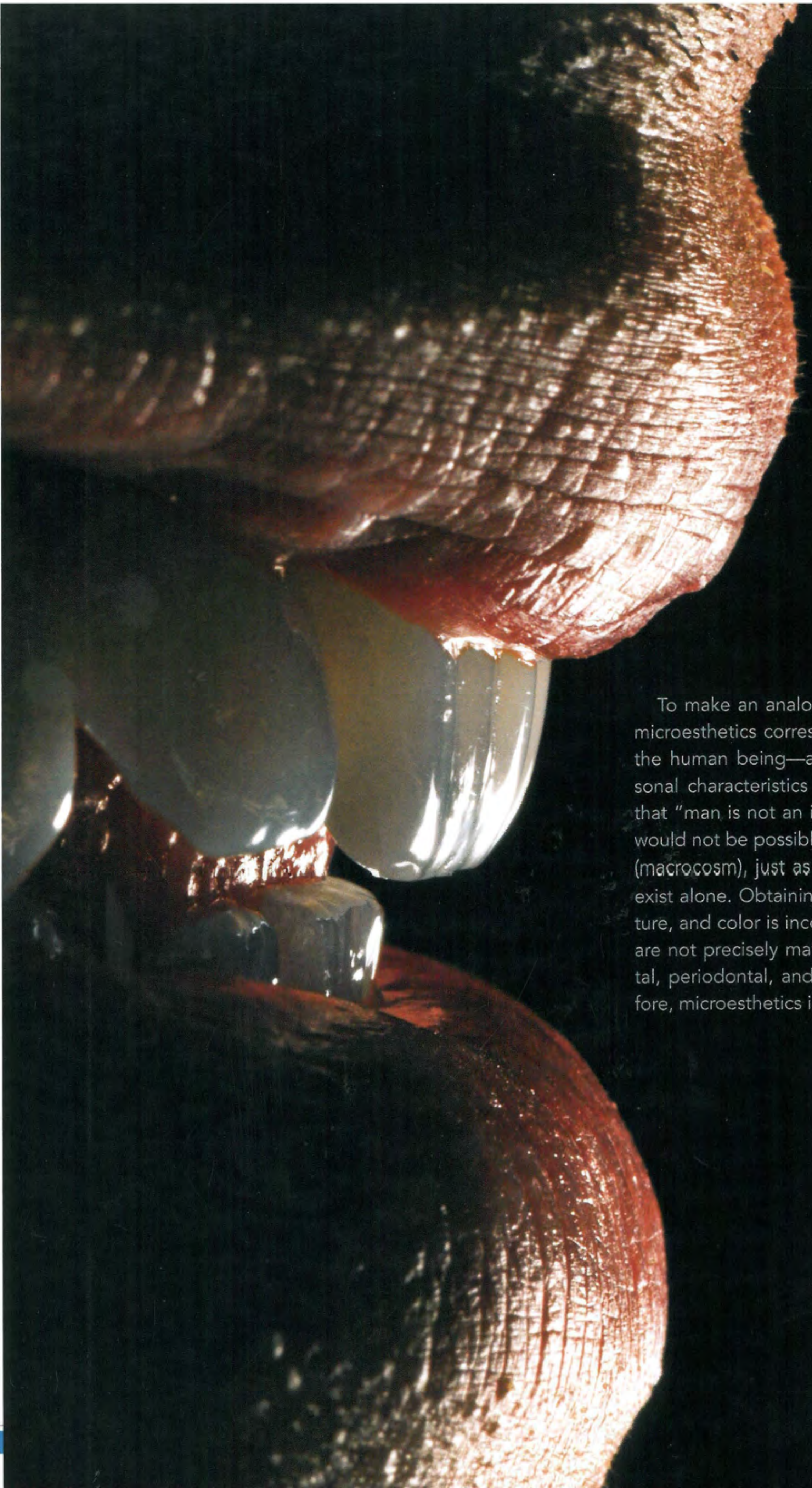
[1]Graduate Resident, Master of Science in Dentistry, Federal University of Santa Catarina, Florianópolis, Brazil.
[2]Professor, Department of Dentistry, Federal University of Santa Catarina, Florianópolis, Brazil.
[3]Professor, Department of Dentistry, Federal University of Santa Catarina, Florianópolis, Brazil.

Correspondence to: Dr Ivan Contreras Molina, Privada Plan de ayutla #39, Colonia Chapultepec sur, CP 58260 Morelia, Mexico. Email: dr.ivancontreras@gmail.com



To make an analogy with the world we live in, microesthetics corresponds to the microcosm, ie, the human being—a complex being, full of personal characteristics that individualize. We know that "man is not an island;" therefore, human life would not be possible if the universe did not exist (macrocosm), just as a dental element would not exist alone. Obtaining the ideal tooth shape, texture, and color is inconsequential if these features are not precisely matched with the patient's dental, periodontal, and facial characteristics. Therefore, microesthetics is a subset of macroesthetics.

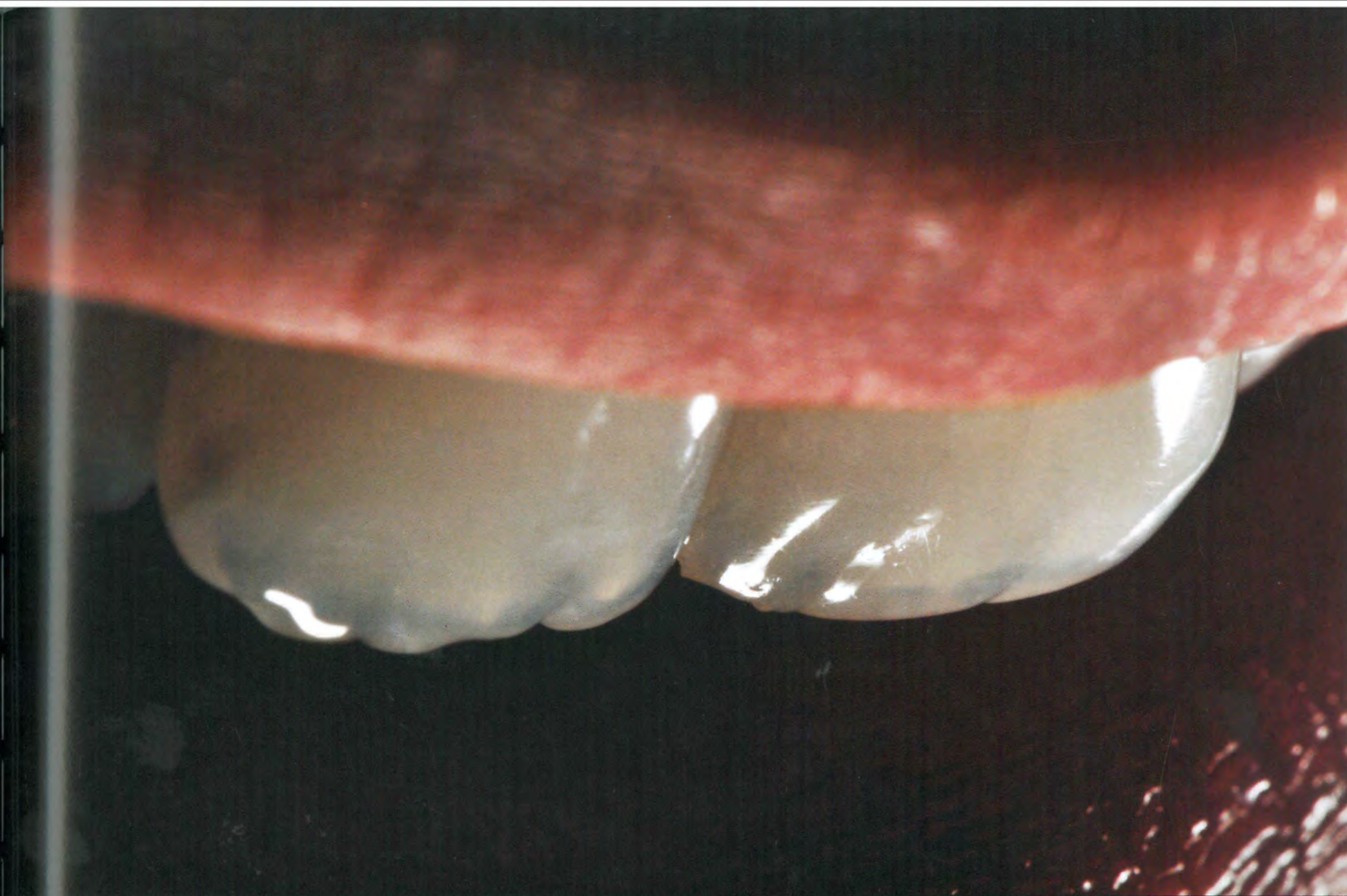
Shape

Shape is a crucial aspect of the appearance of the dental element, and thus for facial esthetics. Any change in shape is easily noticeable. Color mismatches may be overlooked; however, when the shape is compromised, esthetics will not be achieved.

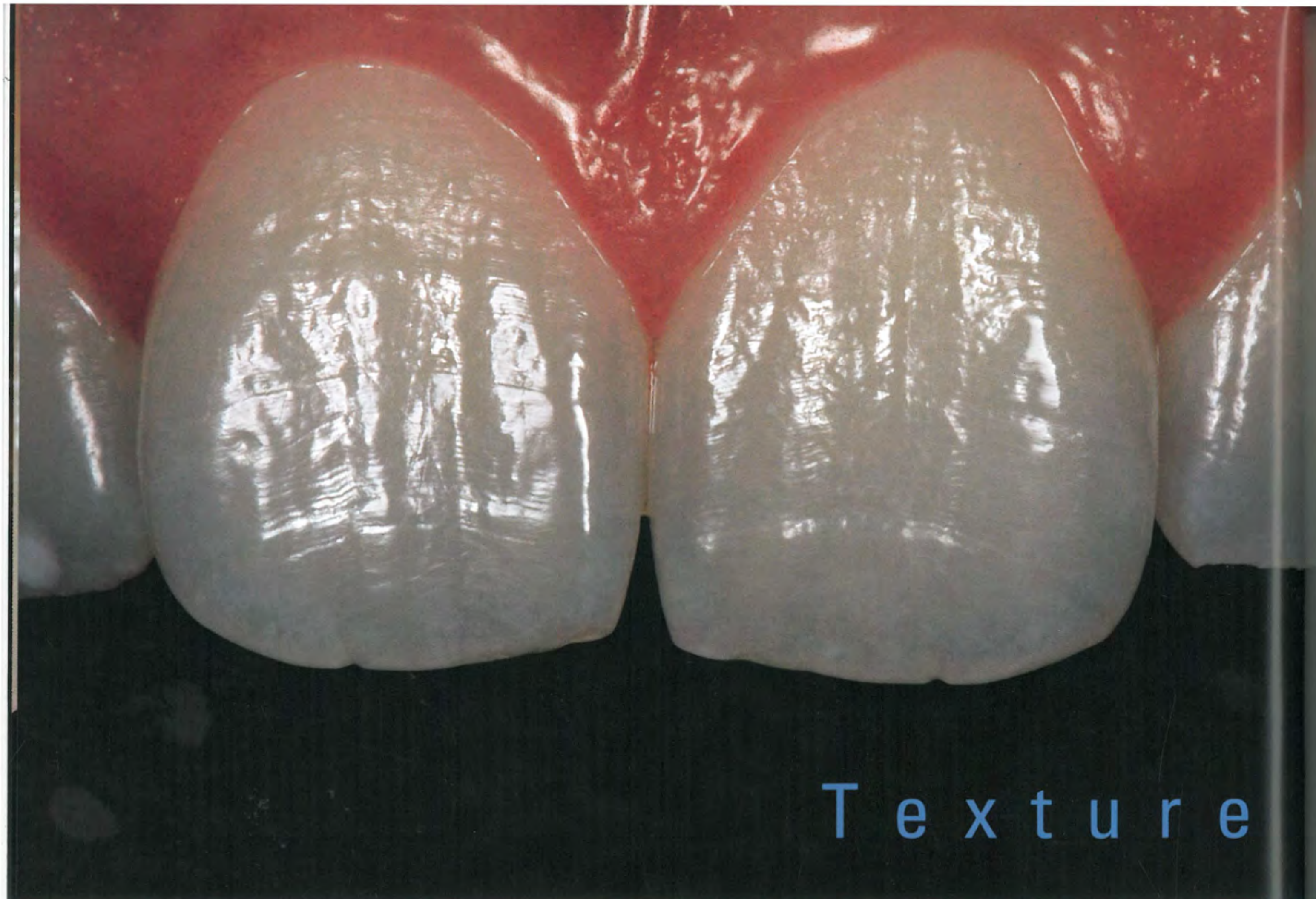
Historically, tooth shapes have been correlated with facial contours. Square teeth, with well-evidenced and parallel lines, were more prevalent in male patients. Conversely, oval and triangular teeth were characteristic of females.[5] However, this dogma has been challenged in recent years, because racial mixing has brought visible changes in the tooth shapes of the population, and currently we find a wonderful variation.[6,7] Therefore, there is no way to standardize tooth shapes. One should know in depth all forms, shapes, sizes, and variations. To blend art with science, we need to correlate these possibilities in a different way, creating individuality and harmony in our restorations.

The shape of a tooth should be closely related to the anatomy and contour of the patient's face. The marginal ridges and the incisal edge visually determine the tooth width and axis, and the outline of the labial surface determines the tooth length. For the natural contour of the tooth to be reproduced properly, these structures are the starting point.[2] When looking at the anterior teeth from the incisal aspect, we can visualize in detail the outline of the buccal and palatal aspects as well as the balance between the proximal surfaces.





The influence of light is another important factor to consider. Depending on how light interacts with the tooth surface, the perception of shape is different. Buccal surfaces with flat and smooth areas reflect more light and, therefore, appear larger, while rounded surfaces reflect light in all directions, creating narrower surfaces.[8] Thus, one could conclude that the optical behavior directly influences the size of the teeth and, where necessary, restorative strategies should be based on this concept.



Texture

The degree of roughness or smoothness of the tooth surface is determined by horizontal (perikymata) and vertical elements (developmental lobes), as well as by defects or depressions. Young teeth have more surface details, whereas adult teeth present smoother, flat facial surfaces due to physiological wear. When necessary, age-related features should be included in restorations.[9]

Similar to shape, the appearance of texture is influenced by light behavior. Smooth surfaces reflect little, making the teeth look darker. When areas are textured, the light is reflected in various directions, resulting in optically clear surfaces. This strategy can be used to influence the overall appearance of a restoration, yielding more natural-looking areas, with reflection and brightness effects.

