Six Month Clinical Evaluation of Interdental Papilla Reconstruction with Injectable Hyaluronic Acid Gel Using an Image Analysis System

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ABSTRACT

Purpose: Obtaining predictable and aesthetically pleasing interdental papilla is challenging in dental reconstruction. Hyaluronic acid gel has been successfully used to reduce facial creases and similar abnormalities. The purpose of this study was to clinically assess the efficiency of interdental papilla reconstruction with injectable hyaluronic acid gel.
Materials and Methods: Ten patients with 43 treated sites in the maxillary anterior region were studied. Photographic standardization devices were designed for image analysis before treatment. This treatment was repeated up to five times during 3-week intervals. Patients were followed 6 months after initial gel application.
Results: Twenty-nine sites had complete papilla reconstruction and 14 sites improved from 39 to 96% of interdental papilla reconstruction rate. Complete interdental papilla reconstruction was performed when black triangle at initial examination had area of $\leq$0.25 mm^2, height of $\leq$1mm, or width of $\leq$0.5mm.
Conclusion: Injectable hyaluronic acid gel may be a promising treatment for enhancing papillary esthetics.

CLINICAL SIGNIFICANCE

Interdental papilla reconstruction with injectable hyaluronic acid gel can be suggested as a minimally invasive treatment option for interdental papilla deficiencies in small areas. However, long-term results of this treatment beyond 6 months are not yet known.

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INTRODUCTION

The increasing demand for esthetically pleasing dental reconstruction requires clinicians to not only restore masticatory function during treatment, but also create visual harmony between the gingiva topography and surrounding gingiva contours. In particular, interdental papilla deficiency affects the aesthetics of maxillary anterior teeth, as well as food impaction and the pronunciation of words.[1] Moreover, the interdental papilla is involved in complex physiological functions such as acting as a biological shield to protect periodontal tissue.[2] Moreover, a complete understanding of the aesthetic interdependency of the bones and soft tissues, as well as the impact of interdental papilla-related appearances on overall oral esthetics can facilitate the achievement of a successful esthetic outcome.[3]

Presently, various techniques including surgical, orthodontic, and prosthetic treatments are used to improve esthetic problems in the maxillary anterior

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region caused by interdental papilla deficiency. There are a few reports of successful reconstructions of the interdental papilla near teeth or dental implants[4–8] but the results are limited and fail to show long-term viability. This is because the interdental papilla region is characteristically narrow, which makes surgery more difficult and limits the blood supply to the associated soft tissue.[9] Orthodontic treatments involve moving teeth closer together when the spacing between them is unpleasantly wide, or the roots are divergent. Furthermore, the orthodontic method of moving the roots closer involves stripping the surface of adjacent teeth to address interdental papilla deficiency.[1,10] However, when there is no excess space between the teeth, this procedure runs the risk of causing periodontal diseases due to the narrowed space between the roots.[11] Moreover, even after such treatment measures, deficient interdental papilla must be supplemented with prosthetics. This treatment involves filling the deficient interdental papilla region with a prosthesis to lower the contact points between teeth or alternatively, the interdental papilla may be filled by shortening the distance between the contact point and the crestal bone to less than 5 mm.[12] However, these methods are highly invasive and have a shortcoming of variability that occurs from differences in the size and height of the interdental papilla based on the individual or the region, which is difficult to resolve.

A study by Becker and colleagues[13] reported that minimally invasive yet viable reconstruction was possible on a small area of deficient interdental papilla using an injectable hyaluronic acid gel. To date, injectable hyaluronic acid gel has been stably and successfully used to reduce wrinkles and improve other similar facial deformities.[14] The currently available injectable hyaluronic acid gels are polymers that are formulated by crosslinking hyaluronic acid produced by *Streptococcus* species, and their durability is often enhanced by improving their biodegradability in skin using advanced cross-linking technology.[15]

Therefore, the objective of the present study was to use hyaluronic acid gel in interdental papilla reconstruction for deficiencies in the maxillary anterior region, and then assess its efficiency using an image analysis system to examine the features of the black triangle (BT) area.

