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Implant placement in the esthetic area: criteria for positioning single and multiple implants

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Implant-based rehabilitation is a clinical challenge, especially in the esthetic area, which is defined as between the first or second contralateral premolars. Numerous factors influence the outcome of the rehabilitation; however, the two main factors are the bone and soft-tissue deficiencies at the intended implant site (66). Planning for these deficiencies is helped by the use of computerized guided surgery (which allows insertion of the implant to be planned in detail) and stereolithographic and three-dimensional printed surgical guides (to aid implant insertion in the most appropriate prosthetic position).

These techniques make implant rehabilitation a more predictable treatment modality and implant survival rates have improved over recent years, as reported in several publications and systematic reviews (55). Nevertheless, expectations from the treatment have changed and esthetics plays an important role in defining the success of rehabilitation. Various surgical approaches are described in terms of timing of implant placement (32) and management of regenerative procedures (73). More than the osseointegration of the fixture, patients expect optimal esthetic results (30) from their rehabilitation, with a concomitant shortening of the treatment time, if possible. These are the main reasons why implantologists have shifted the focus of their study to esthetics, measured using new indices (5, 31, 70) that evaluate the aspects of the prosthesis and soft tissues. Another way of assessing implant 'success' is by using patient-reported outcome measures, introduced at the Eighth European Workshop on Periodontology. Patient-reported outcome measures define the perception of the oral health of the patients and their quality of life, their satisfaction and nonclinical parameters (25, 45). The esthetic area is highly involved in these perspectives and is very challenging for the clinicians. The aim of this article is to discuss the different implant placement alternatives in the esthetic area, in particular:

- the timing of implant placement/regenerative procedures/skeletal growth/altered passive eruption.
- the correct three-dimensional position of the fixture between the cuspids and in the premolar area.
- cases of multiple missing teeth in the esthetic area with single tooth/pontic or cantilevered options/prosthetic compensation.
- implant placement into infected sites.
- the influence of the morphology of the abutments and the crowns on implant position.

Timing of implant placement/regenerative procedures/skeletal growth/altered passive eruption

The frequently cited consensus statements (32) regarding timing of implant placement defines four categories: immediate implant placement (type 1); early placement with soft-tissue healing (type 2); early placement with partial bone healing (type 3); and late placement (type 4). A recent systematic review (14) investigated the outcome of immediate and early placement of implants in the esthetic area: despite the great heterogeneity of the studies included, immediate implant placement provides good soft-tissue esthetic outcomes. The main concern following immediate implant placement is the greater extent of recession of the mid-facial mucosa, compared with early implant placement. Immediate loading in postextraction sockets also leads to promising results (26). Regenerative procedures play an important role in immediate placement, and soft-tissue stability depends strongly on bone volume support and blood supply. Tarnow et al. (68) evaluated changes occurring on the facial and palatal ridges during flapless immediate implant placement and showed that less bone resorption occurred when a bone graft was placed together with a provisional restoration. According to the authors, the bone graft could be placed in the gap between the implant and the alveolus wall and also coronal to the implant–abutment interface in order to provide support and volume to the soft tissues (17). The bone graft particles are incorporated within the soft tissues without any inflammatory response (1). Others have reported similar results in soft tissues (16), and the facial soft-tissue thickness is reported to be greater in grafted sites compared with nongrafted sites and when a provisional restoration is provided. The thickness of soft tissues is important for helping to maintain their stability at the crown margin and to mask the greyish appearance caused by the titanium abutment and the implant collar itself. An established threshold of 2 mm is defined to avoid this complication (37). These esthetic-outcome findings are confirmed by Rieder et al. (57) in randomized clinical trials. The Pink Esthetic Scores of postextraction, immediately loaded implants were superior to those of immediate implant placement and delayed provisional restorations, early implant placement with immediate loading or early implant placement with early loading, and significantly superior when compared with the group with early implant placement and immediate loading. The results of immediate placement and immediate loading seem promising and show how reliable this approach can be. Nevertheless, it is necessary to point out that this approach is technique sensitive and that the skill and experience of the surgeon play a fundamental role in the outcome of the therapy. In immediate implant placement, the biotype used to be considered as an important factor, with several studies in the past only including patients with a thick biotype. However, Khzam et al. (42), in a recent systematic review, failed to find a clear correlation between esthetic results and a thick biotype. In immediate implant placement, soft-tissue augmentation seems to be less important than bone augmentation: a recent systematic review failed to find consistency regarding this topic, although a significant increase in keratinized gingiva was found (47). This is important as keratinized gingiva is thought to contribute toward maintaining health of peri-implant tissues (49, 61).

Resorption of buccal bone follows tooth extraction and early implant insertion (2), necessitating bone augmentation using autologous or heterologous bone covered by a membrane and primary tension-free wound closure. Bone augmentation is necessary in early implant placement cases to re-establish a correct bone volume to support soft tissues (8) with a physiological biological width (21, 40). With a follow-up of 5–9 years, Buser et al. (7) obtained excellent results in terms of esthetic parameters (Pink Esthetic Score and White Esthetic Score) and clinical and radiological findings. The latter were obtained using cone-beam computed tomography postoperatively, permitting assessment of dimensional changes caused by bone resorption (7).

In the last few years, quality of life and patient satisfaction evaluations have been reported in implant literature. Usually, a questionnaire or visual analog scale is used, with no standardized approach to reporting patient-reported outcome measures (25). In clinical studies that evaluated quality of life, immediate implant placement emerged as the preferred alternative because of shortened treatment time, immediate esthetic improvement, reduction of morbidity and fewer surgical interventions (36). This short-term, high satisfaction appears to be maintained in studies with a longer follow-up (44). Nevertheless, only a handful of studies address this issue and conclusive outcomes are still missing (42).

The relationship between time and implant placement is not only related to the time of tooth extraction but also to the age of the patient. In young patients with teeth missing as a result of agenesis or trauma, implant rehabilitation should be postponed until after jaw growth has ceased. Implants do not follow the eruption of natural dentition during growth, with intimate contact with bone; therefore, implant placement in a growing jaw could result in a discrepancy in the occlusal and gingival planes and an unesthetic result (52). Early implant placement presents a further risk in young patients as it could alter the development of a normal jaw. The population can be divided into normal, long or short facial types, and the skeletal growth in each of these categories is different. According to Heji et al. (33), implants inserted during growth in patients with a short facial type will tend to shift palatally compared with the natural dentition. In patients with a long facial type, there is increased vertical movement of the dentition, resulting in disharmony of oral implants. Factors to consider when evaluating growth cessation in younger patients are summarized as follows (33):

- check the tracing of cephalometric radiographs taken at least 6 months apart.
- no growth changes for 1 year.
- body growth, in length, annually for 2 years: annual growth should be <0.5 mm per year.
- control change of dental position (e.g. of the second molar).

Schwartz-Arad & Bichacho (62) compared the submersion rate (formerly 'percent of crown occlusal-gingival length per year') of implants in the maxillary incisor region and natural dentition in two groups: 30 years of age and older; and younger than 30 years of age. The younger group showed a submersion rate three times greater than observed in the older group. Submersion is therefore more important in patients between the ages of 20 and 40 than in those over 40 years of age and its mean rate varies with age. Furthermore, in a large clinical study, Fudalej et al. (54) state that the growth of the skeletal base continues after puberty but the amount of growth decreases steadily after the second decade of life. They also reported a difference in the amount of growth between the sexes, with the rate of eruption in maxillary central incisors being greater in female patients than in male patients. Another developmental condition to consider when planning implants is altered passive eruption, defined as incomplete passive eruption of teeth in patients with completed facial and skeletal growth (77). Altered passive eruption can result in esthetic deficiencies, plaque retention and gingival inflammation (77). When a patient with altered passive eruption needs implant rehabilitation in the esthetic area, it is advisable to plan the periodontal plastic surgery in order to establish correct tooth/soft-tissue parameters before implant placement, to obtain a good esthetic outcome. In cases of dental agenesis, bone recontouring is often needed in order to establish the correct apicocoronal position of the implant (Fig. 1). The following key concepts in implant placement/regenerative procedures/skeletal growth/altered passive eruption should be noted:

- immediate implant placement has a good success rate in terms of esthetics.
- in immediate implant placement, less bone resorption occurs when a bone graft is placed together with a provisional restoration.
- immediate implant placement and immediate loading are technique-sensitive procedures.
- in early implant placement bone augmentation is necessary in order to support the soft tissues.
- quality-of-life evaluations reveal that the preferred alternative for patients is immediate implant placement.
- cessation of skeletal growth should always be assessed before implant placement.
- periodontal plastic surgery should be planned before, or simultaneously with, implant placement.