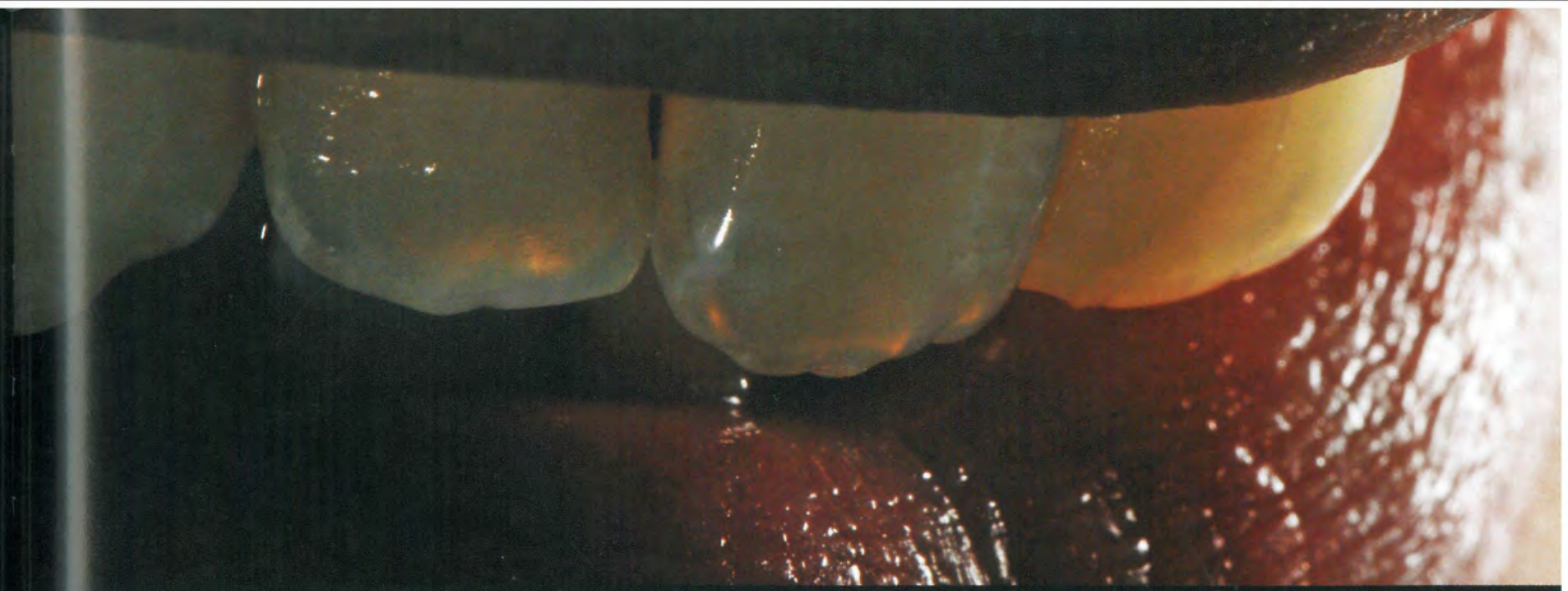
Color

Along with shape and texture, color makes up the triad responsible for dental esthetics. Tooth polychromatism is directly affected by the thickness and composition of tissues. Dentin has a role in the reflection of light, being primarily responsible for the shade of natural teeth, due to its high saturation and low translucency. Since enamel is rich in minerals, it behaves like a translucent object, allowing light to pass through it, come back, and reach dentin, resulting in light scattering. Thus, these two layers provide different optical effects, creating an esthetic result that is unique in the human body.[10]

Shade selection of a natural tooth is a complex process because it involves subjective factors that depend directly on the observer, light source, and the object. The surrounding tissues, the time of observation and weather conditions, the observer's visual condition and experience, as well as the shade guide used may change the perceived color. For standardization, shade guides have been made following Munsell's[11] color parameters. In these shade guides, the color name is known by hue (basic color), chroma (saturation), and value (brightness).

Translucence is an optical phenomenon attributed to enamel, which is a highly mineralized tissue that acts as a filter transmitting waves that reflect both long and short waves. Enamel is primarily responsible for the value and chroma variations observed in the teeth.

Opacity, on the other hand, is directly related to dentin, because when light passes through enamel and dentin, it reflects through enamel again. Variations in thickness of the enamel and dentin influence the degree of translucency. Therefore, in the incisal regions, where dentin is thinner or even absent, the bluish-white effects from light transmission can be observed.[12]



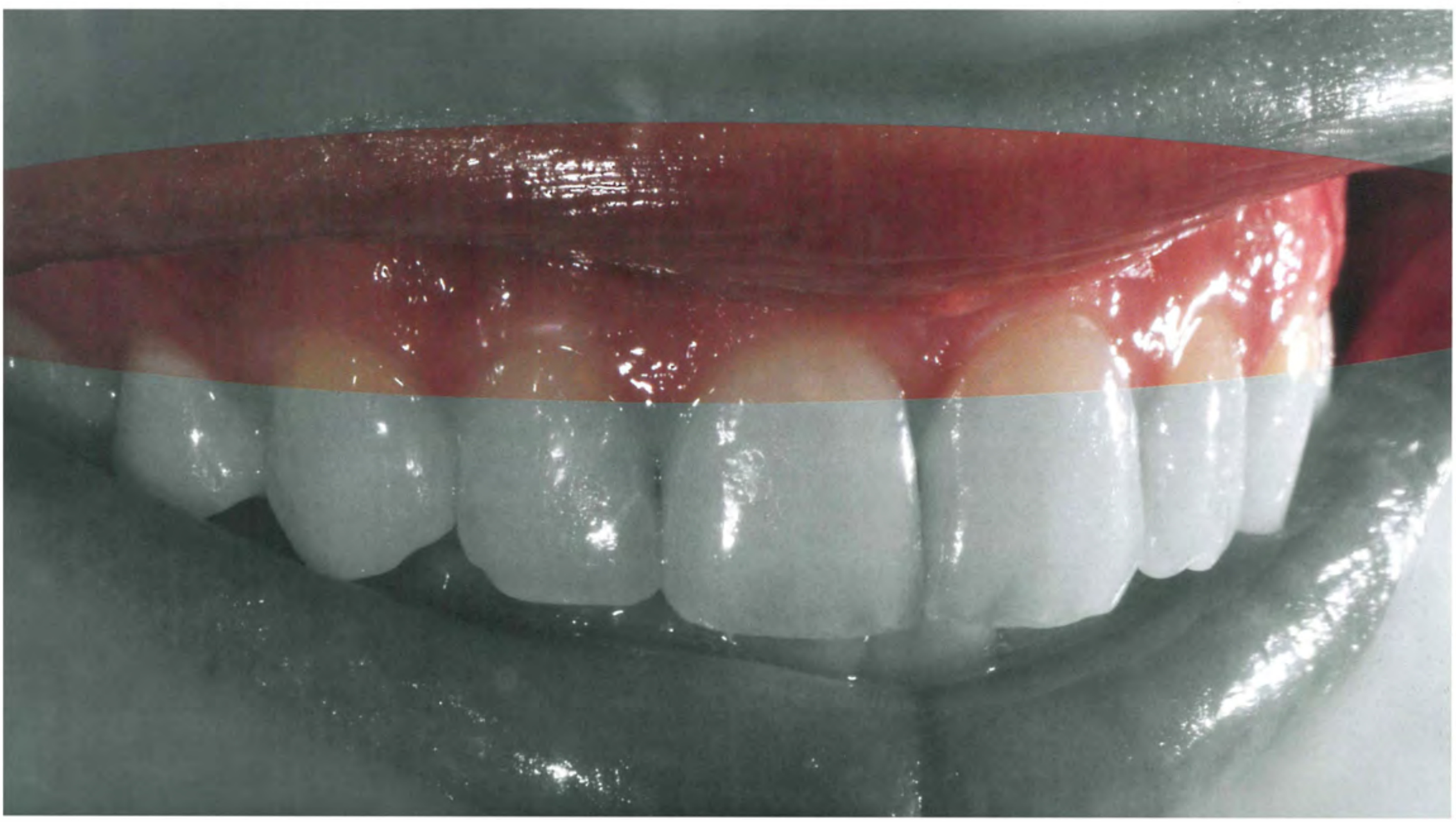
When light enters enamel, the hydroxyapatite crystals that are part of this complex tissue interact differently with it; the longer waves are transmitted and, simultaneously, the shorter waves are reflected. If enamel is subjected to different light sources, this phenomenon results in optical effects ranging from blue to orange. This optical behavior is known as enamel opalescence. The opalescence also allows the long waves that reach dentin to be reflected back, creating orange contraopalescent effects, especially at the regions of marginal ridges and mamelon tips. Together, these two optical phenomena are decisive in the expression and definition of tooth colors.

Another important optical perception occurs when natural teeth are exposed to ultraviolet light. It is the fluorescence, with emission ranging from white to intense blue light, that can be observed. The tissue responsible for this phenomenon is dentin, which has fluorescence three times more intense than enamel due to the higher amount of organic pigment photosensitive to ultraviolet light of the spectrum.[12] Therefore, in the presence of this light source, an effect of inner light is created, which results in a natural-looking tooth.

Macroesthetics

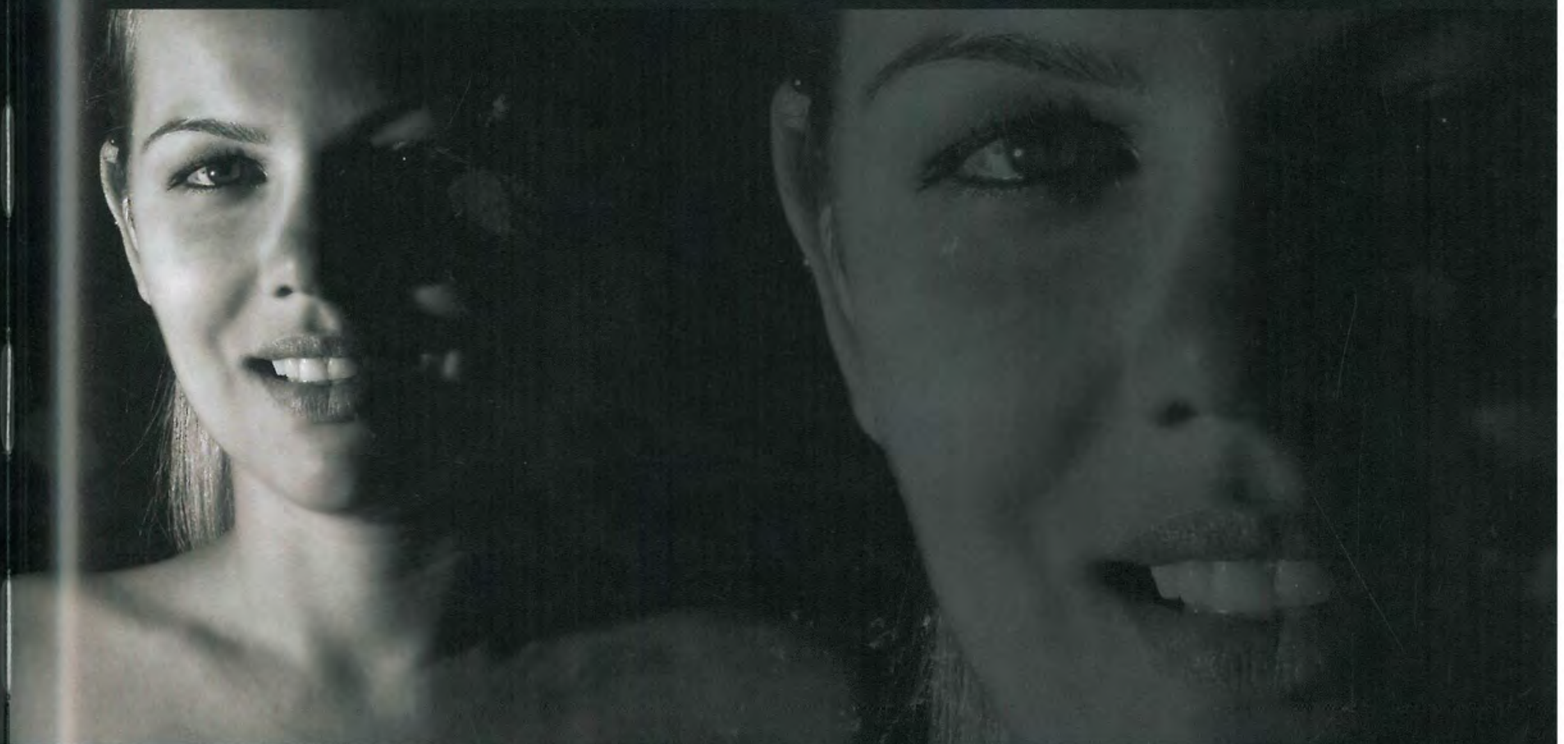
Despite the unique and fantastic features of the natural teeth, dentistry should not be limited to restoring form and function of teeth, but also to creating esthetics through an expressive and pleasant smile that is harmonious to the lifestyle, profession, and status of the patient. Therefore, after the individual dental appraisal, it is imperative to analyze the teeth comprehensively. In this analysis, several aspects must be considered: alignment and proportion of dental incisal curvature, dental midline, axial inclinations, buccal corridor, smile line, and interdental embrasures. A careful analysis of these aspects will allow the esthetic and harmonious dentofacial integration.

The gingival concave arch, gingival zenith, and interdental papilla form the gingival architecture. In a pleasant smile, a regular and continuous gingival contour should exist. Changes in this relationship compromise the esthetic balance, especially when the patient has a high smile line. Healthy gingival tissue, with symmetrical contour and height, is the ideal tissue frame for the dental elements.[4] If the frame is not appropriate, the desired esthetic success of properly restored teeth will not be achieved.



The face is the core of esthetic balance and, therefore, dental planning and treatment should be integrated with it. The professional should examine the shape of the face; the middle, interpupillary, and smile lines; and the type and movement of the lips. It is important to understand that the teeth are more or less visible depending on the thickness and mobility of the lips. Therefore, the static study of form, texture, and color should be reassessed with lip movement that occurs during speech, smile, and facial expressions, and at rest, reinforcing the role of communication and socialization of the individual.[1]

Patients' concerns for natural esthetics can be a real challenge for the dental professional. One must have a passion for detail to achieve esthetic excellence. A deep acknowledgment of the anatomy along with trained eyes to detect the morphological details help us build restorations that mimic natural dentition seamlessly, resulting in more beautiful, expressive, and healthy smiles.



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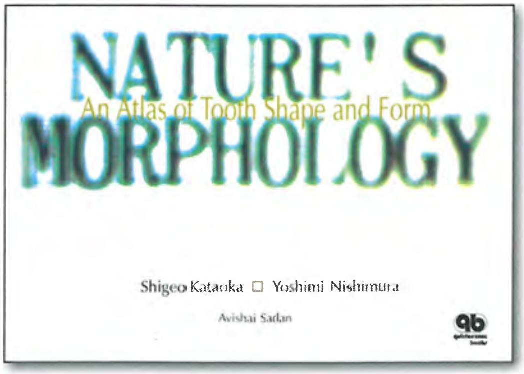

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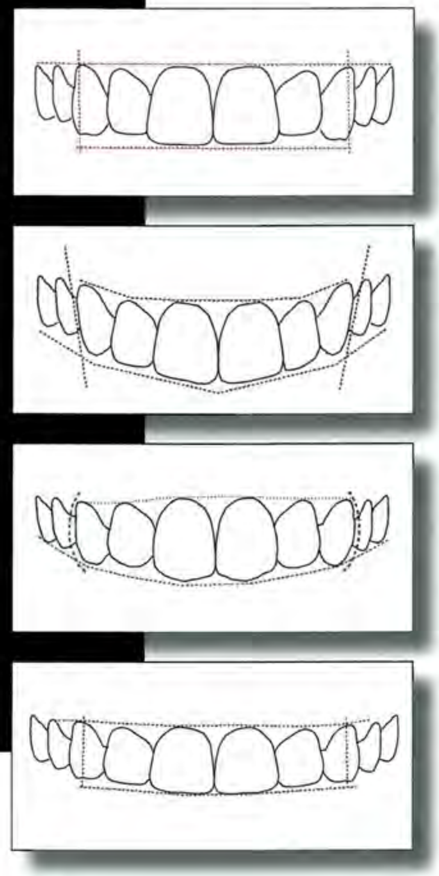
Visagism:
The Art of Dental Composition



Braulio Paolucci, DDS[1]
Marcelo Calamita, DDS, MS, PhD[2]
Christian Coachman, DDS, CDT[3]
Galip Gürel, DDS, MS[4]
Adriano Shayder, CDT[5]
Philip Hallawell[6]

The constant evolution of dental materials and techniques has made it possible to effectively restore tooth form and function using a minimally invasive approach. However, the final esthetic results may fail to meet the patient's expectations due to disharmony between the smile design and the patient's personality. The patient may feel that the restored teeth do not really "belong" to him or her. Without the proper knowledge, the origin of this disharmony can be difficult to identify.