MATERIALS AND METHODS

Study Population

A total of 10 patients, including 4 male and 6 female patients, were recruited from the Chosun University Dental Hospital. All included patients provided verbal and written informed consent according to the Declaration of Helsinki, as revised in 2000. The age of the participants ranged from 27 to 35 years, with a mean age of 32 years and 43 interdental papilla areas in the maxillary anterior region were studied. The selection criteria for the participants were as follows: adult patients with at least one interdental papilla deficiency with the presence of a contact point between adjacent teeth in the maxillary anterior region, as well as plaque[16] and gingival indices[17] between 0 and 1. Exclusion criteria included patients who are pregnant, on medication known to increase the risk of gingival hyperplasia, and those currently receiving orthodontic treatment in the maxillary anterior region.

Photographic Standardization Device

During the first patient visit, a maxillary impression was taken to prepare the study model. Then, white cylindrical posts painted with a brown stripe were vertically affixed on the vacuum former (Omnivac) of the interdental papilla areas in the maxillary anterior region obtained from the model, to fabricate the photographic standardization device (Figure 1). Then, to prevent the cylindrical posts from blocking the BT, they were fixed as close as possible to the incisal area. The clinical photographs were taken to ensure that the brown stripe on the post was not visible to guarantee the same shot composition was obtained in all instances. This was done to minimize any errors that

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FIGURE 1. Photographic standardization device.

may occur during measurement of the BT area (BTA) using the image analysis system.

Procedure

Clinical photographs were taken prior to the procedure. We used a commercially available injectable hyaluronic acid gel (Teosyal Puresense Global Action®, Teoxane, Geneva, Switzerland). The single application volume of the injection-assisting device (CelTick®, Hyundae Mediteck, Wonju, Korea) was set to 0.002 cc. The injectable hyaluronic acid gel and disposable 30 G × ½″ needle (Jungrim Medical, Seoul, Korea) were loaded onto the injection-assisting device and the needle was inserted at a 45° angle in an area 2 to 3 mm below the interdental papilla tip. A one-point injection technique was performed on the connective tissue of the interdental papilla, ensuring the bevel was up by pointing the slant of the needle upward (Figure 2). To prevent the backflow of hyaluronic acid gel owing to pressure from the interdental papilla tissue, a total of 0.01 cc of hyaluronic acid gel consisting of five sessions of 0.002 cc was injected using a shooting method to each interdental papilla deficiency area. Then, the interdental papilla tip was lightly molded in the direction of the incisal edge with gauze. This procedure was repeated up to five times during 3-week intervals until no BT was clinically

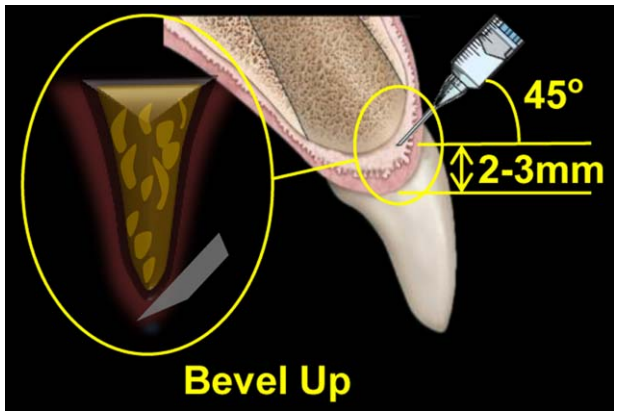

FIGURE 2. Injection technique.

observable. Clinical photographs were taken during each procedure, and the final photograph was taken 6 months after initial gel application.

Morphometric Analysis of Images

Three measurements of the BTA, BT height (BTH), and BT width (BTW) were taken for each of the acquired clinical photographs. The image analysis program (Adobe Photoshop CS5®, Adobe System Inc., San Jose, USA) was used for the measurements. This program predefined the height as the difference between the maximum and minimum y coordinates of the pixels within a designated area while the width was the difference between the maximum and minimum x coordinates. First, we adjusted the contrast of the photograph to be measured to ensure the borders of the BT were distinct, and the physical length of the image was calculated in pixels. Furthermore, the calculations were based on the pixel values that correspond to the length of the periodontal probe, which was 10 mm. The portion of the BT that was measured was demarcated on the image and its area, height, and width were automatically converted to millimeters. All the measurements were performed by a single surveyor, who was blinded to the procedure, and each region was measured 10 times and the mean values were subsequently calculated.