The correct three-dimensional position of the fixture between the cuspids

In the esthetic area, more than elsewhere, placing the implant in the proper position is essential in order to avoid esthetic complications. The objectives are:

- to minimize the resorption of the bundle bone.
- to maintain the correct distance between adjacent teeth/implants to preserve adequate blood supply and maintain healthy, hard and soft tissues.
- To allow a correct prosthetic phase.

As mentioned before, postextraction resorption of bundle bone and consequent mucosal recession are the main concerns in the esthetic area. Therefore, thorough evaluation of the site and buccopalatal planning of the position of the fixture are vital. To determine the feasibility of immediate implant placement, evaluation of the sagittal root position is important. Four classes of sagittal root position have been described by Kan et al. (39):

- Class I: adjacent to the vestibular bone plate.
- Class II: in the middle of the alveolar crest without any contact with vestibular or palatal cortical bone.
- Class III: adjacent to the palatal bone plate.
- Class IV: two-thirds engaging the vestibular bone plate.

Class I represents the most favorable clinical situation as it has a sufficient amount of palatal bone to achieve primary stability during immediate implant placement (Fig. 2). Buser et al. (9) and a recent systematic review (48) identified a so-called 'comfort zone' where the implant should be placed 1.5–2.0 mm palatal to the incisal margin of the central maxillary incisors and should be inserted leaving at least 2 mm of buccal bone (3, 31). In postextractive cases, it is extremely important to evaluate the distance between the implant and the outer surface of the alveolar bone wall. If it is <4 mm, internal (in the alveolus) and external (outside the buccal bone) grafting is recommended to maintain the volume and contour of the ridge in order to achieve a good esthetic outcome (11). The mesiodistal implant position determines the sustaining bone and the blood supply that allows papilla preservation, a fundamental factor in defining a good esthetic outcome. The root position of adjacent teeth should be carefully

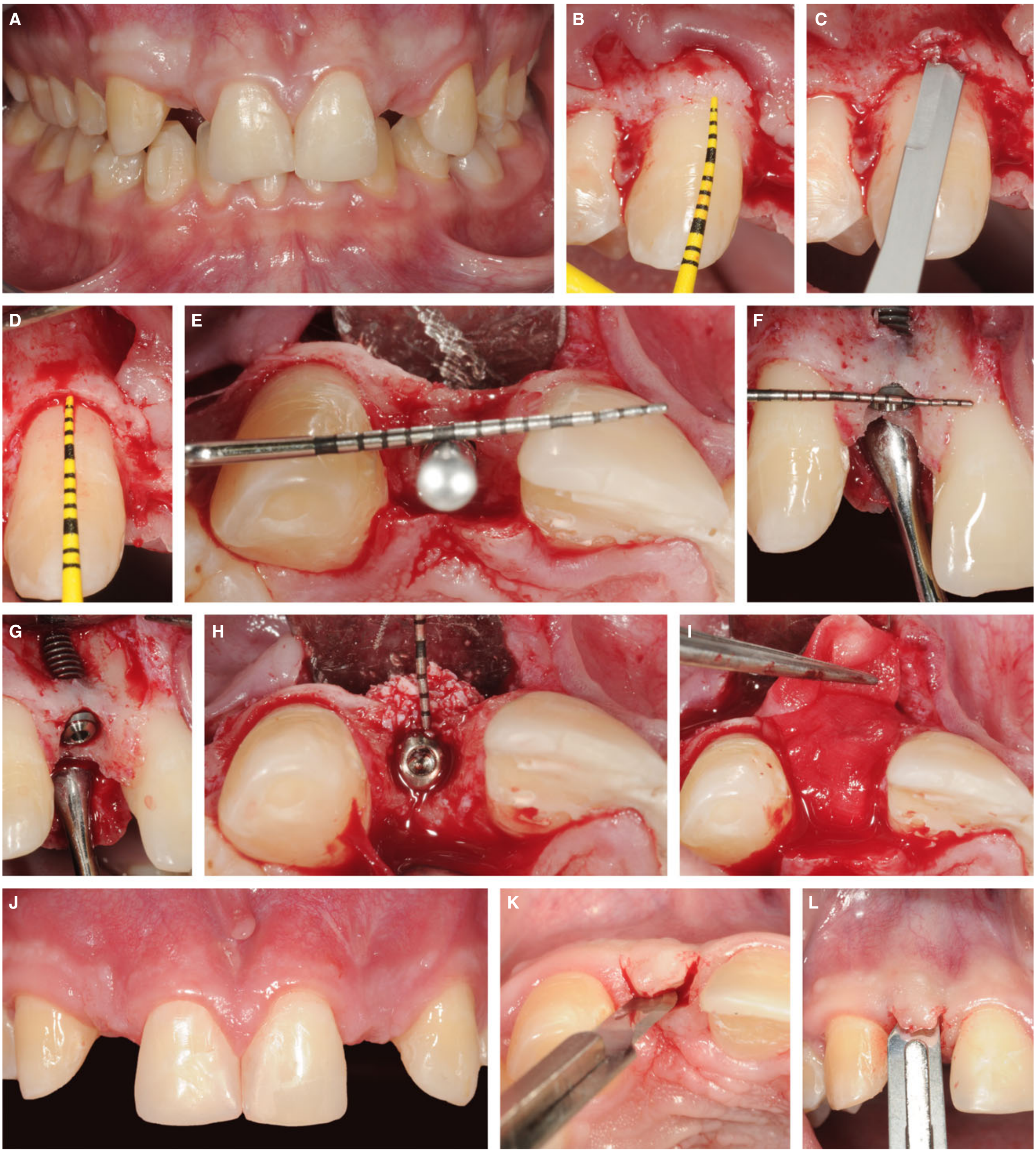

Fig. 1. Bone recontouring is required to establish the correct apicocoronal position of the implant in dental agenesis. (A) Preoperative phase. The patient presents agenesis of the lateral incisor and altered passive eruption. (B–D). During implant insertion, the first objective is to correct the altered passive eruption in order to place the implants in the correct position. (E, F). Insertion of the implant (right lateral incisor position): the site is prepared and a scalloped ostectomy is created at the vestibular plate to allow correct three-dimensional implant placement in harmony with the adjacent teeth. An unavoidable fenestration (G) was necessary to place the implant in the proper position and subsequently vestibular bone augmentation was performed with deproteinized bovine bone (H) and a collagen membrane (I). (J–P) Second-stage surgery: the incision made on the right-hand side preserved the papillae, allowing better maturation in the provisional phase compared with the left-hand side where the papillae were detached. Radiographic evaluation pre (Q–T) and post (U) implant insertion. (V, W) Final restoration. (X, Y, Z1–Z3) Eight-year follow-up.