For decades, dental clinicians have sought to harmonize the shapes of the teeth with the entire face based on parameters such as gender, personality, and age[1–4]; however, truly successful results have been elusive. The aim of this article is to present a novel concept: Visagism.[5,6] The Visagism concept helps dental clinicians provide restorations that account not only for esthetics, but also for the psychosocial features of the created image, which affect patients' emotions, sense of identity, behavior, and self-esteem. These factors, in turn, affect how observers react to patients following treatment.

[1]Private Practice, Barbacena, Brazil.
[2]Private Practice, São Paulo, Brazil.
[3]Private Practice—Well Clinic, São Paulo, Brazil.
[4]Private Practice, Istanbul, Turkey.
[5]Dental Technician, Well Lab, São Paulo, Brazil.
[6]Artist, Atelier São Paulo, Brazil.

Correspondence to: Dr Braulio Paolucci, Rua Rodrigues Alves, 53, Barbacena, MG, Brazil 36.200-000. Email: braulio@brauliopaolucci.com.br

THE CONCEPT OF VISAGISM

Derived from the French *visage*, meaning "face," the concept of Visagism was never precisely defined until it was expanded and developed by the artist Philip Hallawell.[5,6] Visagism involves the creation of a customized personal image that expresses a person's sense of identity. The method used to apply this concept is derived from the association of the principles of artistic visual language with disciplines such as psychology, neurobiology, anthropology, and sociology. Visagism makes it possible to determine which emotions and personality traits patients wish to express through their appearance and, specific to dentistry, through their

Fig 1 Choleric/strong temperament: determined, objective, explosive, intense, and passionate.

Fig 2 Sanguine/dynamic temperament: extroverted, expansive, communicative, joyful, full of life, and enthusiastic.

Fig 3 Melancholic/sensitive temperament: organized, meticulous, perfectionist, timid, reserved, and with a great capacity to think abstractly.

Fig 4 Phlegmatic/peaceful temperament: diplomatic, pacifist, mystic, and spiritual, but with a tendency to be apathetic and conformist.

smile. With the Visagism concept, clinicians can design a smile that blends the patient's physical appearance, personality, and desires. One of most significant challenges is to uncover these personality traits and desires in order to translate them into natural tooth shapes in psychodentofacial harmony. The achievement of this goal is what we call beauty.

Archetypical Symbols and the Emotional Brain

Carl Jung spent the final years of his life researching different cultures and civilizations. He discovered that certain symbols and images have been used in all cultures with the same meaning. Jung created the term *archetypical symbols* to define these images.[7]

The simplest of these archetypes are geometrical shapes: the square, the triangle, the circle, the lemniscate (figure-eight), and their variations. Primary and secondary colors are also archetypes. Hallawell observed that every visual composition is structured on one or a combination of these shapes and that the lines that form them can also be considered archetypical. These visual elements—lines, shapes, and colors—establish a universal language, regardless of an individual's culture, race, or education.[5,6]

Jung theorized that this language was part of the subconscious. Although it is not yet known how the brain recognizes an archetype, recent research has explored how these symbols are processed mentally and how they affect the viewer.[7] The neuroscientist Joseph LeDoux discovered that the limbic system is not responsible for the creation of emotions, as was commonly assumed. Several autonomous systems are associated with basic survival functions, indicating that the visual thalamus is capable of recognizing archetypes that trigger the systems that generate emotions.[8] This would explain why an image always provokes an immediate emotional reaction, as observed by many researchers and artists. When an individual observes an image, the emotional brain first perceives it as a combination of lines, shapes, and colors that have specific meanings. Only afterward, once the visual cortex is stimulated, is the image observed as a whole concept.

When the clinician provides personalized treatment using Visagism, an immediate emotional reaction by the patient is evident and can be accompanied by changes in behavior, posture, and even phonetics.

The Temperaments

According to Hippocrates,[9,10] an individual's personality is formed by a unique combination of four types of temperament: choleric (Fig 1), sanguine (Fig 2), melancholic (Fig 3), and phlegmatic (Fig 4). One or two of these types are generally dominant in relation to the others.

Fig 5 Trapezoidal tooth shape.

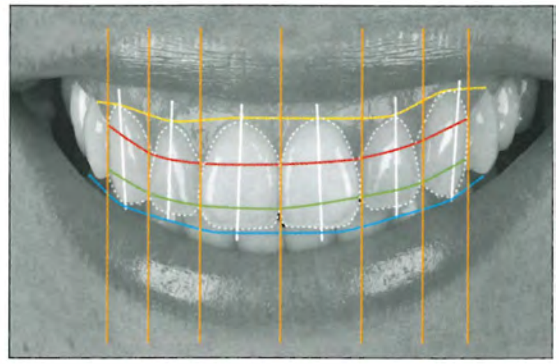


Fig 6 The smile and its configurative lines and forms: incisal plane, tooth axis, gingival zeniths, papillae, incisal embrasures, and tooth shapes proportions.

Clinicians should note, however, that patients will likely feel uncomfortable being classified as melancholic or choleric and may not understand terms such as sanguine and phlegmatic. Therefore, the authors prefer to substitute Hippocrates' original denominations with the terms strong, dynamic, sensitive, and peaceful.

Facial Analysis

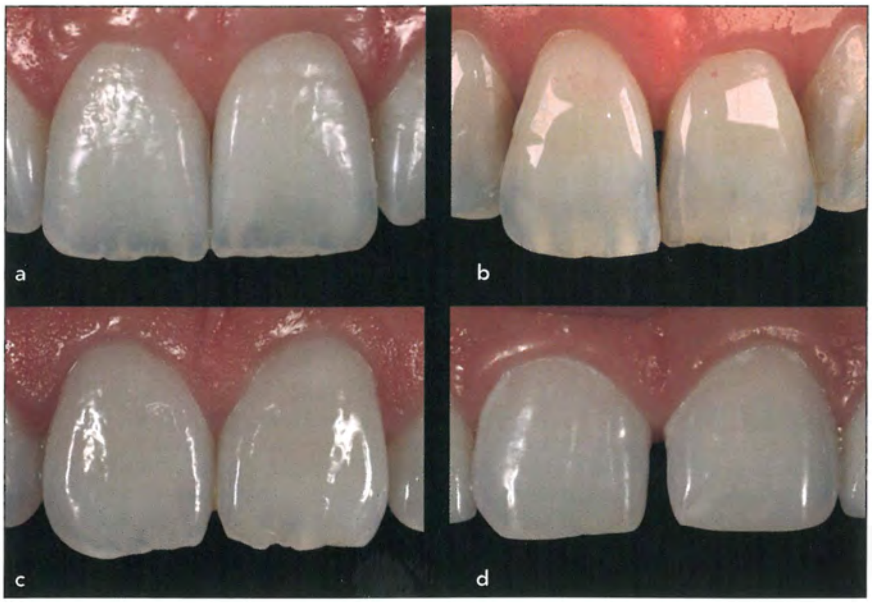
By integrating the theory of archetypical symbols with visual elements from the art world, Hallawell attributed meaning to the lines, angles, shapes, and colors that compose objects. Now, all professionals who deal with facial esthetics can apply theses elements to their work. The shape of the face in relation to the four temperaments can be described as follows:

- *Choleric/strong:* This type of individual has a rectangular face formed by well-defined angles, vertical and horizontal lines around the forehead and mouth, and deep-set eyes. Choleric/strong individuals have a personality characterized by strong leadership qualities, decisiveness, daring, and fearlessness.
- *Sanguine/dynamic:* This type of individual has an angular face formed by slanting lines around the eyes and forehead, a prominent nose, and a wide mouth. The sanguine/dynamic individual is very active, communicative, and extroverted.
- *Melancholic/sensitive:* This type of individual has close-set eyes and an oval face with features that are either rounded or formed by thin lines. The melancholic/sensitive personality is characterized by gentleness and a capacity for awareness and abstract thinking.
- *Phlegmatic/peaceful:* This type of individual is gentle, discreet, and diplomatic; he or she has a round or square face, protruding lower lips, and heavy eyelids.

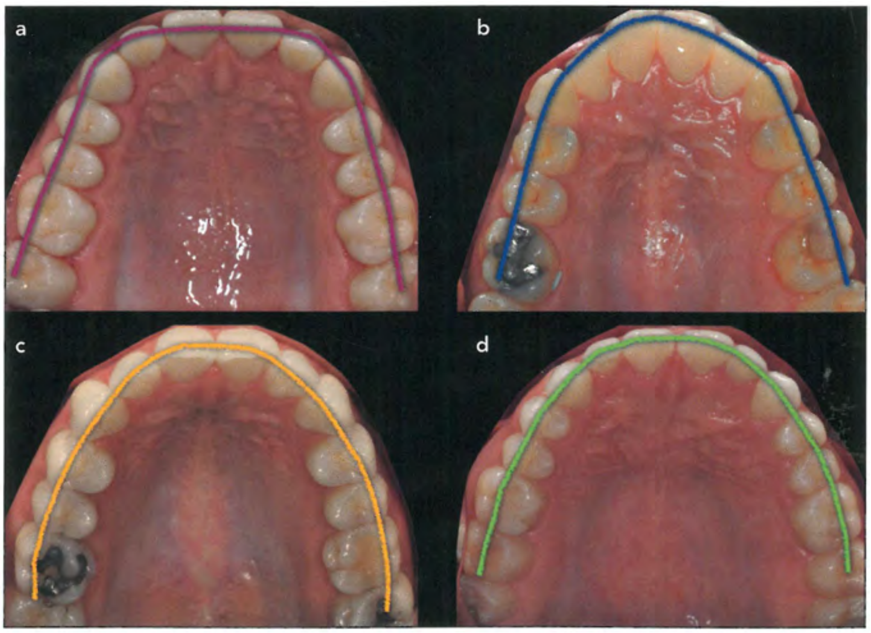
VISAGISM IN DENTISTRY

The shapes of the anterior teeth are defined by the area that reflects light directly forward, ie, the area between the cusps of reflection of mesial, distal, cervical, and incisal light, forming the so-called Pincus silhouette (Fig 5).[11–15]

When observing maxillary anterior teeth, a number of reference lines should be considered, such as those that unite the gingival zeniths, incisal embrasures, gingival papillae, and incisal plane (Fig 6). These lines are archetypical symbols, which means specific variations in their composition will arouse different emotions in the observer. Clinicians must understand the emotional message behind any smile design, and this aspect should be discussed with the patient before treatment.



Figs 7a to 7d Basic shapes of maxillary central incisors: *(a)* rectangular, *(b)* triangular, *(c)* oval, *(d)* and square.



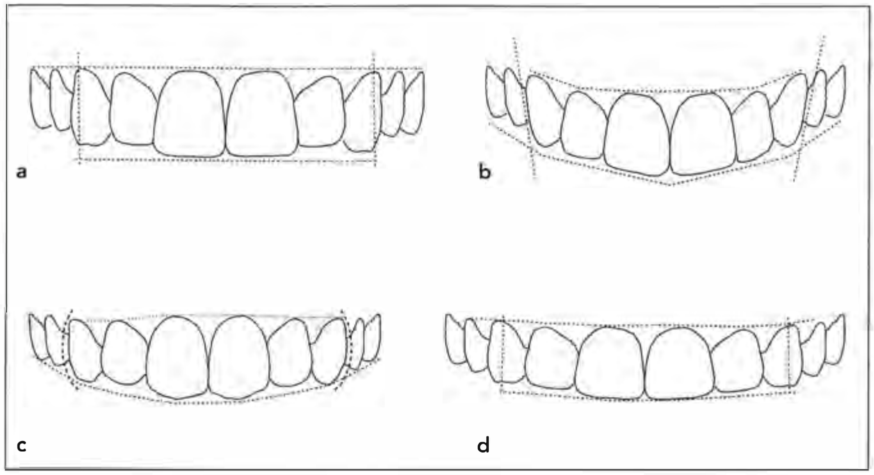
Figs 8a to 8d Basic arch forms: *(a)* rectangular, *(b)* triangular, *(c)* oval, and *(d)* circular.

There are four basic tooth shapes: rectangular, triangular, oval, and square (Fig 7), with some possible variations. Vertical, horizontal, inclined, straight, and curved lines interact in infinite ways to create the diversity of natural tooth shapes. These lines contain their own power of expression and emotional significance, which can be classified as follows:

- Vertical straight lines represent strength, power, and masculinity.
- Horizontal straight lines represent the surface on which we are born, live, and die and express equilibrium, passivity, and tranquility. They can also represent a barrier.
- Inclined straight lines express dynamism, movement, and joy.
- Curved lines represent the gradual transition between two planes (vertical and horizontal) and express gentleness, delicacy, femininity, and sensuality.

The dental arches also follow these basic formats, though it is important to note that variations are frequently encountered (Fig 8).

Figs 9a to 9d Maxillary arches with esthetic designs in relation to the four temperaments: *(a)* strong, *(b)* dynamic, *(c)* sensitive, and *(d)* peaceful.



Figs 10a to 10d Schematic drawing of maxillary teeth with esthetic designs in relation to the four temperaments: *(a)* strong, *(b)* dynamic, *(c)* sensitive, and *(d)* peaceful.

Nonverbal Communication

The oral region dominates the lower third of the face and immediately attracts the human eye because it contains both verbal and nonverbal communicative functions. Nonverbal communication, which is the primary issue of study in Visagism, occurs in only a fraction of a second. When the eye focuses on the mouth, the archetypical symbols are instantly registered in the brain and understood unconsciously and emotionally.[5–8,16]

The maxillary central incisors are the most important dental elements in nonverbal communication because of their prominent position in the mouth.[7,8,16] The maxillary lateral incisors are associated with intellectual and emotional aspects of the personality, while the canines express an individual's aggressiveness, ambition, and dynamism. The lips also express important information through their shape, size, thickness, and smile width.

Intraoral Design

The design of the maxillary anterior teeth, the characteristics of the lips, and the form of the dental arch compose a potent nonverbal message. The esthetic dental design in relation to the four temperaments can be categorized as follows (Figs 9 and 10):

- *Choleric/strong:* This design is composed of the maxillary anterior teeth positioned with their long axes perpendicular to the horizontal plane, visually dominant rectangular central incisors, and vertical canine position. The choleric/strong design shows radial symmetry. The connection line of the embrasures is horizontal between the central and lateral incisors, while the connection line of the gingival zeniths from canine to canine is horizontal with the lateral incisors below it. The maxillary arch is predominantly rectangular.
- *Sanguine/dynamic:* This design is composed of the maxillary anterior teeth positioned with their long axes slightly inclined distally, with discreet radial symmetry. The connection line of the zeniths is ascendant or in a zigzag pattern, and the connection lines of the embrasures and the incisal plane are ascendant from the medial line. The central incisors are usually triangular or trapezoidal, and the labial aspect of the canines is straight and inclined palatally. The maxillary arch is predominantly triangular or polygonal.
- *Melancholic/sensitive:* This design is composed of the maxillary anterior teeth with rectilinear or distally inclined long axes, with discreet radial symmetry. The connection lines of the zeniths and embrasures descend from the medial line, creating an inverted incisal plane. The shape of the central incisors is usually oval, while the labial aspect of the canines is curved and inclined medially. The maxillary arch is predominantly oval.
- *Phlegmatic/peaceful:* This design is composed of the maxillary anterior teeth with long axes perpendicular to the horizontal plane, except for the canine, which may be slightly rotated sideways. No group of teeth is dominant. Horizontal symmetry is present, generally with diastemata in a wide arch. The connection line of the gingival zeniths is straight, as is the connection line of the embrasures. The central incisors tend to be square and small, while the labial aspect of the canines is curved and vertically positioned. The maxillary arch is usually round.

Consultation and Treatment Planning

The consultation involves an analysis of the face to determine the patient's dominant temperament(s). Based on this information, the clinician should explain to the patient which emotions and personality traits are evoked by his or her appearance. The objective is to help patients reflect on what messages they would like to express through their smile and which personality traits they wish to emphasize. The whole process makes the patient a co-creator of the work, which enhances satisfaction with the treatment provided.

After consultation, the restorative team develops a treatment plan using the Visagism concept. The Visagism begins with one or more diagnostic digital smile designs, wax-ups, and mock-ups of the maxillary anterior region, which are evaluated by the patient and clinician with the aid of extra- and intraoral photographs.

CASE REPORT (FIGS 11 TO 31)

The 34-year-old female patient came to the clinic with complaints about the worn aspect of her teeth. The anamnesis was conducted with a visagistic approach, and all of the patient's complaints and expectations were recorded in writing. During the first consultation, irreversible hydrocolloid impressions of both arches were made. Study casts were fabricated and mounted on a semi-adjustable articulator. A complete photographic protocol was followed, including photographs of the smile, face at rest, forced smile, half-opened mouth, profile, dental arches in occlusion, anterior maxillary arch without the mandibular teeth, and maxillary and mandibular occlusal views. Further, the patient interview was video recorded, not only the to keep the conversation on file, but also to capture the relationship of her teeth with the lips and face during speaking and smiling. After this session, the interdisciplinary team defined which morphopsychologic facial and intraoral features required treatment.

Next, a second consultation took place with the patient. The patient and clinician discussed how the visual elements of her teeth affected her image. The information gathered during this consultation was used to help the patient decide which characteristics of her temperament she would like to emphasize in her smile and which she would like to soften.

CASE REPORT

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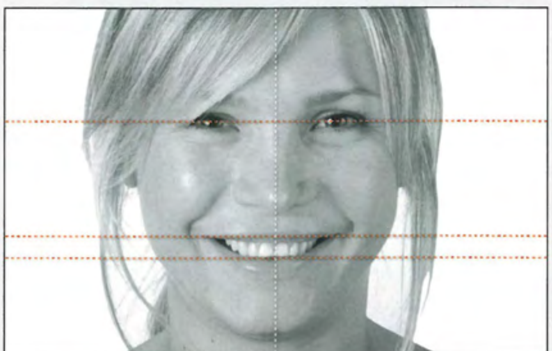

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Fig 11 Photographic records according to the Digital Smile Design (DSD) protocol.

Fig 12 Intraoral preoperative view. Esthetic issues included the presence of old restorations, an inverted smile line, mandibular extrusion, and incisal and labial abrasion.

Fig 13 Occlusal view showing severe palatal erosion.

Fig 14 Facial photograph following the DSD protocol. The facial midline and horizontal plane of reference are determined digitally.

Fig 15 Transferring the reference lines to the intraoral photograph. The tooth outline is placed according to the Visagism interview with the patient.

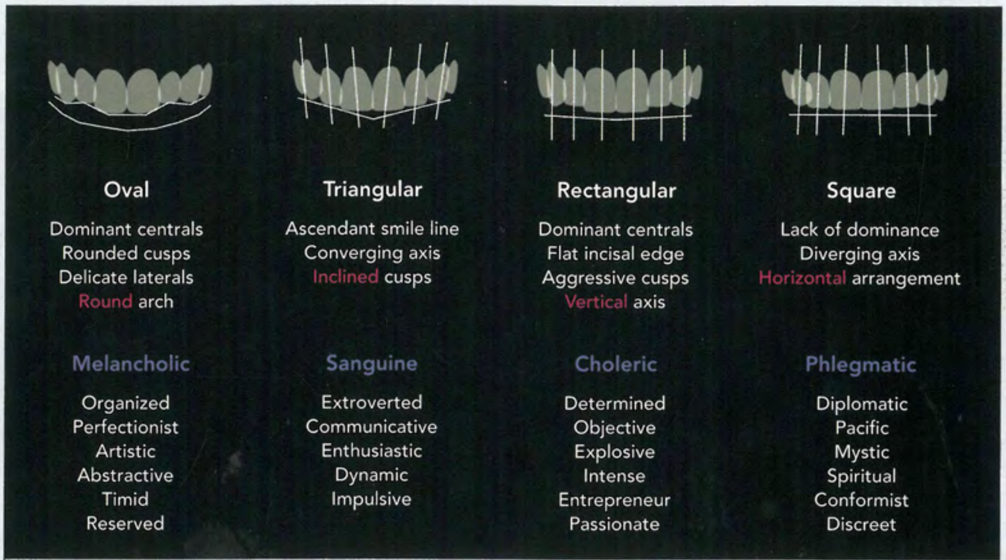

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Fig 16 Basic intraoral designs in relation to the four temperaments.

Fig 17 Guided diagnostic wax-up following the DSD protocol and the Visagism interview with the patient.

Fig 18 Mock-up done on top of the teeth with the silicone index fabricated over the wax-up cast.

Figs 19 and 20 Facial views with the mock-up in place.

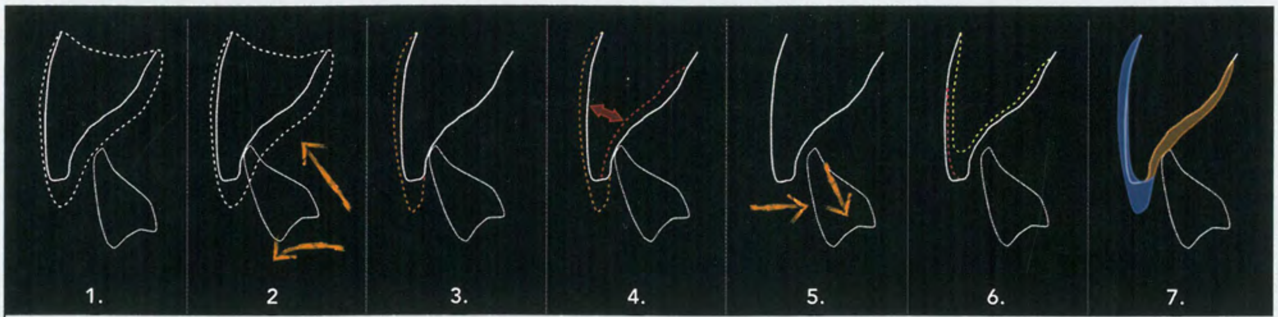

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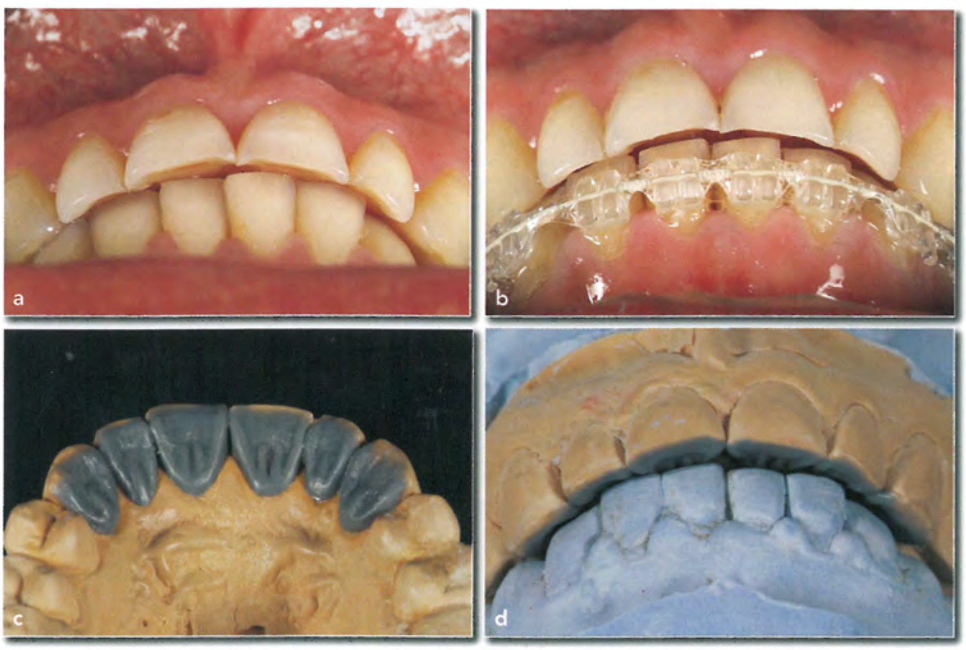
Fig 21 Tooth analysis prior to preparation. *(1)* The dotted line shows the estimated shape of the central incisor before abrasion and erosion; the full line shows the actual shape. *(2)* The mandibular incisors extruded and moved buccally. *(3)* The orange dotted line shows the mock-up and the amount of volume that was added buccally and incisally. *(4)* The red line shows the amount of tooth preparation needed to restore the palatal aspect of the maxillary central incisors; however, this would probably expose dentin. *(5)* To preserve the palatal structure of the maxillary incisors, orthodontic movement of the mandibular incisors was planned (intrusion and lingual movement). *(6)* The red dotted line shows the minimal reduction needed for a thin veneer; the yellow dotted line shows the reduction needed for a full crown. *(7)* To avoid the crown preparations and preserve tooth structure, the restoration was divided in two, with a direct composite resin on the palatal aspect and a thin veneer on the labial aspect.



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Figs 22a to 22d *(a)* Preoperative occlusal relationship of the incisors, showing the insufficient space for a restoration. *(b)* Orthodontic treatment, showing the clearance obtained for the restorations. *(c and d)* Palatal wax-up used to guide the direct composite resin restoration.

The patient wished to express the strength and sensitivity of her smile because she believed those were her most striking features. Thus, the dental team developed a design with straight lines and rectangular shapes (strength) that were slightly rounded to accent her sensitivity and femininity. The lateral incisors were designed to be straight and slightly rounded (sensitivity and intensity), while the canines were given inclined labial surfaces (dynamism and perfectionism) (see Fig 16).

23

Fig 23 Fabrication of the palatal direct composite resin restoration.

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Figs 24a to 24d Tooth preparation sequence: *(a)* Replace the bis-acrylic resin mock-up; *(b)* create grooves with depth-cutter burs to guide the depth of the preparation; *(c)* remove the bis-acrylic resin and analyze the amount of enamel reduction; *(d)* finalize the preparation by smoothing the grooves, placing the finishing lines, and rounding all edges.

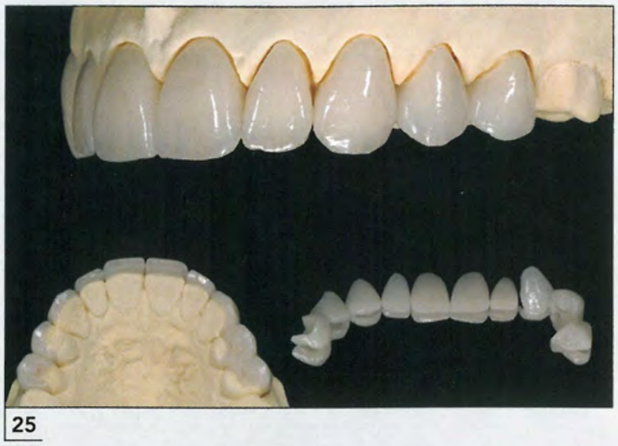

Fig 25 Final ceramic veneers (IPS e.max LT ingots with incisal layering using IPS e.max Ceram, Ivoclar Vivadent).

Fig 26 Final try-in.

Fig 27 Bonding procedure.

The wax-up was produced according to the patient's desires and reproduced as a mock-up in bis-acrylic resin for the try-in stage. Some adjustments were made before patient approval, and the ceramic veneers were fabricated in lithium disilicate glass-ceramic (IPS e.max, Ivoclar Vivadent, Schaan, Liechtenstein).

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Fig 28 Before-and-after facial views.

Fig 29 One year after bonding, good integration with the soft tissue is evident.

CONCLUSION

Visagism is a novel concept that applies the principles of visual art to the composition of a customized smile. The aim is to create a smile design that expresses the patient's personality and lifestyle, ensuring harmony between the restorations and the patient's physical appearance, values, and attitudes.

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Figs 30 and 31 Final result.

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Porcelain Buildup Inspired by Nature

Domenico Cascione, CDT, BS[1]
Tzur Gabi, DMD[2]
Jack Goldberg, DDS[2]
Alireza Moshaverinia, DDS, MS, PhD[2]
Mamaly Reshad, BDS, DDS, MSc[3]

To mimic natural tooth structure, the dental technician must appreciate all of the esthetic properties related to the composition of natural teeth. The dental technician must therefore be "inspired by nature"—a concept so important in today's dental ceramic restorations.[1]

In addition to having passion and talent, the dental technician needs to be aware of the myriad colors and shades available and how to apply them to build a restoration that mimics nature.[2] It is possible to mimic even the horizontal bands of color found in natural teeth (also known as striae of Retzius structure) through the combination of talent, experience, and skill required to understand, mix, and apply the appropriate porcelain powders. This clinical report describes the application of porcelain powder colors and shades used in combination with dental technician expertise to make restorations that reflect natural tooth texture and structure.

[1]Clinical Assistant Professor, Division of Primary Oral Health Care, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA.

[2]Resident, Advanced Prosthodontics, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, California, USA.

[3]Honorary Clinical Teacher, Eastman Dental Institute, London, Private Practice, London, England.

Correspondence to: Domenico Cascione, Operart LLC, 1332 Berkeley Street #3, Santa Monica, CA, 90404, USA. Email: cascione@usc.edu

Fig 1 Liner fluorescent is applied to zirconia framework.

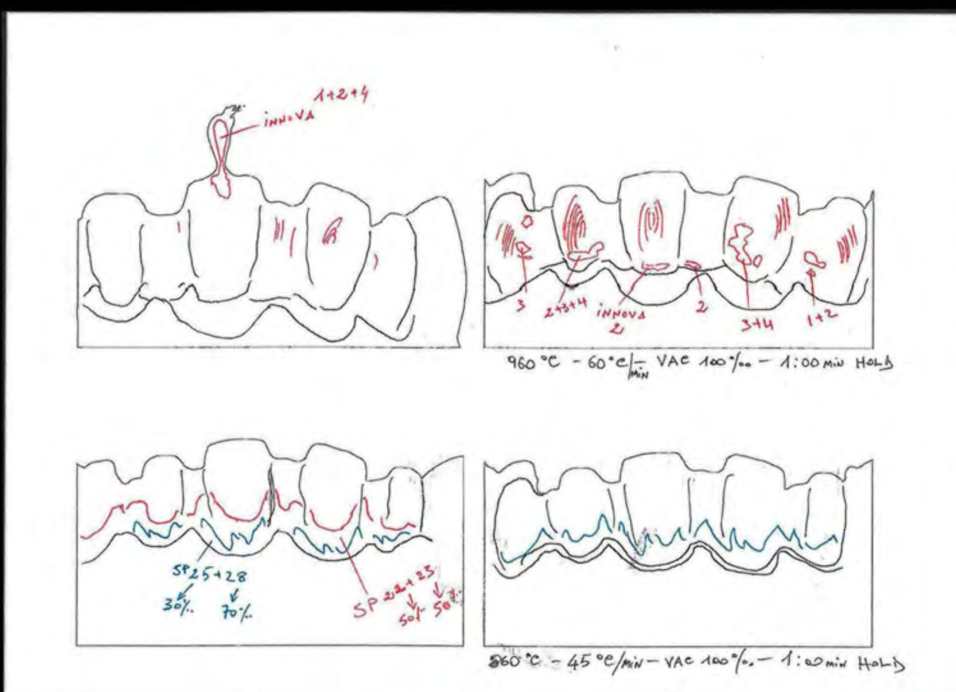
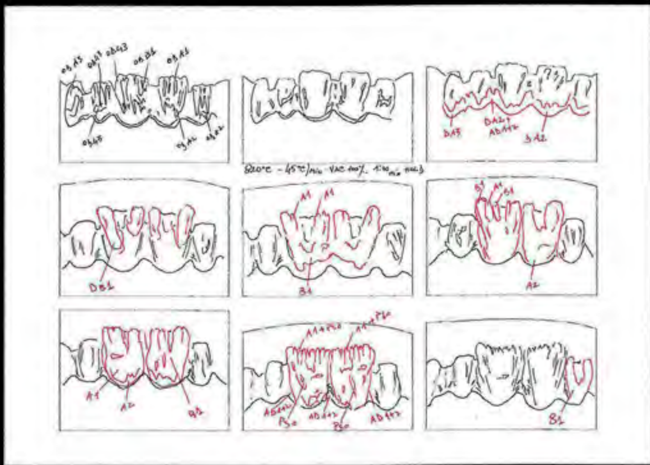


Fig 2 Porcelain map for the first bake.