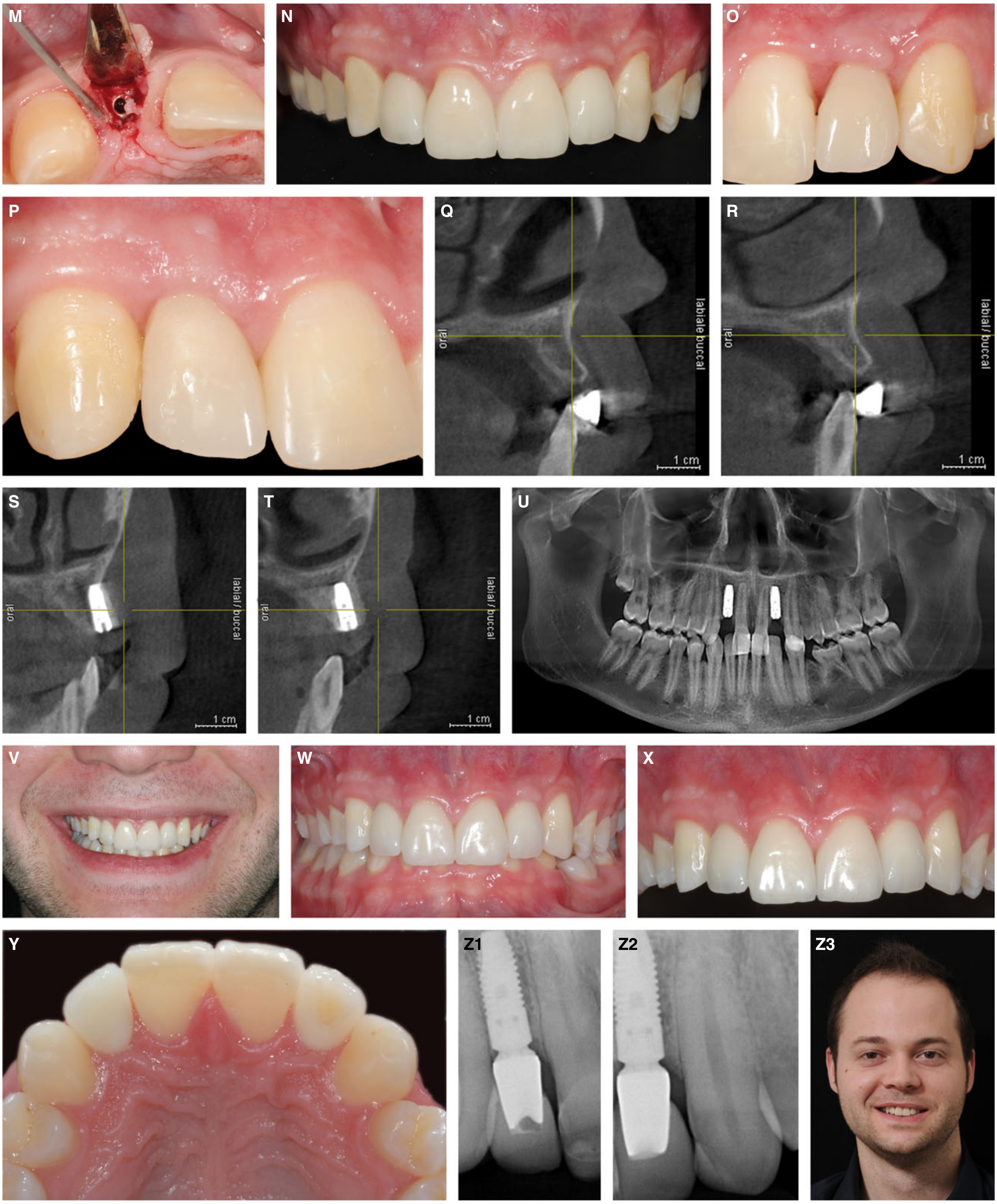

Fig. 1. Continued.

evaluated as when they are too close to the future implant site, the residual thin bone could be resorbed, resulting in reduced support for the soft tissues. Orthodontics could be very useful to re-establish a proper restorative space. Implants should be placed at least 1.5 mm away from the adjacent tooth (31), a measurement that derives from the process of horizontal remodeling of the proximal bone (67). When there are two adjacent implants, a distance of 3 mm should be left between them (31) in order to preserve bone level at the implant shoulder. Platform switching, defined as reducing the diameter of the abutment with respect to the diameter of the implant (46), could reduce peri-implant bone loss, thus preserving soft-tissue levels (34). Some authors present evidence that with platform switching, the interimplant distance could be reduced (72). This is interesting, especially when the space available for implant placement is reduced, such as for maxillary lateral incisors. In the apicocoronal dimension, a distance of 5 mm from the contact point and alveolar crest allows good soft-tissue esthetics to be maintained (15, 69). As with teeth, in implant restoration, the level of the papilla is strongly related to the bone level adjacent to the teeth/implant (15). In the apicocoronal direction, the implant should be inserted 3–4 mm apical to the gingival margin of the future restoration (12, 59). The use of a surgical stent (reproducing the dimensions of the definitive prosthetic crown) during implant placement is helpful in determining this measurement (35) (Table 1) (Fig. 3).

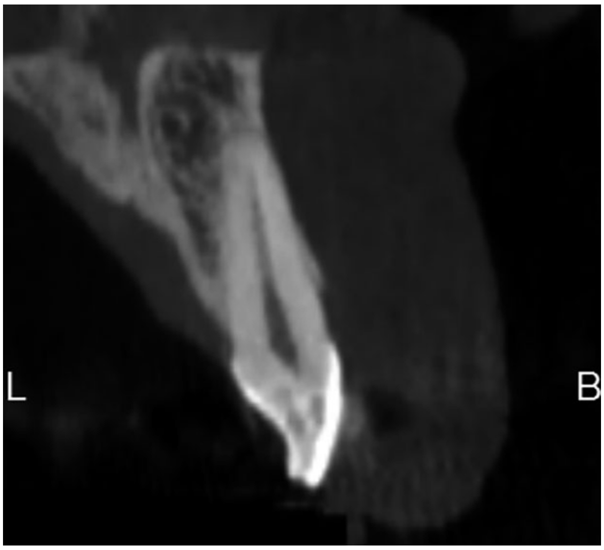

Fig. 2. Radiograph showing the most frequent class of sagittal root position classification, Class I (86.5% in the maxillary central incisors), according to Kan et al. (39). B, buccal; L, lingual.

The correct three-dimensional position of the fixture in the premolar area

When it comes to evaluating an esthetic result, the patient's perception may differ from that of the clinician. The commonly used subclassification of esthetic outcome, based on a high, medium or low lip line, may not fulfill the patient's needs, and the authors suggest considering each anterior case as an esthetically important case regardless of the lip line. In the premolar area, the implant should be buccally inclined to provide two clinical advantages: first, to

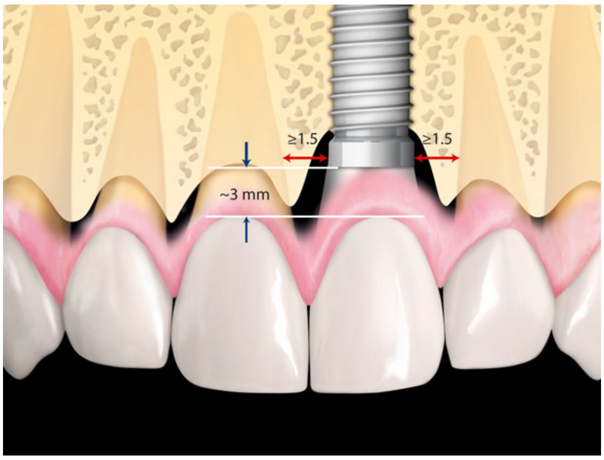

Fig. 3. Correct maxillary anterior implant position, mesiodistally and apicocoronally (courtesy of Capelli & Testori [12]).

Table 1. Literature corresponding to the correct three-dimensional positioning of an implant

Literature	Mesiodistal	Literature	Apicocoronal	Literature	Buccopalatal
Grunder et al. (2005) (31)	1.5 mm to adjacent tooth			Buser et al. (2004) (9)	1 mm palatal to the point of emergence of the adjacent teeth
Vela et al. (2012) (72)	1 mm to adjacent tooth with platform switching	Saadoun et al. (1999) (59), Grunder et al. (2005) (31), Capelli & Testori (2012) (12)	3 mm below the apical margin of the crown		
Grunder et al. (2005) (31)	3 mm to adjacent implant	Buser et al. (2004) (9)	1 mm apical to the cementoenamel junction of the adjacent tooth	Scutella et al. (2015) (63)	Long axis of the implant should correspond to the incisal edge of the future restoration or to the adjacent teeth

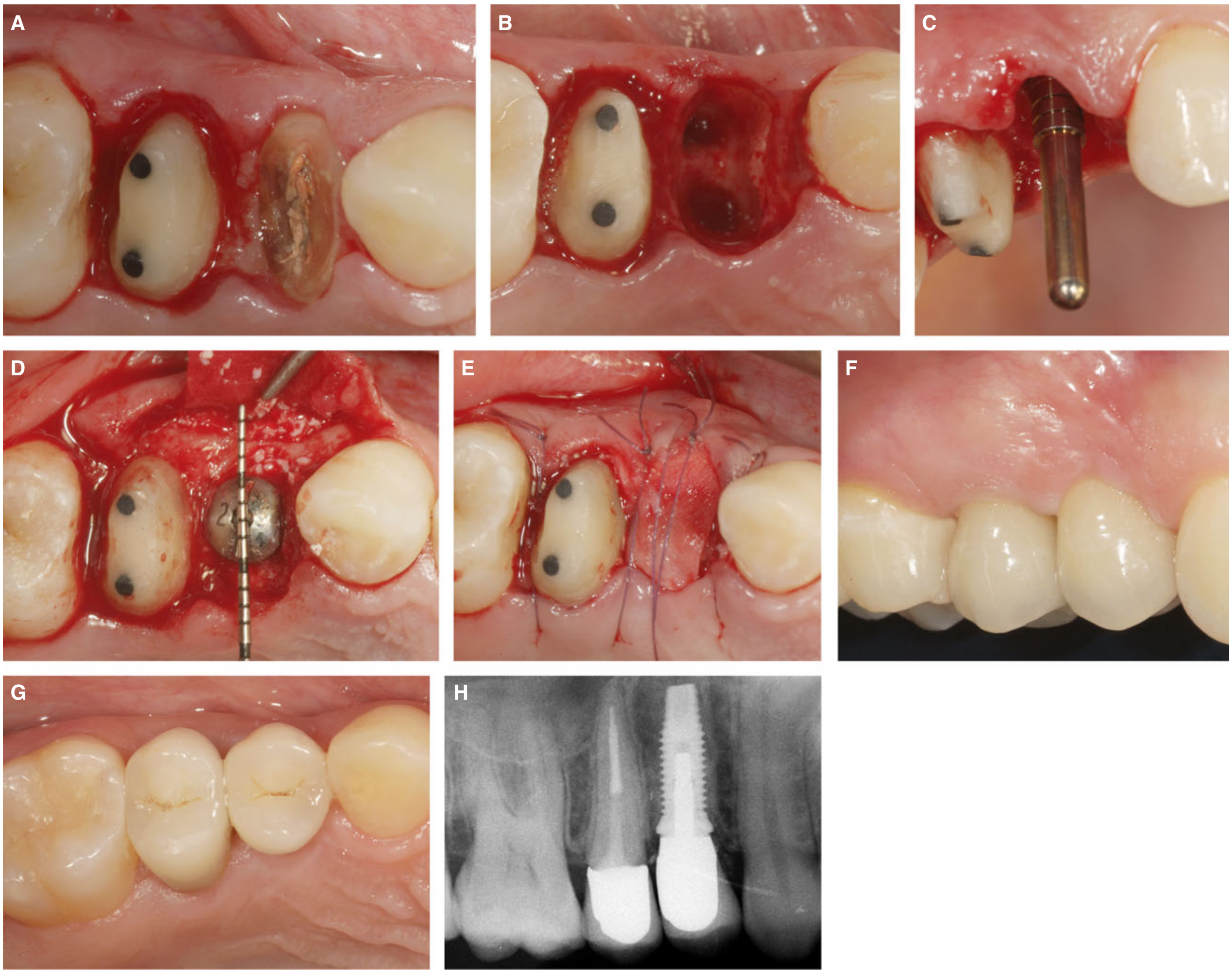

Fig. 4. Buccal positioning of implant. (A) Destructive caries renders a first upper premolar as hopeless. (B) Tooth socket after atraumatic extraction of the hopeless tooth. (C) Implant direction pin parallel to the root of the adjacent premolar, which shows that the implant should be angled toward the buccal side. (D) Intra-external grafting with small particles of deproteinized bovine bone. (E) Bone graft covered with a collagen membrane. In our experience this grafting prevents resorption of the buccal bone plate with a subsequent concavity in the esthetic zone. The membrane is intentionally left exposed in order to avoid any secondary mucosal approximation and to increase the amount of keratinized peri-implant mucosa in a single procedure. Definitive prosthesis: vestibular (F) and occlusal (G) views. (H) Radiograph of the final prosthesis with the platform switching concept.

avoid apical fenestration as a result of the natural morphology of the maxilla; and, second, to achieve the correct emergence profile of the future crown if the implant platform is more buccally positioned. It is easier to create the correct prosthetic profile when the implant is buccally inclined (Fig. 4).

Multiple missing teeth in the esthetic area with single tooth/pontic or cantilevered options/prosthetic compensation

In the esthetic area, when multiple teeth are missing or need to be extracted, careful planning is required to determine the number of implants to be placed and their positioning. Cone-beam computed tomography can be used to measure the available residual bone in three dimensions. In the mesiodistal aspects, as mentioned above, the interimplant distance (3 mm minimum) should be greater than the tooth–implant distance (1.5 mm minimum) in order to preserve the residual bone and achieve stability of the soft tissues.

It is important to evaluate the changes in the residual bone in the edentulous arch in order to plan the correct number and position of the implants. For example, when replacing four anterior teeth, the use of four implants is rarely possible because of space issues. According to the author's clinical experience, 5 mm of