The required steps for porcelain application and addition are presented in Figs 1 to 12. To improve the bonding between feldspathic porcelain and zirconia framework, a layer of Innova stain (Creation, Willi Geller International, Meiningen, Austria) was applied to the framework (Fig 1). Figures 2 and 3 show the porcelain maps for the first bake and for dentin buildup. Figures 4 and 5 show the porcelain dentin and enamel buildup, and Figs 6a and 6b show the facial and palatal views of the full-contour anatomic porcelain buildup. Internal characterization was accomplished using Innova stain; white stain was applied to mimic the natural tooth texture (Figs 7 to 9).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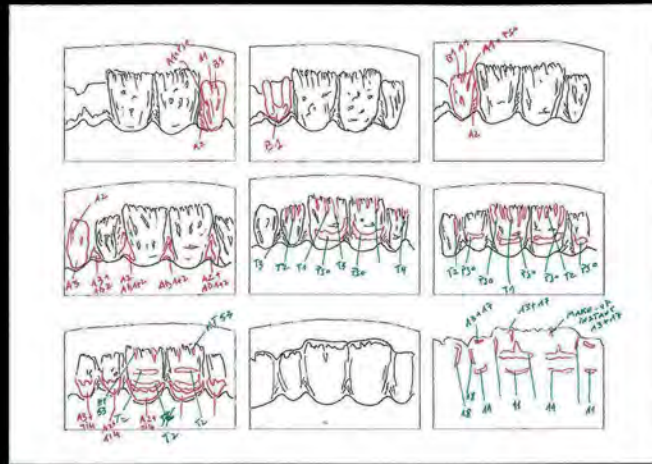
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Figs 3a and 3b Porcelain map for dentin buildup.

Fig 4 Porcelain dentin buildup.

Fig 5 Porcelain enamel buildup.

Figs 6a and 6b Full-contour anatomic porcelain buildup (facial and palatal views).

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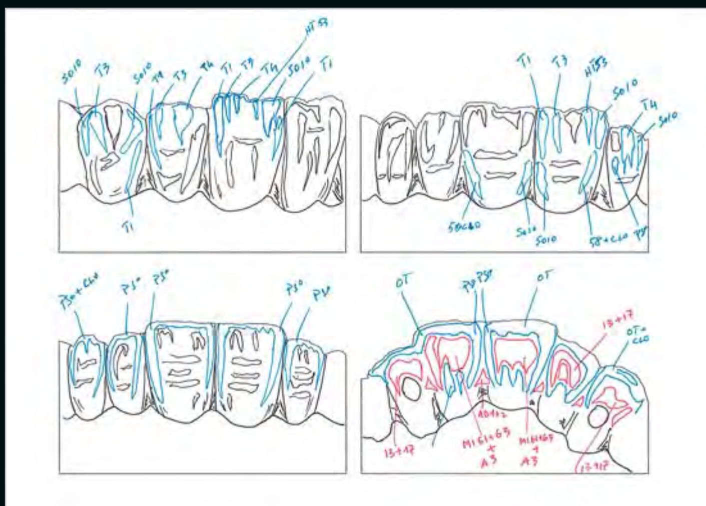
Fig 7 Horizontal bands added to the porcelain buildup to mimic the natural tooth structure and surface texture.

Fig 8 Internal aspect of the porcelain buildup.

Fig 9a and 9b Internal stain.



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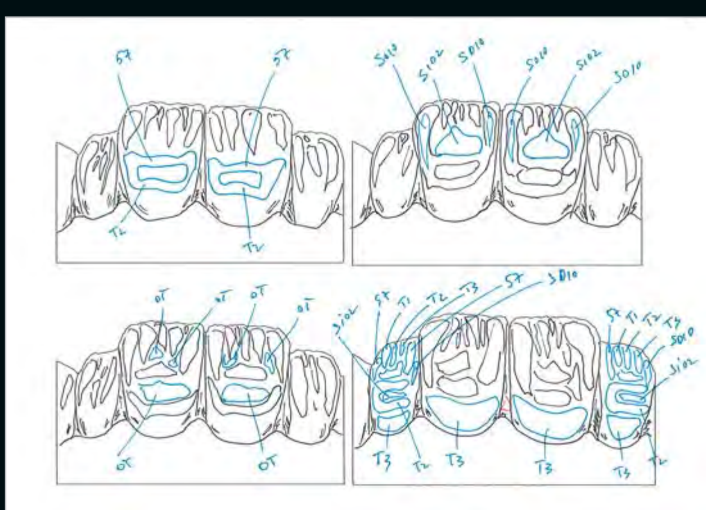

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Figs 10a and 10b Transparent and translucent porcelain buildup.

Fig 11 Transparent and translucent powders.

Fig 12 Surface texture added.

Fig 13 Final restorations on the cast prior to delivery.

Final porcelain buildup and characterization are carried out as mapped (Figs 10 to 12). Figure 13 shows the definitive restorations prior to delivery and Fig 14 in smile view upon delivery—satisfactory in terms of form, color, phonetics, and function.

Fig 14 Smile view of the definitive restorations upon delivery.

ACKNOWLEDGMENTS

The authors would like to acknowledge Biotech S.R.L. Italy Milling Center Bernardo Manfré for providing the zirconia framework.

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Photography in Dentistry

Theory and Techniques in Modern Documentation

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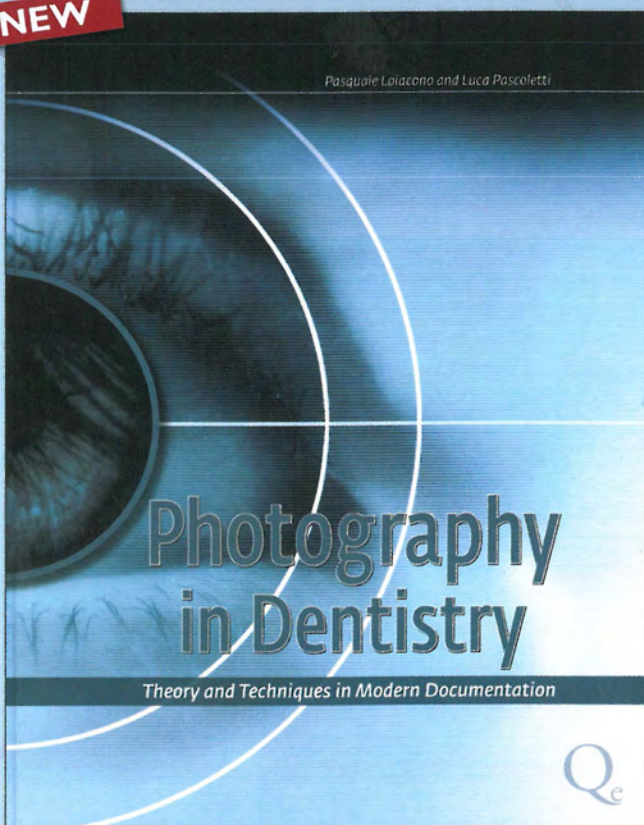

336 pp; 847 color illus;
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Pasquale Loiacono and Luca Pascoletti

Whether they are used for patient communication, consultation with a laboratory or colleague, diagnosis, clinical or legal records, or scientific presentation or publication, images are a much more powerful means of communication in the field of dentistry than the spoken or written word. However, dental photography is lacking set standards that would allow the continuity and reproducibility essential to clinical and scientific documentation. To address this need, this book presents guidelines for photographic documentation that will enable practitioners to produce images that faithfully convey clinical data. Precise instructions, including the positions of the patient, assistant, and practitioner; camera settings and flash positions; aiming and focal points; and the types and positions of required accessories are detailed in text and images, and an example of the desired final image is provided.

Contents

Customized Treatment for Esthetic Success: A Case Report

Stefano Inglese, CDT[1]

Esthetic dentistry involves the principles of natural and artistic beauty. Clinicians should not approach esthetics solely from an objective point of view based on rigid esthetic parameters; rather, esthetics must also be considered in terms of the individual patient's personality and character. Only in this way will true harmony between the patient's face and the dental restorations be achieved. If treatment is not customized and personalized for each patient, clinicians risk producing restorations that are ideal in theory but too artificial in reality.

Modifying the morphology of only a few teeth in the maxillary anterior segment can have a profound effect on the overall esthetics not just of the mouth and smile, but also of the patient's entire face. This article presents a case report involving the restoration of maxillary central and later incisors with severe esthetic deficiencies.

[1]Pescina, L'Aquila, Italy.

Correspondence to: Stefano Inglese, Via Romolo Tranquilli 15, 67057 Pescina, L'Aquila, Italy. Email: stefanoinglesedentalart@yahoo.it

CASE REPORT

The patient presented to the clinic with a desire to improve the esthetic appearance of her maxillary anterior teeth (Figs 1 to 4). She wanted to be able to smile freely without embarrassment or insecurity. Her primary complaint was the appearance of her maxillary central incisors, which were oddly shaped, crooked, and severely discolored. Both central incisors had been endodontically treated years earlier. She wished to avoid orthodontic realignment, which would have eliminated the crowding and simplified the prosthetic treatment.

Diagnostic Procedures

Careful analysis of the lips revealed disharmony between the smile curve of the lower lip and the incisal edge of the maxillary central incisors (Fig 5). It was necessary to adjust the proportions and symmetry of the central incisors by altering their relationship with each other and with the lateral incisors.[1,2] It was planned to provide two crowns for the central incisors and two veneers for the lateral incisors. This would help to restore the proper relationships between the teeth,[2–4] thus optimizing the overall esthetic appearance while preserving function and phonetics. Another important

CASE REPORT

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Figs 1 to 3 Preoperative views.

Fig 4 Ideal midline and esthetic plane.

Fig 5 Ideal smile curve.

task was to restore the vertical midline, which was established after careful analysis of the face.[5]

After endodontic retreatment and internal tooth bleaching of the maxillary central incisors, fiberglass posts were cemented. The enamel surface was kept intact to preserve the sound tooth structure and original tooth shapes for the diagnostic wax-up (Figs 6 and 7). Thus, no reference points on the teeth were lost before the patient consented to the procedure following an esthetic mock-up.

A preliminary analysis of the diagnostic casts (Figs 8 and 9) helped to determine whether the morphologic changes for each tooth required an additive, subtractive, or combined approach. Before any additive procedures were carried out, the tooth areas to be reduced were marked with red pencil on the cast to


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Figs 6 and 7 Reconstruction of the central incisors with fiberglass posts and composite resin using an adhesive technique.

Figs 8 and 9 Diagnostic casts.

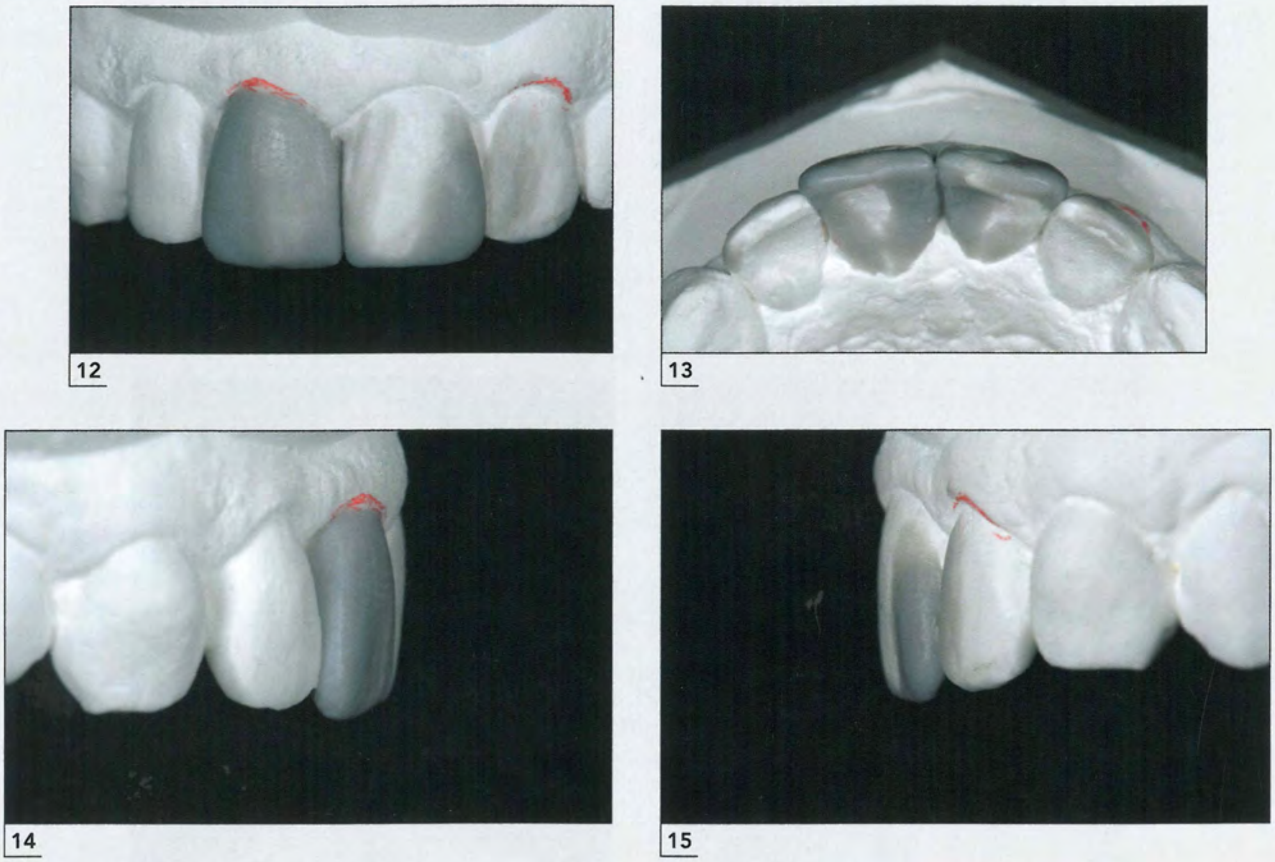
Figs 10 and 11 Areas to be reduced were marked in red on the wax-up.

obtain an accurate mock-up (Figs 10 and 11). The cast was checked using silicone guides obtained from the final wax-up.[6,7]

The gingival contours were also marked for correction. In these areas the preparation limits were extended a bit subgingivally to permit buildup of the new cervical emergence of the restorations to support the marginal gingiva and move the gingival zenith distally from the tooth axis, optimizing the esthetic gingival design.

The treatment plan was to create more rounded mesiodistal incisal angles for the lateral incisors, which would produce a more youthful appearance. This would also provide additional space for the central incisors, which needed to be made more dominant.

On the right central incisor, which exhibited pronounced rotation, a combined subtractive and additive wax-up was performed. An additive wax-up was performed for the left central incisor, while a subtractive wax-up was carried out for the lateral incisors at



Figs 12 to 15 Finished wax-up.

the mesial surface and incisal angles, optimizing the tooth shapes. Figures 12 and 13 show the finished wax-up, which can be duplicated to produce a single-color wax-up suitable for visualizing tooth shapes and fabricating silicone guides without risking damage to the wax-up.