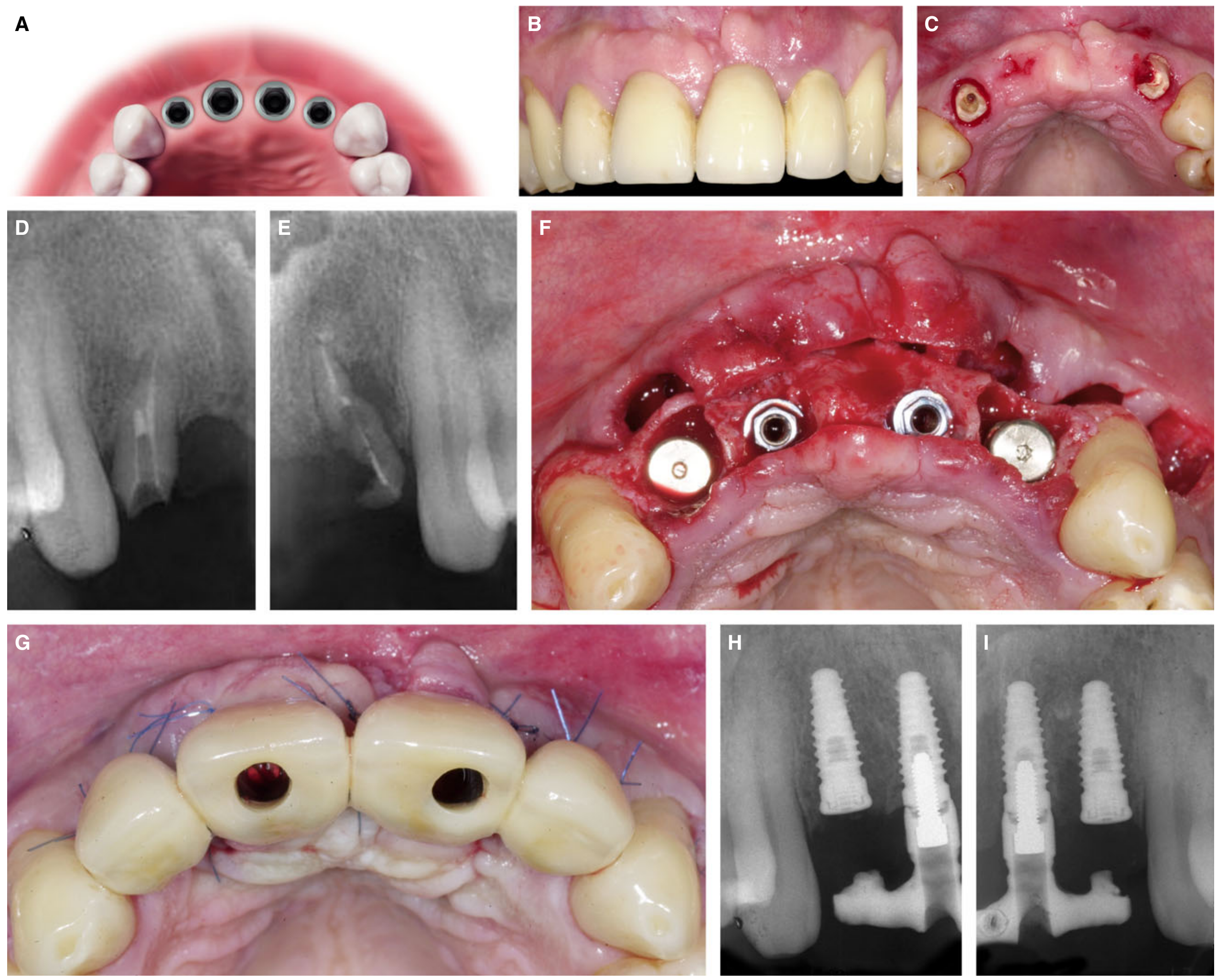

Fig. 5. (A) Rehabilitation of four implants replacing four maxillary incisors (courtesy of M. Capelli & T. Testori [12]). (B) Preoperative clinical photograph of the failing fixed partial prosthesis. After removal of this failing fixed partial prosthesis (C), periapical radiographs revealed that both lateral incisors were fractured and unsalvageable (D, E). (F) Implants were placed in the central and lateral incisor positions. Occlusal view (G) and radiographic images (H, I) of the laboratory-fabricated screw-retained provisional restoration placed 1 day after implant placement. (J) Six months later the implants in the lateral incisor position were uncovered and the soft tissue was left to heal for an additional 2 months. (K) Implant pick-up impression copings were placed onto the implants and periapical radiographs were taken to ensure proper seating of the copings. (L, M) A silicone impression of the provisional restoration was used to create the second provisional restoration as well as the definitive restorations. (N) The silicone impression was fitted onto the land area of the cast (over the ZiReal® Posts) and identified the amount of reduction needed. (O) A red marker pen was used to indicate the locations of the planned reductions on the abutment. (P) The prepared abutments in place on the master cast. These were prepared consistent with the contours of the provisional restoration. (Q) Composite image of the prepared ZiReal® Posts in place on the implants. Note that the margins of the abutments were subgingival. (R) Clinical photograph of the provisional restorations in place. (S, T) Postrestorative periapical radiographs show minimal bone remodeling around the implants, more than 1 year after placement. (U) Clinical photograph of the definitive restoration at the 9-year follow-up. Note the stability of the peri-implant soft tissues. (V) Extra-oral view of the final case. The patient has a very low lip-line. Orthopantomograph (W) and periapical radiographs (X, Y) of the definitive restoration at the 9-year follow-up.

interimplant space is recommended in the esthetic zone (70). Therefore, in a rehabilitation involving the four maxillary incisors, it is possible to insert four implants only if there is a minimum intercanine prosthetic space of 33 mm and thus the correct distance between teeth and implants and between implants can be respected (70) (Fig. 5). A tooth-borne computerized surgical stent is recommended in such cases, although training is necessary to avoid complications (51). Placing four implants to replace four missing maxillary incisors will allow for the provision of four single prosthetic crowns and a better distribution of the occlusal

Fig. 5. Continued.

forces. In any case, implants with oversized or greater diameter are considered a risk factor for the esthetic area leading to midfacial recession (10, 18).

In Table 2 (12), the ideal diameter of an implant according to the site of implantation, as well as the anatomical features of the tooth being replaced, are

Table 2. Ideal diameter of implants in relation to the implantation site and the anatomic features of the tooth being replaced

Maxillary	Mesiodistal dimension of the crown (mm)	Mesiodistal dimension of roots at the cementoenamel junction (mm)	Implant diameter (mm)
Central incisor	8.6	5.5	4–5
Lateral incisor	6.5	4.3	3–3.25
Canine	7.6	4.6 ± 1	4/5
First premolar	7.1	4.2 ± 1	4/5

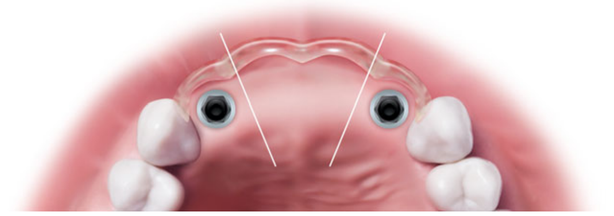

Fig. 6. Two implants replacing maxillary lateral incisors (Courtesy of M. Capelli & T. Testori [12]).

stated for the maxillary anterior region. However, following tooth/teeth extraction, the ridge will resorb preferentially buccally, reducing the arch available for placing implants, resulting in palatal displacement of the available residual bone. When the placement of four implants is contraindicated, provision of two implants in the lateral incisor sites, supporting fixed dental prostheses with two ovate pontics in the central positions, is one feasible solution (Fig. 6) (43). In some clinical scenarios the root morphology of the adjacent teeth prevents placement of the implant in the most favorable prosthesis position. In such cases, the use of cantilever restorations is strongly recommended (Fig. 7). Rehabilitation in the esthetic area could be impaired by a great deficiency of bone in horizontal and vertical dimensions. This could lead to unsatisfactory restoration in terms of soft-tissue volumes, incorrect tooth proportions, misalignment of the tooth axes and an unsupported lip profile (19). Sometimes there is no alternative but to reconstruct both hard and soft tissues and use artificial gingiva to compensate for the soft-tissue deficiencies (20, 60) (Fig. 8).

Postextraction implants in infected sites

Teeth are often extracted because of an irreversible infective process. In the past, any ongoing infective process represented a contraindication to implant insertion because of the possibility that the infection could interfere with the healing process, hinder osseointegration and lead to implant failure. However, later investigations showed that an accurate socket debridement before implant placement could allow successful osseointegration of the fixture. Studies show that survival rate does not significantly differ from those of implants placed into noninfected or healed sockets (4, 13, 22, 23, 28, 29, 38, 50, 64, 71). A recent retrospective study with 369 patients and 527 implants placed in infected and noninfected sites, followed for an average of 54 months, found no statistical difference between the two approaches in terms of implant survival rate (78) (Fig. 9).

Influence of abutment morphology and crown contours on peri-implant soft tissue

There is little literature regarding the soft-tissue response to different implant abutment designs, with a PubMed search revealing only four studies investigating this topic, none of which were randomized controlled trials (Table 3). The gold standard, concerning abutment shape, is still the one with a

Fig. 7. Four failing upper incisors requiring extraction because of root resorption after trauma. Frontal (A) and occlusal (B) views, together with an orthopantomograph (C) and periapical radiographs (D) showing root resorption. Frontal (E) and occlusal (F) views after extraction of the teeth; frontal view (G) and orthopantomograph (H) after provisional restorations are in place. (I) Adapted provisional restoration after implant insertion to permit correct healing. (J, K) The soft tissues are conditioned by the provisional prosthesis. The implants were placed in positions 1.1 and 2.2 because of the altered morphology of the cuspid with a mesially curved root. Frontal view (L) and periapical radiograph (M) of the metal ceramic bridge immediately after placement. Twelve-year follow-up: extra-oral (N) and intra-oral (O) frontal views and periapical radiograph (P).

divergent profile to establish an emergence profile similar to a natural tooth. However, divergent transmucosal profiles can have an adverse effect on tissues, with negative pressure, ischemia and a tendency for recession. Rompen et al. (58), in 2007, were the first to show that a concave, gingivally converging transmucosal profile could improve soft-tissue stability and thus avoid tissue recession. In this

Fig. 8. Preoperative phase: patient presents an existing, fixed prosthetic restoration in the esthetic area (A) and two cuspids with a hopeless prognosis (B, C). (D) Implants were inserted in the canine sites and in the right lateral incisor site. The final fixed restoration with pink ceramic (E, F) to compensate for the bone deficit, allowing adequate lip support as well as improving facial esthetics. Intra-oral frontal (G), lateral (H, I) and occlusal (J) views. Extra-oral side (K) and frontal (L) views. Orthopantomograph (M) showing the three implants in the esthetic area without bone reconstruction and prosthetic compensation. Twelve-year follow-up. Intra-oral frontal view (N) and periapical radiographs (O).

Fig. 9. Patient with two hopeless central incisors: extra-oral photograph (A); medium lip-line smile (B); a sinus tract present (C). Periapical radiographs (D) and cone-beam computed tomography images showing the fracture line (E) and external root resorption (F). After atraumatic extractions, two implants are positioned intentionally, leaving a gap buccally (G). Two provisional posts are adjusted intra-orally and an acrylic-resin splinted, screw-retained provisional restoration is placed (H). Postoperative radiograph (I). Final result with a definitive prosthesis 3 years postextraction and implant placement (J, K). Note the maintenance of the buccolingual width (L). Periapical radiograph 3 years postoperatively showing bone preservation both distally and mesially (M). Cone-beam computed tomography images 3 years postoperatively (N, O). Note that the buccal wall thickness is maintained.

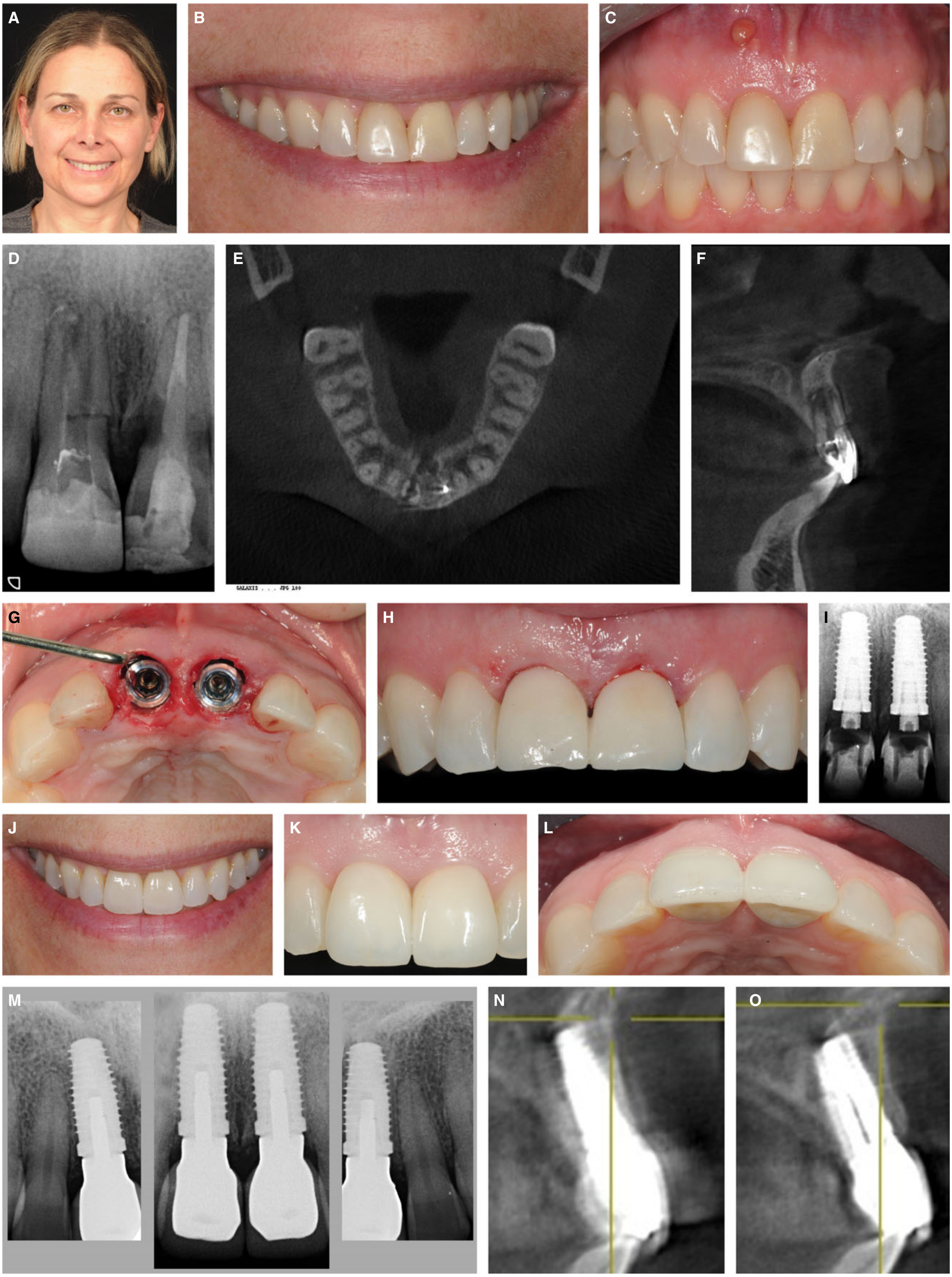
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Table 3. Studies published on implant design

Study	Study type	Follow-up period	Number of implants and protocol	Surgery procedure	Results
Rompen et al. (2007) (58)	Pilot clinical	24 months	41 patients; 54 implants. Replace, select 25 postextraction implants and 29 in edentulous sites.	52 implants: 1-stage approach. 2 implants: 2-stage approach.	13% with recession <0.5 mm. 33.3% with recession = 0. 53.7% with vertical gain.
Redemagni et al. (2009) (56)	Prospective, comparative	20.4 (range 6–50) months	28 patients; 33 implants. Xive, immediate placement, immediate provisional but no loading.	Connective tissue harvest and Bioss Collagen when gap present.	Buccal recession of 0.0 (range: 0.5−1) mm. Significant loss of height, on average 0.21 (range: −0.5−2) mm at mesial papilla. No significant loss of height, on average 0.021 (range: −0.5−1) mm at the distal papilla.
Patil et al. (2011) (53)	Retrospective, clinical with split-mouth design (concave abutment vs conventional abutment)	6 weeks	29 patients; 58 implants. Replace select, delayed.	No guided bone regeneration.	No significant difference in marginal recession and in deseating force between abutments from the experimental group and the control group.
Bishti et al. (2014) (6)	Systematic review	Searching randomized controlled trials, specifically on this topic, found that no long-term clinical studies are available.			

study, experimental titanium abutments with a concave, inwardly narrowed profile at the transmucosal level were selected (Curvy; Nobel Biocare AB, Goteborg, Sweden). They evaluated 54 implants placed in esthetically demanding areas, with a follow-up of 1–2 years; vertical gain or no recession in soft tissues was observed in 87% of the tested sites, while no recessions >0.5 mm were found in the remaining sites. These authors related the positive behavior of the soft tissues to the combination of three factors: first, the circumferential microgroove creates a void chamber in which the blood clot forms, providing space for soft-tissue growth and thickening; second, the curved profile allows for increased area of the interface between the soft tissue and the implant; and, third, after soft-tissue maturation, a ring-like seal is created, stabilizing the connective tissue adhesion, thus mimicking (from a functional point of view) the effect of the Sharpey's fibers on natural teeth. However, the study was designed without a control and therefore the scientific impact of such an experiment is limited. Redemagni et al. (56) retrospectively evaluated the soft-tissue stability around immediate implants and single-tooth restorations with a concave abutment (Curvy; Nobel Biocare AB, Goteborg, Sweden). The study was performed on 28 patients with a mean follow-up time of 20.4 months and showed buccal soft-tissue stability and very little recession. However, the prosthetic design was not the only variable investigated. Sometimes the implant–bone gap was filled with biomaterial and, in all cases, connective tissue was harvested from the palate and grafted without raising a flap. Patil et al. (53) published a comparative, single-center, prospective clinical study to evaluate the effect of two different abutment designs – conventional divergent type and curved (Curvy; Nobel Biocare, AB, Goteborg, Sweden) – on soft-tissue healing and the stability of the mucosal margin in 29 patients. They concluded that abutments with a circumferential groove do not lead to a different response of the mucosal margin compared with a regular abutment and they are no more resistant to removal than regular abutments after 6 weeks of function. Finally, Bishti et al. (6) recently undertook a systematic review to determine the peri-implant tissue response to different implant

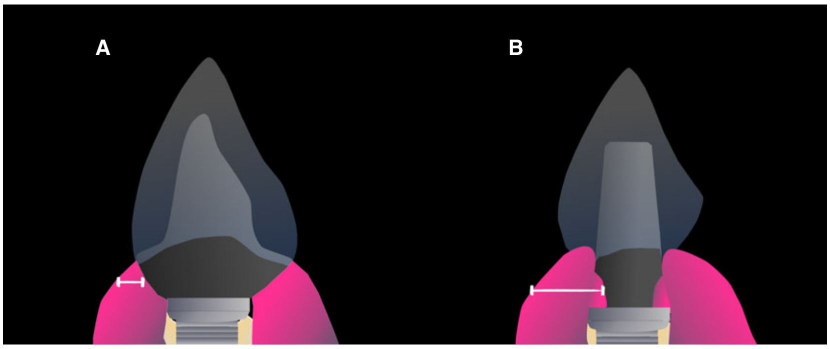

Fig. 10. **A convergent abutment profile (B) is the ideal morphology to allow soft tissue to proliferate compared to a divergent design (A).**