The labial profile plays an important role in esthetics and function as well as in the biologic integration of the restoration (Figs 14 and 15). The extent of labial convexity affects the optical dimensions of the tooth, while proper positioning of the incisal edge is crucial for anterior guidance and phonetic function. In addition, accurate emergence profiles support the gingival marginal tissues, improving their appearance and biologic integration.[8]

Tooth Preparation

It is important to establish the correct tooth shapes for the restoration before carrying out any irreversible steps, such as tooth preparation. The diagnostic wax-up and subsequent mock-up serve as a preview of the final restoration. The use of silicone guides simplifies

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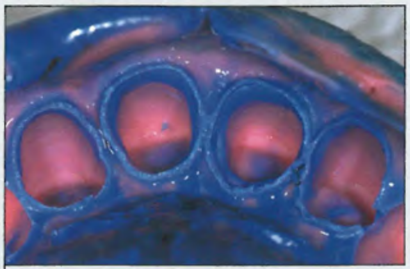
Figs 16 to 18 Silicone guides were used to determine the amount of tooth preparation.

the clinician's work by ensuring preservation of the biologic structures. Silicone guides also reduce treatment time and thus make visits to the clinic less stressful for the patient.

Following these diagnostic measures, the necessary space can be made for a restoration that is thick enough to provide adequate strength and has sufficient ceramic buildup to create the desired esthetic effects. The silicone guides helped the clinician establish a definitive dental midline and reduce the number of teeth involved by limiting mesial preparation to the left central incisor (Figs 16 and 17). Similarly, the lateral incisors were reduced more markedly at the mesial aspect to create space for the reshaped central incisors (Fig 18).

The goal should be rational tooth preparation that preserves as much tooth substance as possible, especially enamel, which is needed for adequate bonding. According to the dental literature, the longevity of metal-free restorations depends less on the strength of the ceramic material and more on the quality of the bond established between the material and the tooth itself.[9]



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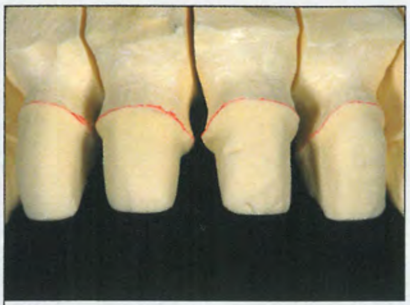

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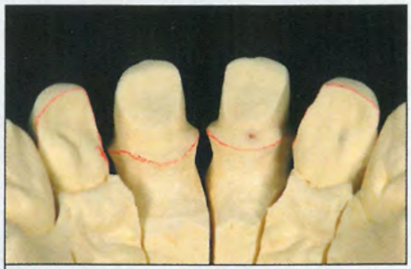

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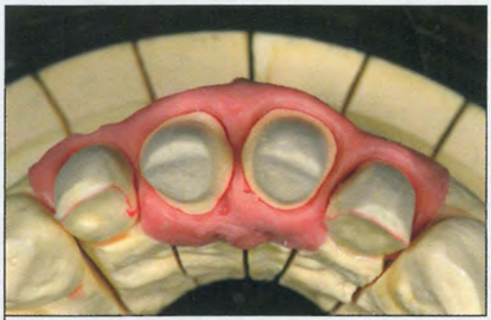

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Fig 19 The impression must reproduce details without defects and distortion.

Figs 20 to 23 Master casts with the gingival tissues reproduced in silicone.

Fabrication of Crowns and Veneers

Careful impression and master cast procedures are an important way for the dental clinic and laboratory to communicate. Missing or incorrect information, a lack of precision caused by a poorly produced cast, or even tiny distortions or an "illegible" area of the impression, especially at preparation margins, can adversely affect the fit of the restorations (Figs 19 to 21). Equally important is the creation of artificial gingival tissues (Figs 22 and 23), which serve as the reference points for the emergence profile and provide support for the natural gingival tissues.

A metal-free technique was used to fabricate the veneers and crowns with lithium disilicate glass-ceramic (IPS e.max press, Ivoclar Vivadent, Schaan, Liechtenstein) individually layered with IPS e.max Ceram (Ivoclar Vivadent). The tooth shapes from the diagnostic wax-ups were reproduced and then carefully cut back so that the ceramic buildup could be fabricated.

The lost-wax technique for pressed ceramic was used for fabrication (Figs 24 to 29). Sprues (3-mm wide and 3- to 4-mm long) were attached to the wax crowns. The lithium disilicate ceramic was injected into the cavity of an investment ring preheated at 850°C for approximately 1 hour. Modern pressing furnaces have a series of predefined programs to accommodate the size of the investment ring and the type of material to be pressed. The ingots to be pressed should be chosen based on the desired degree of luminosity and the color of the tooth preparations; further, different materials offer varying degrees of fluorescence and opacity. The pressed lithium disilicate cores were fitted onto the master cast, and any rough spots were removed to achieve completely passive fit. The spatial relationships that guided the buildup were checked using silicone guides.

The dentin ceramic should be trimmed lightly to avoid microcracks in the substructure. Microcracks, which cannot be repaired, will inevitably open as a re-

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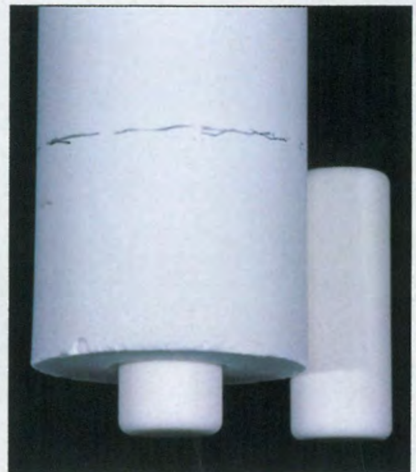

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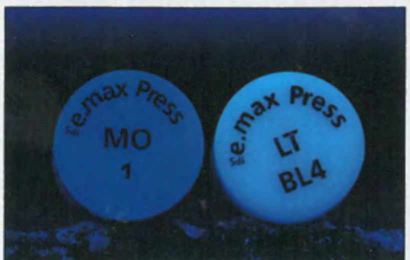

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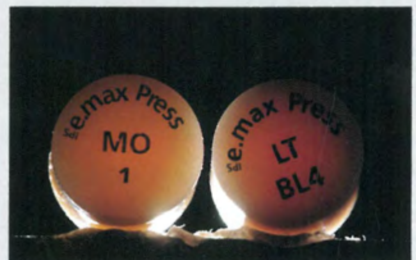

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Figs 24 to 29 Fabrication of the lithium disilicate glass-ceramic substructure.

sult of heat stress during ceramic firing or masticatory stress after cementation. This can ultimately lead to complete crown failure. Therefore, indiscriminate finishing must be avoided. Instead, it is recommended to refine the dentin structure with small amounts of ceramic of varying degrees of translucency and fluorescence during the buildup stage.

A wash firing (IPS e.max Ceram) was first carried out to improve the dentin shape and to aid in the application of all internal effects in the appropriate locations,

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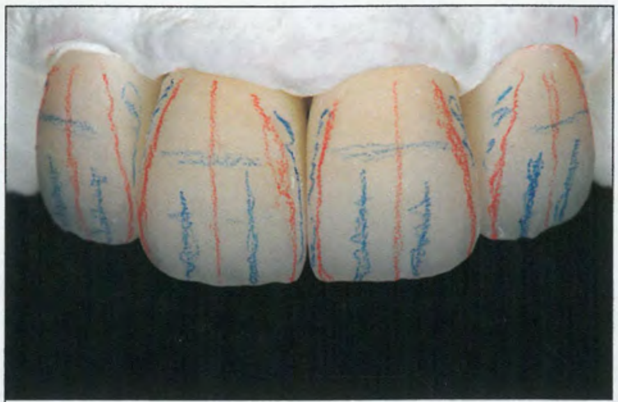
Figs 30 and 31 Wash firing for adhesion and to improve the morphology of the dentin. Enamels and other internal effects are applied later during the body firing.

Figs 32 and 33 The middle third of the tooth received opaque enamel with a high degree of diffusion (shades OE3 and OE4) to create a high-value zone. The incisal zone received translucent materials with different degrees of luminosity, applied alternately and irregularly (Ti, I, EO, and CT enamels).

assisted by silicone guides (Figs 30 and 31). Fixation of the optical effects through wash firing ensures predictable esthetic results. In addition, this technique greatly reduces sintering contraction of the enamels in the first body firing and avoids repeated heat cycles for corrections that may compromise the optical properties of the ceramic. Naturally, the application of enamel ceramic should be clearly defined and performed carefully. Enamel with different optical properties should be applied alternately and irregularly to enhance the light dynamics inside the restorations (Figs 32 and 33).

If the ceramic buildup is performed correctly, minimal retouching will be needed after firing. The labial profiles were defined and subdivided into three distinct planes, and the mesiodistal transition lines were established. The farther the line angles are located from the dental axis, the broader and shorter the resulting teeth will be (Fig 34).

Particular attention must be paid to the interproximal contacts, which should be checked on a solid cast. The most apical portion of the contact areas should be located approximately 5 mm from the tip of the crest



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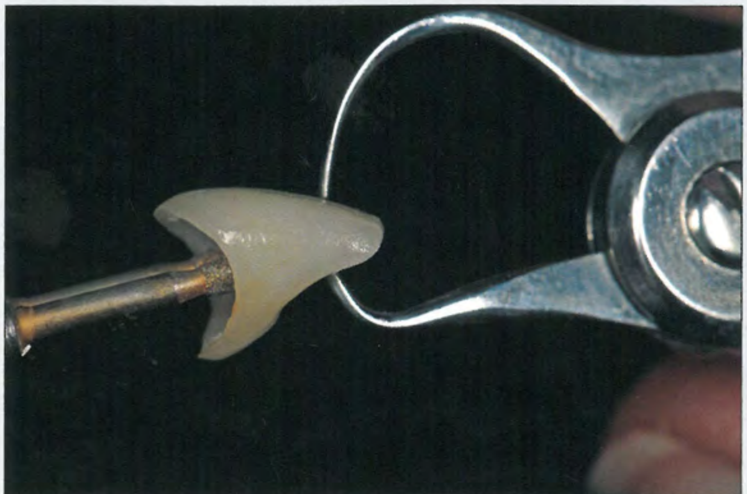

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Figs 34 Defining the contour and texture of the restorations, responsible for optical tooth dimension.

Figs 35 to 37 After pre-polishing firing, additive corrections were made as needed, and the thickness of the incisal third was checked.

of the intraradicular bone. During the biscuit bake try-in, the clinician should take all measurements required and mark the correct levels on the proximal aspects of the crowns. This is the only way to ensure that every interdental space has been closed with properly supported gingival papillae.[10]

After establishing the proper tooth shapes and appropriate macro- and microfinishing, the restorations received a pre-polishing firing (Fig 35). This is also the stage in which to make any additive corrections needed. To achieve natural translucency and an anatomical shape, the thickness of the incisal edge should not exceed approximately 3.0 to 3.5 mm at the incisal third (Figs 36 and 37).

When seating the restorations on the master cast, the emergence profiles can be assessed in relation to the gingival margins, bearing in mind any retraction caused by the cord when lifting off the impression

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Figs 38 to 41 Restorations seated on the master cast.

(Figs 38 and 39). In this case, the cast showed small triangular interdental spaces, which were perfectly filled by the papillae after the restorations were cemented and the gingival tissues had matured.

Achieving the correct surface texture and light dynamics is crucial for a successful esthetic result, especially in cases where the restorations are adjacent to natural teeth. Any variations in light reflection will be immediately obvious even to an untrained eye.[11–14] The labial aspect exhibits the mesiodistal transition lines marking the border between light reflection and light deflection (Fig 40). This interplay of light and shade creates dynamic three-dimensional effects. The total reflection of light determines the halo effect. This total reflection is a result of the typical angle of the incisal plane to the labial surface (Fig 41).

Cementation

Precise crown margins ensure a good seal and minimize the thickness of the resin cement layer. At the crown cementation appointment, the gingival tissues should have a satisfactory appearance (Figs 42 and 43). After carefully cleaning the preparations, the crowns were cemented (Fig 44). Gingival fluids were isolated with retraction cord. Once any excess cement was removed, the veneers were also cemented (Figs 45 to 48). Rubber dam was applied for all subsequent procedures to prevent contamination of the preparation surfaces and ensure perfect adhesion.

Figs 42 and 43 Preparations ready for crown cementation.

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Figs 44 to 48 The crowns were cemented first, followed by the veneers, using an adhesive technique.

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Figs 49 to 51 A few weeks after crown cementation, the restorations are well integrated with the gingival tissues.

Final Result

A few weeks after cementation, the excellent condition of the gingival tissues indicated successful biologic integration (Figs 49 to 51). Correct emergence profiles and good support for the gingival margins ensured rapid soft tissue healing and maturation, tested by applying retraction cords and retraction clamps (no. 212) to attach rubber dam during cementation of the lithium disilicate crowns and veneers, respectively. The pink esthetics plays an important role in the overall esthetic appearance. Even a highly esthetic restoration cannot compensate for defects in the gingival tissues, just as perfect, healthy gingiva cannot distract from unsightly restorations. Both dental and gingival esthetics must be in harmony.[15]

Figures 52 and 53 show the final treatment result. The dominance of the central incisors distracts the eye from any imperfections of the posterior teeth that were visible before treatment. The incisal edge was placed in perfect harmony with the curve of the smile. The patient's face has become more luminous, and the mouth has become more dominant, producing a rejuvenating effect.[7,16]

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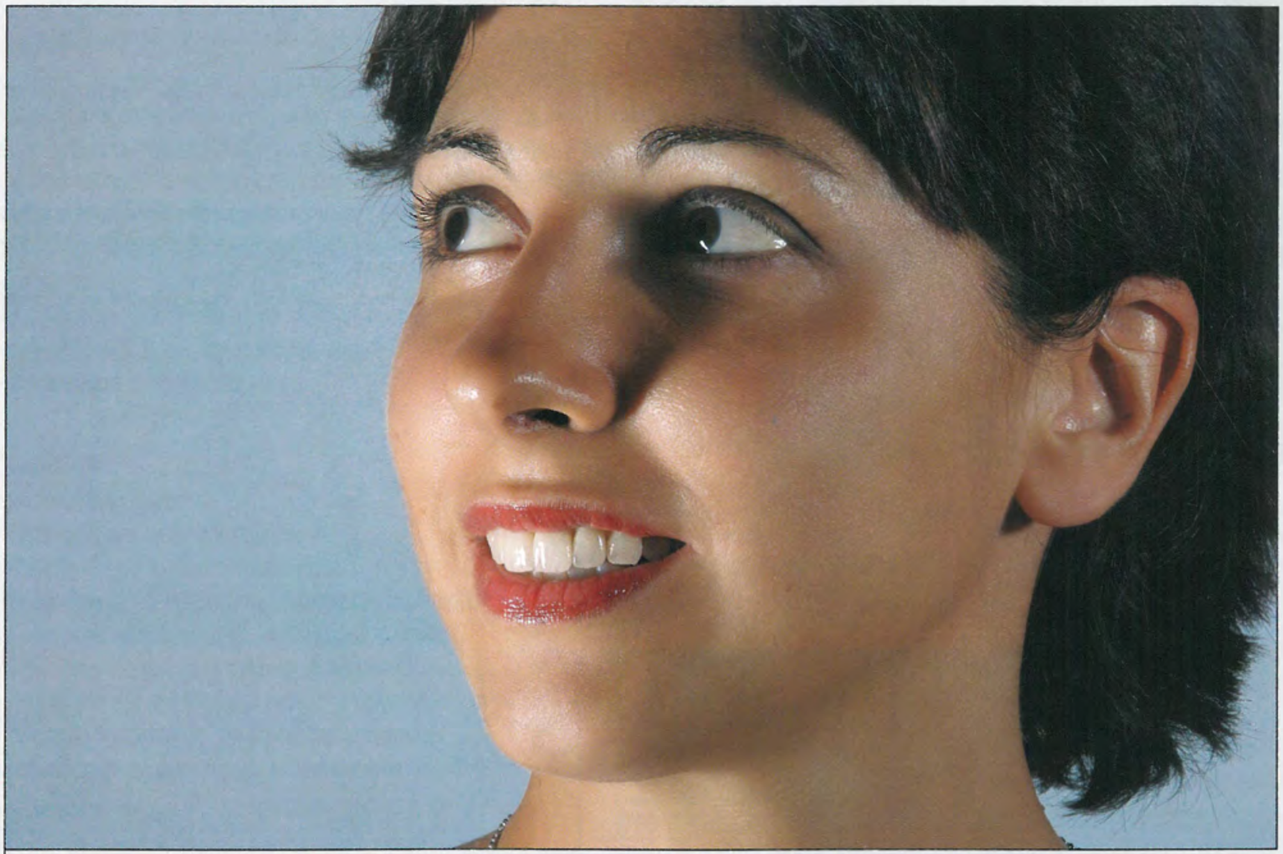

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Figs 52 and 53 Final result. The incisal edge of the restorations is now in harmony with the smile.