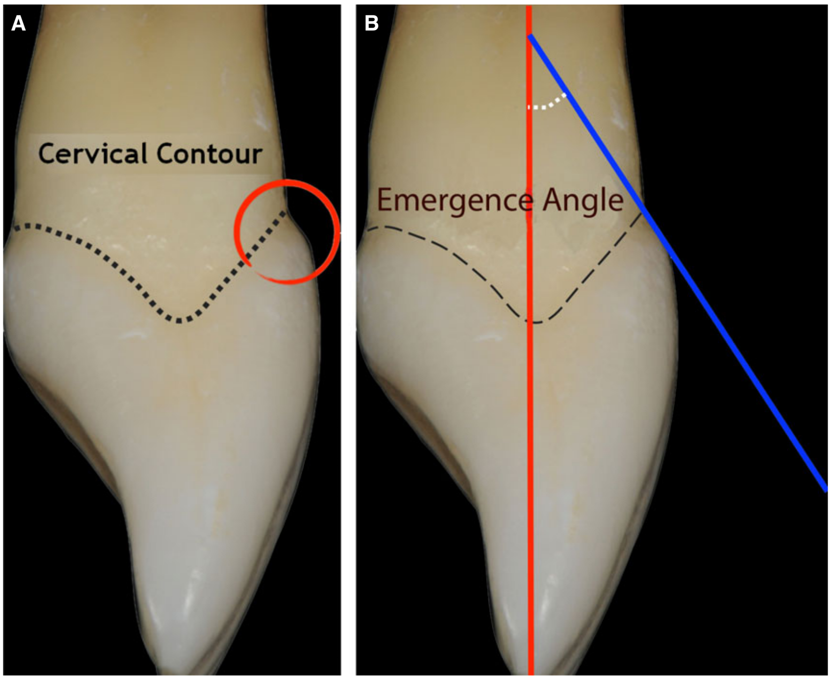

Fig. 11. **A natural maxillary incisor. (A) The lateral view shows a convexity corresponding to the cervical contour. (B) The emergence angle is formed by the junction of a line through the long axis of the tooth (red line) and a tangent drawn to the coronal aspect of the tooth as it emerges from the sulcus (blue line).**

abutment materials and designs, assessing, at the same time, the impact of tissue biotype. The focus of their research included the transmucosal part of abutments, scalloped implants, platform switching and abutment materials. They concluded that the current literature provides insufficient evidence regarding the effectiveness of different implant abutment designs and materials on the stability of peri-implant tissues. However, it stands to reason that circumferential reduction of the prosthetic abutment will leave more room in the area of the subcritical contour (65). This space will eventually be filled with new tissue that will be thicker and may be more stable. This is why a gingivally convergent abutment profile, rather than a divergent one, would be ideal to create such a void into which tissues are allowed to proliferate (Fig. 10). Another important restorative aspect is the contour of the coronal restoration, which contributes strongly to maintaining healthy and thick soft tissues.

The implant/abutment contour has been divided into two separate portions (65): (i) critical contour, defined as the area of the implant abutment and crown located immediately apical to the gingival margin, corresponding to the artificial crown contour; and (ii) subcritical contour, located apical to the critical contour and corresponding to the intramucosal portion of the implant abutment not covered by the artificial crown. These two entities will exist provided that sufficient 'running room', defined as the distance from the neck of the implant to the free gingival margin, is present (65). Both critical and subcritical

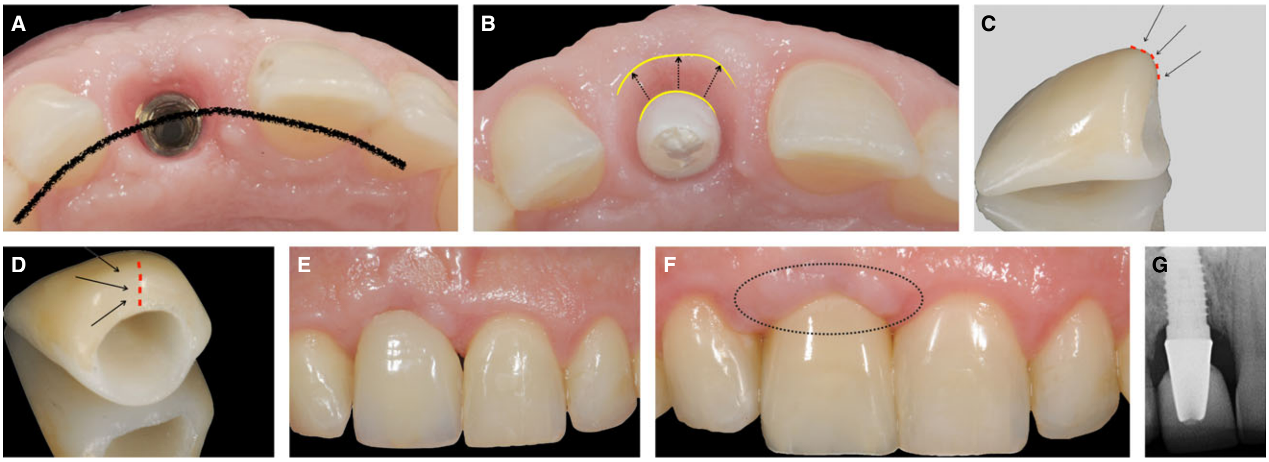

Fig. 12. (A) The center of the implant corresponds to the cingulum of the adjacent teeth. (B) Occlusal view of the final zirconium abutment. The distance A-B will be filled by the cervical contour of the final crown (marked by inner and outer semicircles shown in yellow). (C, D) The definitive lithium disilicate crowns with a cervical contour (marked by red dashed lines and black arrows) out of the physiologic parameters determined by the implant position associated with a vertical finish line geometry. (E) Provisional restoration in place. (F) One-year follow-up of the definitive crown showing signs of tissue reaction (marked by black dashed-line oval). (G) Periapical radiograph of the definitive crown.

contours, if properly modulated and shaped, may be used to modify the esthetic outcome of the coronal restoration. As mentioned above, in order to prevent buccal bone resorption, the literature suggests implant placement at the cingulum of the future restoration or 1.5–2.0 mm palatal to the incisal margin of the central maxillary incisor. However, this approach can lead to problems that may jeopardize the esthetic outcome as well as the survival of the implant as the crown contour created by such placement is substantially different from the natural crown contour. In the natural dentition, the tooth contour comprises two separate entities: the emergence profile; and the cervical contour. The emergence profile is straight and corresponds to the part of the tooth emerging from the gingiva. In contrast, the cervical contour is convex and is located at the bottom of the gingival sulcus, corresponding to the area where the enamel overlaps the cementum at the cemento–enamel junction (Fig. 11A). This convexity has been identified by Wheeler (75), who referred to it as the cervical ridge or cervical contour, and has the function of holding the gingiva under definite tension. The amount of this convexity is given by the value of the 'emergence angle' (Fig. 11B), which is defined as 'the angle formed by the junction of a line through the long axis of the tooth, and a tangent drawn to the coronal of the tooth as it emerges from the sulcus' (24, 41). The emergence angle was recently measured on extracted, natural maxillary teeth and it was found to have a mean value of 15° (27). In implant rehabilitation, the value of the emergence angle and the convexity of the cervical contour are influenced by the buccopalatal position of the implant. The more palatal the implant placement, the greater the emergence angle and therefore the greater the cervical contour. As one of the tasks of the restorative dentist is to make artificial crowns appear similar to and to function like natural teeth, the restorative angles and contours should also be very similar to those of natural teeth (75).

Through the years it has become evident that implant placement following the traditional guidelines, using abutments with a light chamfer or feather edge geometry, often results in fabrication of crowns with a critical contour that is greatly different from those of a natural tooth. An implant placed in accordance with conventional guidelines (i.e. at the cingulum of the future restoration) and restored using a shoulderless narrow abutment (to allow a thicker tissue) resulted in a final restoration with an excessively convex contour that in the short term (after 1 year) was already causing the surrounding soft tissue to react adversely (Fig. 12). Traditional guidelines for implant placement have been conceived and widely adopted for restorative wide abutments made with a horizontal preparation (shoulder). However, placing a shoulderless abutment in a cingulum or a palatal (Fig. 13) position would lead to a crown with a cervical contour far from the anatomic ones described by Wheeler & Du (27, 75). On the other hand, when the implant is slightly more buccally positioned, the emergence angle and cervical contour look much more natural. There is no scientific evidence at the moment that an excessive artificial cervical contour, out of the physiological range (75), is either beneficial or detrimental to soft-tissue stability, even though some adverse soft-tissue behavior has been noted. However, increasing the convexity of the critical contour will create an undercut that will ultimately make cement removal, in a cemented crown restoration, more difficult (74). Leaving residual cement inside the gingival sulcus is more likely to occur with restorations that have a ridge lap, thus placing the implant at great risk of peri-implantitis and eventual loss (76). Whenever a light chamfer or a feather edge preparation, rather than a wide shoulder, is chosen in the definitive implant abutment, the buccolingual position of the implant should be changed, especially in the esthetic area. The center of the implant should correspond to the incisal edge of the future restoration or of the adjacent teeth, assuming that 1.5–2.0 mm of buccal bone can be maintained. This is the only

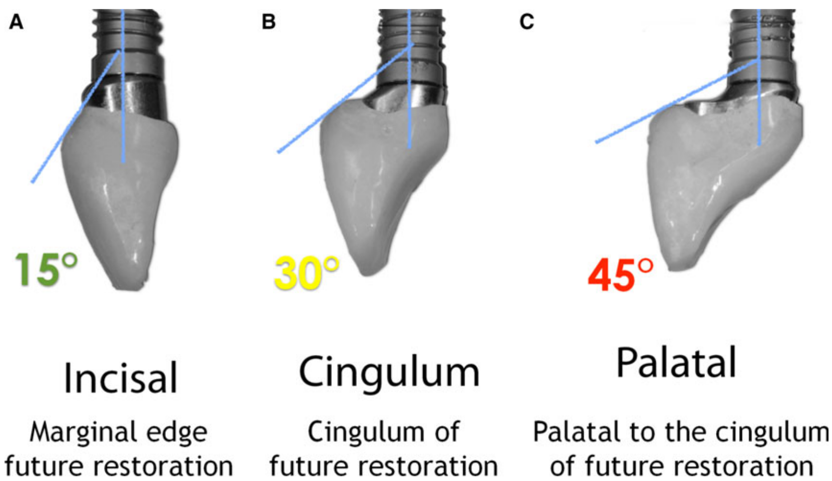

Fig. 13. The long axis of the implant aiming (A) at the incisal edge of the future restoration, (B) at the cingulum of the future restoration and (C) palatal at the cingulum of the future restoration.

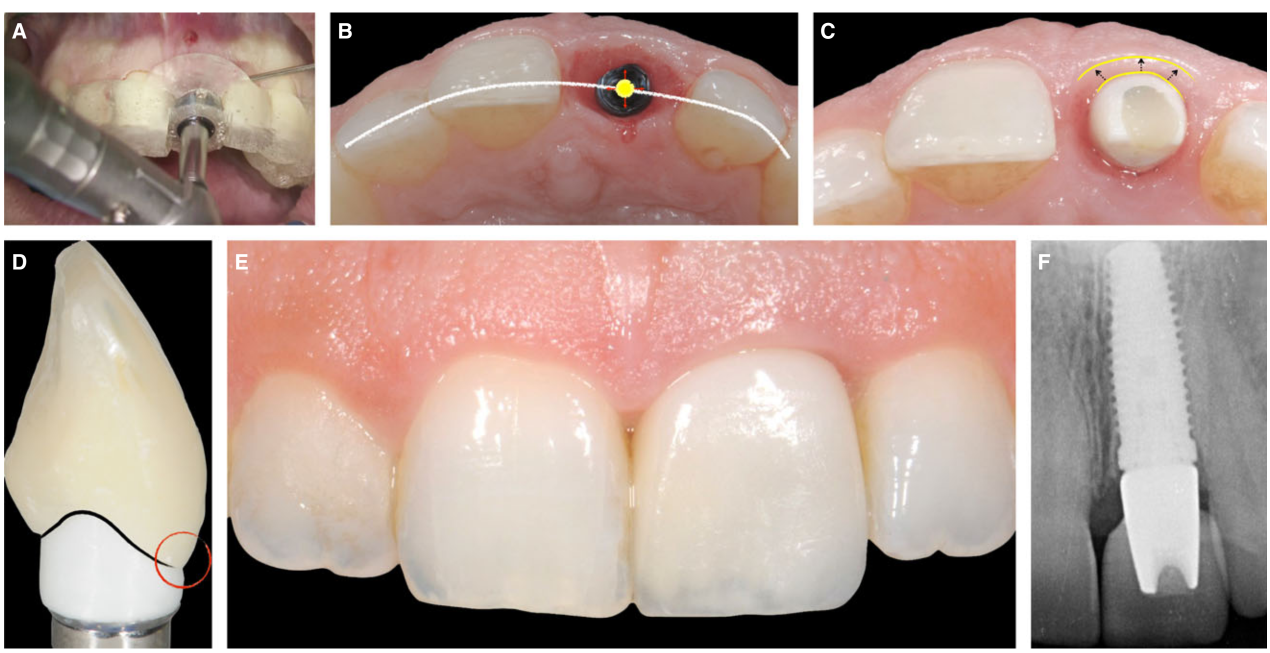

Fig. 14. (A) The position of the implant is driven by a computerized surgical stent. (B) Occlusal view of the implant in place at the time of the final impression. The center of the implant (yellow circle) corresponds to the incisal edge of the adjacent teeth. (C) Occlusal view of the final zirconium abutment in place. Phisiologic profile determines a good tissue response as marked by the two yellow lines. The screw access hole has been filled with Teflon and composite. (D) The ideal placement of the implant will generate a correct cervical contour and emergence angle (marked by the red circle). (E) Final lithium disilicate crown cemented. (F) The final radiograph.

position that enables fabrication of a restorative crown with a cervical contour resembling, as closely as possible, the natural tooth dimensions. It also eliminates problems with cement removal, reducing the incidence of iatrogenic peri-implantitis and making dental-hygiene procedures much easier (63) (Fig. 14). In summary:

- the critical contour should resemble the physiologic contour of a natural tooth and it is mainly influenced by the implant position.
- traditional guidelines for implant placement have been conceived for restorative abutments made with a wide horizontal preparation.
- the long axis of the implant should correspond to the incisal edge of the future restoration or to the adjacent teeth, assuming that 1.5–2.0 mm of buccal bone can be maintained.
- the sub-critical contour should be concave, rather than convex, allowing growth of soft tissue, which will become thicker and less susceptible to recession, thus also creating a strong barrier for bone protection.

Conclusions

Implant rehabilitation in the esthetic area is a clinical challenge because patients expect not only implant osseointegration but also an esthetically ideal result and a reduction in the treatment time. Of the many factors that contribute to the final outcome, the two most important ones are the bone and soft-tissue deficiencies at the implant site. Combining our long-standing clinic experience and the pertinent literature, the following conclusions can be drawn:

- immediate implant placement can be a successful procedure in terms of esthetics but it is technique sensitive and requires an experienced team.
- immediate placement is less traumatic to the patient as fewer surgical procedures are involved and patients tend to prefer this clinical approach regarding quality of life.
- the diagnostic phase is of utmost importance, with not only bone and soft-tissue deficiencies being addressed but also skeletal growth, dental/implant soft-tissue parameters (such as altered passive eruption) and the morphology of the roots adjacent to the edentulous area.
- postextraction immediate loading is feasible in infected sites.
- the correct position of the fixture should follow widely accepted guidelines but the abutment morphologies play a role in the vestibular/palatal position of the implant.
- the long axis of the implant, aiming at the incisal edge of the future restorations, is the most appropriate implant position when a shoulderless abutment is used and allows a restorative crown morphology with a cervical contour resembling a natural tooth.
- the use of a shoulderless abutment gives more space for the tissue to grow compared with the traditional abutment with a shoulder finish line.

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