An entity becomes an entity with individuality when it stands out because of its own proper characteristics. Diversity is a precondition of individuality.

CONCLUSION

Correcting the shape of only the four maxillary incisors completely changed the overall appearance of the patient's face. Esthetic success can be achieved by considering both objective and subjective perceptions of esthetics. Treatment should be customized to the individual patient's personality and desires to achieve the best restorative results.

ACKNOWLEDGMENTS

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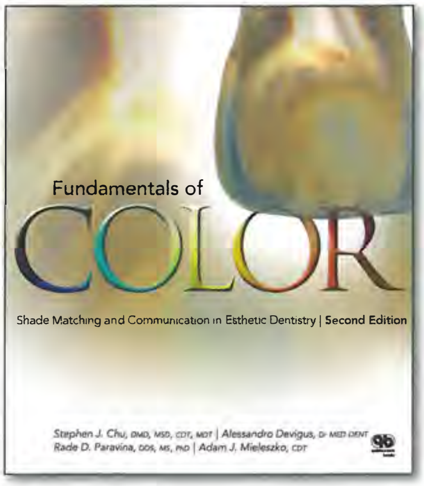
Tools for Treating the Esthetic Zone



Fundamentals of Color: *Shade Matching and Communication in Esthetic Dentistry, Second Edition*

Stephen J. Chu, Alessandro Devigus, Rade D. Paravina, and Adam S. Mieleszko

When dental practitioners lack training in the art and science of color, the deficiency often becomes glaringly evident in the quality of their restorative work. This book was written to simplify the study of color and help dentists communicate shade easily and accurately. It begins by presenting the basics of color theory within the context of esthetic dentistry and the factors that affect the transmission and perception of color. This is followed by how-to chapters on conventional and technology-based shade matching, which highlight the advantages and drawbacks of each approach and provide step-by-step shade-matching methods and protocols. This updated and expanded second edition also includes chapters on the use of digital photography for shade verification and the influence of material selection on color matching. In the final two chapters, the authors present their own recommended shade-matching protocol (which combines conventional and computer-based techniques) and an expanded series of cases demonstrating its application in various clinical scenarios. Highly recommended for students, general practitioners, and specialists.

Contents

Why Study Color • Color Theory • Elements Affecting Color • Conventional Shade Matching • Technology-Based Shade Matching • Digital Photography • Material Selection • Recommended Shade-Matching Protocol • Clinical Cases

168 pp; 366 illus (mostly color); ISBN 978-0-86715-497-9 (B4979); **US $68**

World of Anterior Ceramic Restorations

Yeojoon Koh

This beautifully designed and visually stunning clinical atlas offers myriad clinical situations in which anterior ceramic restorations can be used to correct esthetic problems. Each section presents one case that focuses on a distinct set of esthetic and dental conditions that necessitate restoration, such as fracture, crowding, rotation, asymmetry, discoloration, contour, caries, or implant considerations, among others. The case presentation begins by showing the definitive esthetic result alongside a succinct, multilingual (English, German, Japanese, and Korean) description of the initial conditions and the procedure used. Then follow the clinical images illustrating the procedure, step-by-step. With its inviting presentation and its emphasized visual component, this book is intended as a communication tool between the dentist, the ceramist, and the patient: It functions as a guide to various approaches for the dentist, a tool for understanding tooth shape and conditions for the ceramist, and a preview of the esthetic result for the patient. Because communication and cooperation between these three parties are essential for a successful esthetic outcome, this book is an indispensable resource for any esthetic dentist.

Contents

Light and Color/Form • Normally Aligned Tooth • Rotated or Malpositioned Tooth • Discolored Tooth • Severely Destructed Tooth • Periodontally Compromised Tooth • Porcelain Laminate Veneer • Bridge • Implant

216 pp; 614 color illus; ISBN 978-89-5741-207-7 (BC997); **US $120**

Chipping Occurrence in Zirconia-Based Prostheses

Francis Cunha Lima, DDS[1]
Luiz Narciso Baratieri, DDS, MS, PhD[2]
Renan Belli, DDS, MS, PhD[3]

Catastrophic fracture is the characteristic failure mode for porcelain- and glass ceramic–based prostheses.[1] In fact, high-strength core ceramics that contain glass, such as lithium disilicate glass-infiltrated alumina (In-Ceram Alumina, VITA Zahnfabrik, Bad Säckingen, Germany) and glass-infiltrated alumina/zirconia (In-Ceram Zirconia, VITA Zahnfabrik), also tend to fail by fracture. Although the high crystalline phase in high-strength ceramic acts via toughening mechanisms that decrease crack energy and increase durability, the glass phase surrounding crystals and grains is still the weak link through which the crack propagates.[2] An example of this phenomenon is evident in the small gain in strength observed for In-Ceram Zirconia in comparison to In-Ceram Alumina, even though the former comprises approximately 33% zirconia.

Glass-free ceramics for infrastructures such as densely sintered alumina (Procera, Nobel Biocare, Göteborg, Sweden, or In-Ceram AL, VITA Zahnfabrik) and yttrium- or ceria-stabilized tetragonal zirconia polycrystals, on the other hand, tend to deflect the propagating crack, resulting in veneer crack alone. This fracture mode resembles that of metal-ceramic prostheses. Therefore, chipping occurrence in reinforced ceramic prostheses should not be regarded as an unexpected phenomenon. Nonetheless, the high chipping incidence reported for zirconia-based prostheses has placed clinicians, technicians, and researchers on full alert. In a clinical trial of 33 three- to five-unit fixed partial dentures (FPDs), a 15% incidence of veneer fracture was reported after 5 years.[3] Another study reported a chipping incidence of 25% for three-unit FPDs after 2 to 5 years.[4] In a study of 19 three-unit FPDs, 36% developed veneer fracture after 5 years.[5] Vult Von Steyern et al evaluated the clinical performance of 23 three- to five-unit FPDs and found that 15% presented veneer chipping after only 2 years.[6]

[1]Private Practice, Goiânia, Brazil.

[2]Professor, Department of Operative Dentistry, School of Dentistry, Federal University of Santa Catarina, Florianópolis, Brazil.

[3]PhD Candidate, Department of Operative Dentistry, School of Dentistry, Federal University of Santa Catarina, Florianópolis, Brazil.

Correspondence to: Dr Renan Belli, Universidade Federal de Santa Catarina, Campus Universitário, Centro de Ciências da Saúde, Departamento de Odontologia, Disciplina de Dentística, Florianópolis, Santa Catarina, Brazil 88040-900.
Email: renanbelli@yahoo.com.br

For implant-supported prostheses, the lack of compliance provided by the periodontal ligament during occlusion seems to escalate stresses at the contact point and accelerate crack development in the veneer porcelain. In a clinical trial by Larsson et al, 54% of 13 two- to five-unit zirconia-veneered FPDs placed onto titanium implant abutments showed veneer fracture after 1 year in service.[7] A direct comparison between three- to five-unit FPDs with either zirconia or metal-alloy frameworks revealed that the incidence of minor chipping was equivalent for both materials, whereas chipping that required replacement of the prosthesis occurred only for zirconia-based FPDs (8.4%) after 3 years.[8] After systematically evaluating clinical studies that compared zirconia and metal as infrastructure materials for FPDs, Heintze and Rousson found chipping rates of 54% for the former and 34% for the latter after 3 years.[9]

This article briefly discusses the thermodynamics of the sintering process and focuses on the factors that influence the chipping phenomenon in zirconia-based prostheses. Additionally, the authors present a case report involving full-mouth prosthetic rehabilitation employing the measures discussed to prevent premature failure and increase clinical longevity.

THE SINTERING PROCESS

In any bilayer system (metal-ceramic or ceramic-ceramic), the mechanical properties (eg, elastic modulus) and thermal properties (eg, thermal conductivity, heat capacity, thermal diffusivity, coefficient of thermal expansion [CTE]) of the components affect the stress state of the other during cooling from the final sintering temperature. At the heating stage, the veneering porcelain powder covering the framework turns from a solid state to a viscoelastic state at the glass transition temperature (T_g) (around 550°C to 600°C for most veneering porcelains). The temperature is further increased so that the veneer particles fuse homogeneously, but never to the melting point (after which the material would become a liquid). Between T_g and the final sintering temperature, the veneer assumes a viscoelastic behavior, in which all deformation is relaxed through molecular rearrangement. Therefore, the contraction deformation from the final sintering temperature down to T_g is not converted into stress. However, as the temperature further decreases, the veneer solidifies, and all contraction down to the ambient temperature cannot be dissipated through viscous flow. This becomes a problem when there is a mismatch between the CTEs of the infrastructure and the veneering porcelain. If one of the components contracts more during cooling than the other, stress is built up at the interface and spontaneous cracking may occur.[10] Moderate mismatches usually do not result in immediate veneer fracture but may generate stresses below the tensile strength of the porcelain. Under occlusal loading, tensile stresses locked in the interior of the porcelain affect crack propagation resistance and decrease the life span of the prosthesis. To prevent highly unstable tensile stresses from developing within the veneer, a positive mismatch ($\alpha_{core} - \alpha_{veneer} = +\Delta\alpha$ ppm/°C) is preferred over a negative mismatch.[11] Since the CTE of the infrastructure material does not vary greatly from one manufacturer to another, the choice of veneer will determine the thermal compatibility of the system. As opposed to in the core materials, CTE differences between veneering porcelains may surpass 1 ppm/°C. Table 1 shows the CTEs for some commercially available veneering porcelains. Unfortunately, many technicians choose their working veneer porcelain based only on personal preferences, handling, and esthetic properties. To improve mechanical longevity, the CTE, which can be found in the manufacturer's instructions, should be given increased importance in the adopted criteria for material selection.

In an attempt to revert the stress state from tensile to compressive at the surface of the porcelain, many laboratories employ strengthening techniques used in the glass industry for tempering dental prostheses. Basically, instead of turning off the oven after glaze firing and leaving the working piece to cool down slowly, technicians remove the prostheses immediately after firing to cool them benchside. Forced air stream has also been used to cool down the veneer after removal from the oven. This quickly cools downs the porcelain surface, generating high compressive stresses on the outer 15% of the veneer. The interior of the veneer layer, however, instantly develops tensile stresses due to the increased density on the surface layer under compression.[12] Clinically, surface wear and occlusal adjustments performed by the clinician remove the strengthening compressive layer and expose the tensile zone

Table 1 Coefficients of Thermal Expansion (CTEs) of Commercially Available Veneering Porcelains

Brand	Manufacturer	CTE (ppm/°C)*
Noritake CZR	Noritake (Aichi, Japan)	10.1
Lava Ceram	3M ESPE (St Paul, Minnesota, USA)	9.9
IPS E.max ZirPress	Ivoclar Vivadent (Schaan, Liechtenstein)	9.75
Nobel Rondo	Nobel Biocare (Göteborg, Sweden)	9.7
IPS E.max Ceram	Ivoclar Vivadent	9.5
Wieland XRZ	Wieland Dental+Technik (Pforzheim, Germany)	9.3
Vita PM9	VITA Zahnfabrik (Bad Säckingen, Germany)	9.2
Vita VM9	VITA Zahnfabrik	9.1

*CTE of zirconia = 10.5 ppm/°C.

underneath. Contact-induced cracks initiate and propagate much faster in a substrate under tension, greatly compromising the life span of the prostheses.

Zirconia Sintering

Zirconia is not necessarily a special case in terms of the factors that influence the chipping phenomenon. The same primary factors responsible for residual stress build-up within the veneer in other bilayer systems (ie, thermal mismatch and cooling rate) also apply to the thermal behavior and mechanical response of zirconia-based prostheses. The reason for the higher chipping incidence of zirconia-based prostheses is related to the increased sensitivity of the zirconia bilayer to these factors.

Because zirconia has a low thermal conductivity (2 $Wm^{-1}K^{-1}$) compared to other infrastructure materials (base metals and In-Ceram Alumina, for example, have a thermal conductivity of 40 and 14 $Wm^{-1}K^{-1}$, respectively) and a high density (6.1 g cm^{-3}), the quantity of heat that dissipates from the zirconia core into the adjacent porcelain and out to the external environment per unit time is also reduced in comparison to other materials.[13] In other words, the zirconia core remains hot for a longer period of time,[14] and thus the adjacent porcelain cools down at a slower rate than it would if adjacent to more thermal conductive materials. Therefore, upon cooling from the sintering temperature down through T_g, a high temperature gradient is created across the thickness of the veneer and tensile stresses develop close to the core. These stresses are proportional to the temperature difference between surface and inner porcelain, which in turn is somewhat proportional to the cooling rate.[15] When using fast-cooling protocols, stresses add up for high-mismatch zirconia-veneer systems,[16] and the longevity of the prosthesis decreases substantially.[17] For areas with a high core-veneer thickness ratio, these effects escalate and increase the residual stresses inside the veneer porcelain. Interestingly, anatomically designed frameworks (with a thicker zirconia core at regions of unsupported porcelain) do not seem to ameliorate the situation even though the thicker core stores heat for longer periods.[14]

Thus, by making adjustments in the fabrication process and controlling the factors discussed in this article (ie, choosing a veneer with a CTE close to the zirconia's and employing a slow-cooling protocol at the last firing), the technician can significantly enhance the durability of zirconia-based prostheses. Waiting for nearly 1 hour for every glazed prosthesis to slowly cool inside the oven may be too unproductive for the workflow of some laboratories. The wait time for slow-cooling protocols can be reduced by opening the oven after the temperature has dropped below T_g. However, since the inner veneer remains in the viscoelastic state while the surface veneer has already solidified, it is best to wait until the temperature drops approximately 100°C below T_g (the manufacturer should provide the glass transition temperature in the product information sheet).

CASE REPORT


1a

1b

1c


2a

2b

2c


2d

2e

2f


3

4

Figs 1a to 1c Initial extraoral views.

Figs 2a to 2f Initial intraoral views.

Fig 3 The maxillary anterior teeth showed the presence of multiple restorations with poor esthetics.

Fig 4 The mandibular anterior teeth presented severe wear and non-carious cervical lesions.

CASE REPORT

Figures 1 to 21 present a case involving the full-mouth rehabilitation of a patient with existing unesthetic restorations, severe wear, and noncarious cervical lesions. All-ceramic restorations were fabricated using a slow-cooling protocol after firing to minimize stress development and reduce the potential for fracture. At the 2-year follow-up appointment after cementation, clinical inspection for chipping found no structural damage to the veneer other than wear facets.


5a


5b


5c


6


7a


7b

Figs 5a to 5c Preparations were made on the cast for the fabrication of provisional restorations.

Fig 6 Extraoral view of the cemented provisional restorations. Note the recovery of interocclusal space.

Figs 7a and 7b Preparations ready for impression procedures.

Fig 8 A double-cord technique was used for impression taking with a vinyl polysiloxane material.

Figs 9a to 9c Full-mouth and partial impressions were taken for the fabrication of zirconia copings.


8


9a


9b


9c

10

Fig 10 Single zirconia copings with a thickness of 0.5 mm were fabricated.

Figs 11a to 11c Framework try-in.

11a

11b

11c

12

Fig 12 Interocclusal records for accurate transfer of the vertical dimension of occlusion and cross-mounting of the casts.

Figs 13a to 13c Full-arch pickup impressions.

Figs 14a and 14b Zirconia frameworks on the master casts.

13a

13b

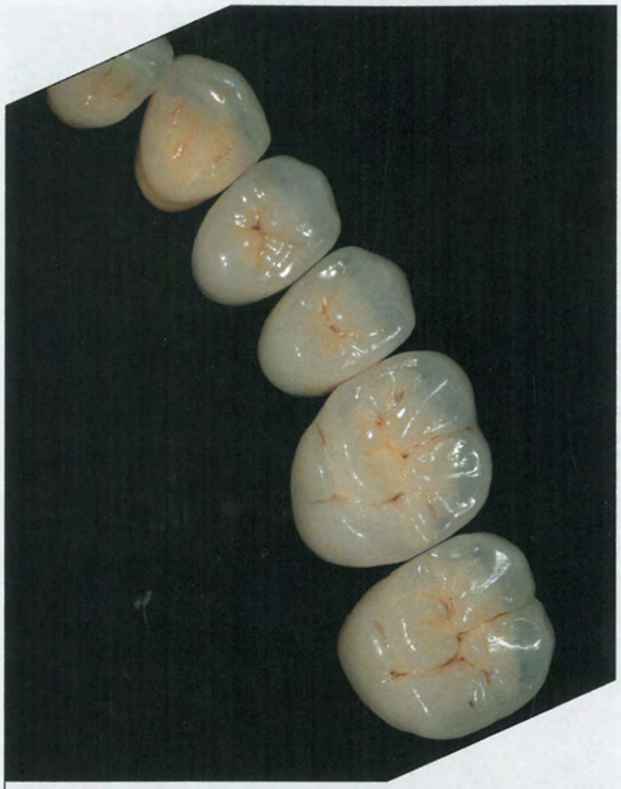
13c

14a

14b


15a

Figs 15a to 15f Definitive all-ceramic crowns. During the final firing, the crowns were left inside the oven to cool slowly to minimize stress development within the veneer.

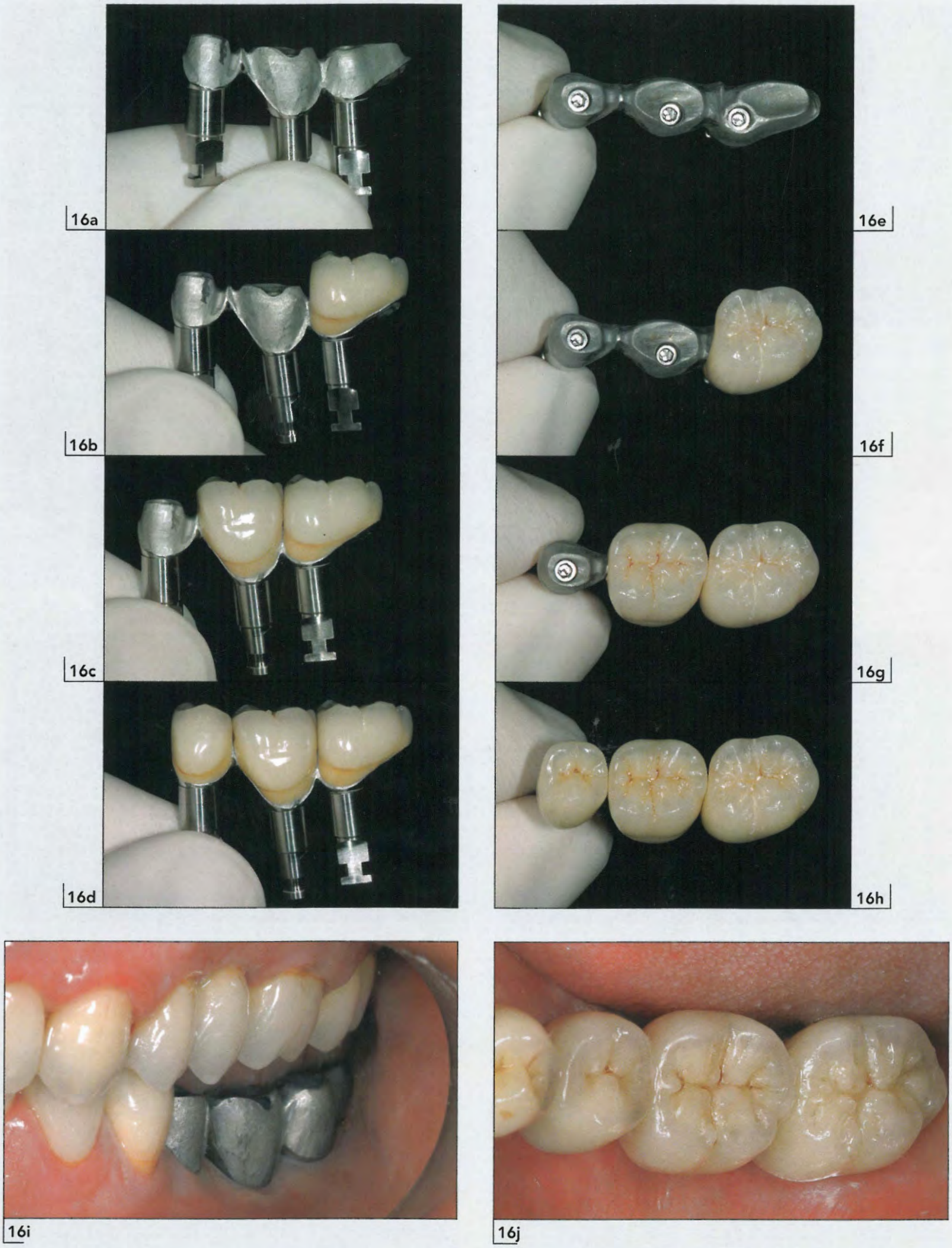

15b


15c


15d

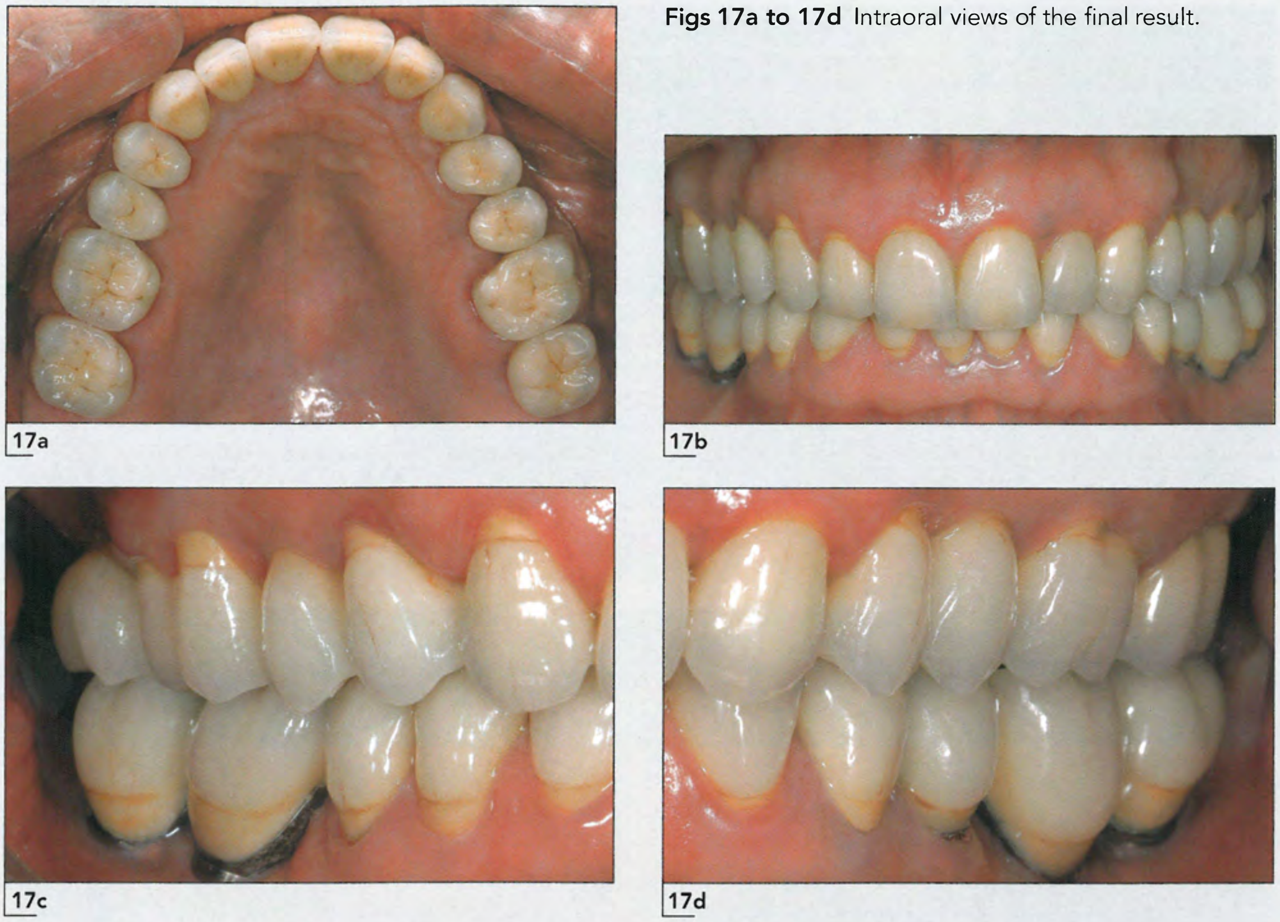

15e


15f

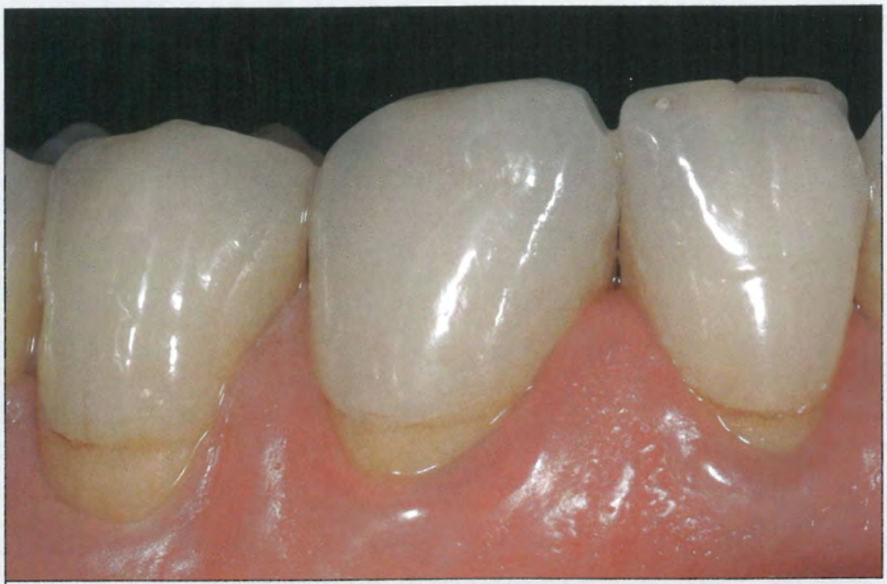


Figs 16a to 16j Implant-supported zirconia crowns were separately cemented over a metal infrastructure.

Figs 17a to 17d Intraoral views of the final result.



Figs 18a to 18e Definitive maxillary anterior crowns.



19a

19b

19c

Figs 19a to 19c Definitive mandibular anterior crowns.

20a

20b

20c

20d

21

Figs 20a to 20d Definitive posterior crowns.

Fig 21 Extraoral views of the final result.

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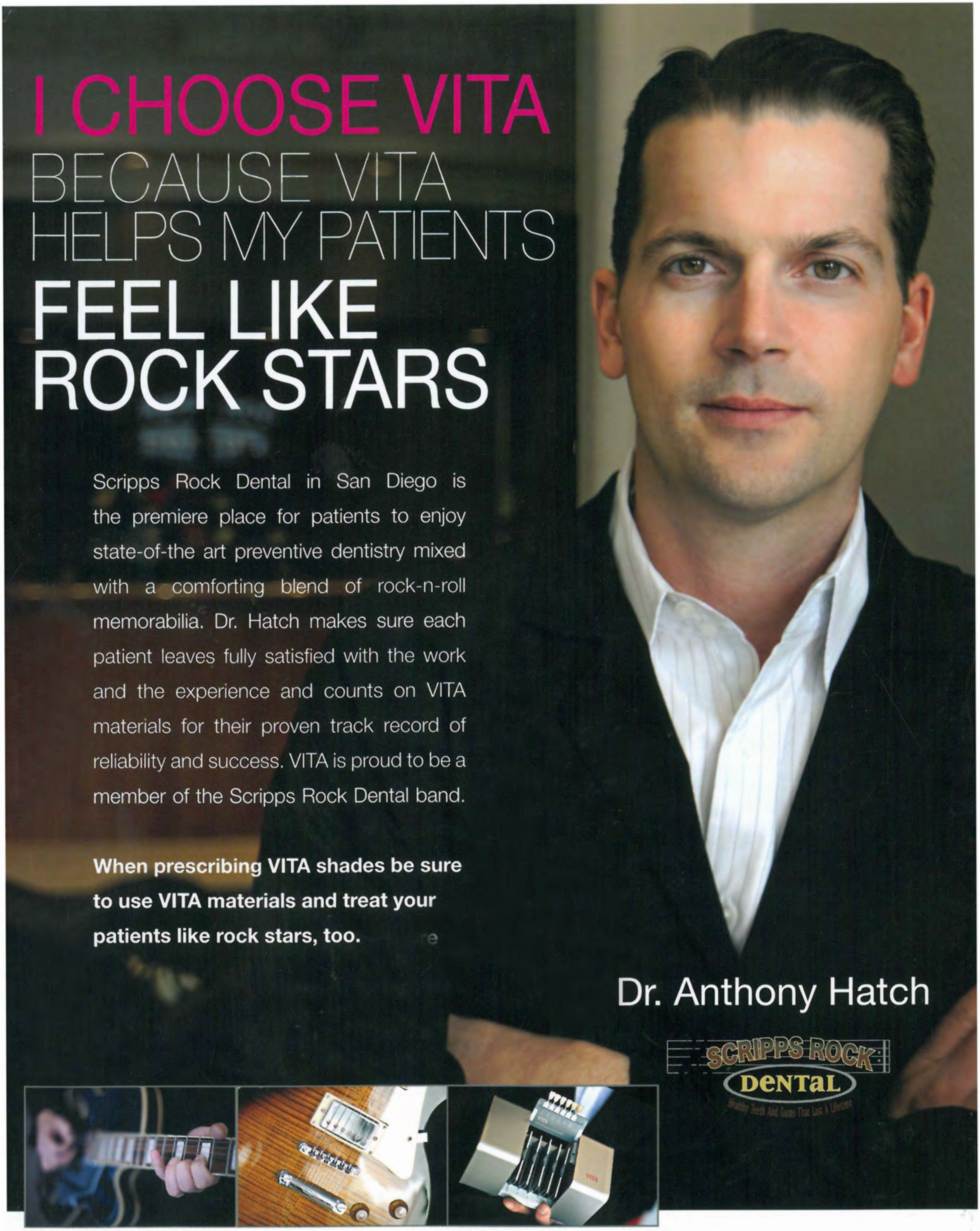
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