Decreases in the BTA, BTH, and BTW compared to values obtained at the initial examination (ΔBTA,

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TABLE 1. Description of patients and IPRR(%) each site

Patient	Age(year)	Gender	Site				
			1	2	3	4	5
1	32	F		100	87	100	100
2	30	F	100	100	85	100	100
3	34	F	100	100	96	100	100
4	35	M	100	89	100	100	100
5	27	M	100	39	72	74	91
6	28	F			63		
7	34	M	63	85		71	
8	33	M	100	100	100	100	100
9	34	F	100	100	100	100	100
10	31	F	100	100	100	82	82

IPRR = interdental papilla reconstruction rate; Site 1 = interdental papilla between maxillary right canine and maxillary right lateral incisor; Site 2 = interdental papilla between maxillary right lateral incisor and maxillary right central incisor; Site 3 = interdental papilla between maxillary central incisors; Site 4 = interdental papilla between maxillary left central incisor and maxillary left lateral incisor; Site 5 = interdental papilla between maxillary left lateral incisor and maxillary left canine.

ΔBTH, and ΔBTW, respectively) were calculated from the measured variables for each application. Then, the interdental papilla reconstruction rate (IPRR) was calculated to determine the effects of the injectable hyaluronic acid gel. The IPRR was defined as the percentage change in the BTA between initial treatment and each procedure.[13]

Data Analysis

The data analysis was performed using software (SPSS version 20.2, IBM Corp., Armonk, NY, USA). Cases showing no clinically visible evidence of the BT in the final clinical photographs that were taken were classified as the complete interdental papilla reconstruction (CIPR) group while those with clinically observable BT were designated as the partial interdental papilla reconstruction (PIPR) group. Variables of the two groups were compared using the nonparametric Mann–Whitney U test to determine significant differences. The number of applications in the CIRP group was used as the reference for further classifying it into four subgroups based on whether CIPR was achieved after the 1st, 2nd, 3rd, 4th, or 5th application. After the mean values of the BTA, BTH, and BTW were obtained following the initial examination of each subgroup, the tendencies of each variable and number of applications were analyzed using the Jonckheere-Terpstra test. The significant changes in the IPRR of the PIPR group based on the number of applications from one to five were determined using the Wilcoxon signed rank test. Using BTA, BTH, and BTW values of 0.25 mm^2, 1.0, and 0.5 mm, respectively obtained at the initial examination as the cutoff, two groups were formed consisting of those below versus above the cutoff. Then, a simple regression analysis was performed to analyze the correlation between the group above the cutoff and the IPRR. A p value < 0.05 was considered to be statistically significant.

RESULTS

In the present study, interdental papilla reconstruction using an injectable hyaluronic acid gel was performed on a total of 43 interdental papilla sites in the maxillary anterior region of 10 patients. As a result, a total of 29 and 14 sites showed 100 and 39–96% IPRR, respectively (Table 1). A mean reduction in the BTA, BTH, and BTW of 0.20 mm^2, 0.71, and 0.32 mm, respectively, was observed. Furthermore, each site showed a mean IPRR of 92.55% while the mean number of hyaluronic acid gel applications was 3.42 (Table 2).

Comparison of CIPR and PIPR Groups

Comparison of the CIPR group variables, which showed CIPR in 29 out of 43 sites (Figure 3) and those of the PIRP group, which showed PIPR in 14 out of 43 sites (Figure 4), showed a significant difference in the BTA, BTH, and BTW at the initial examination, as well as the ΔBTA, IPRR, and number of applications. Conversely, ΔBTH and ΔBTW were not significantly different (Table 3). Moreover, within the CIPR group,

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TABLE 2. Total outcomes of interdental papilla reconstruction

	Baseline			6 months				
	BTA (mm^2)	**BTH (mm)**	**BTW (mm)**	**ΔBTA (mm^2)**	**ΔBTH (mm)**	**ΔBTW (mm)**	**IPRR (%)**	**No of App**
Mean	0.24	0.93	0.41	0.20	0.71	0.32	92.55	3.42
SD	0.19	0.45	0.18	0.13	0.27	0.13	13.46	1.40

BTA = black triangle area; BTH = black triangle height; BTW = black triangle width; ΔBTA = reduction in BTA; ΔBTH = reduction in BTH; ΔBTW = reduction in BTW; IPRR = interdental papilla reconstruction rate; No of App = number of gel applications; SD = standard deviation.

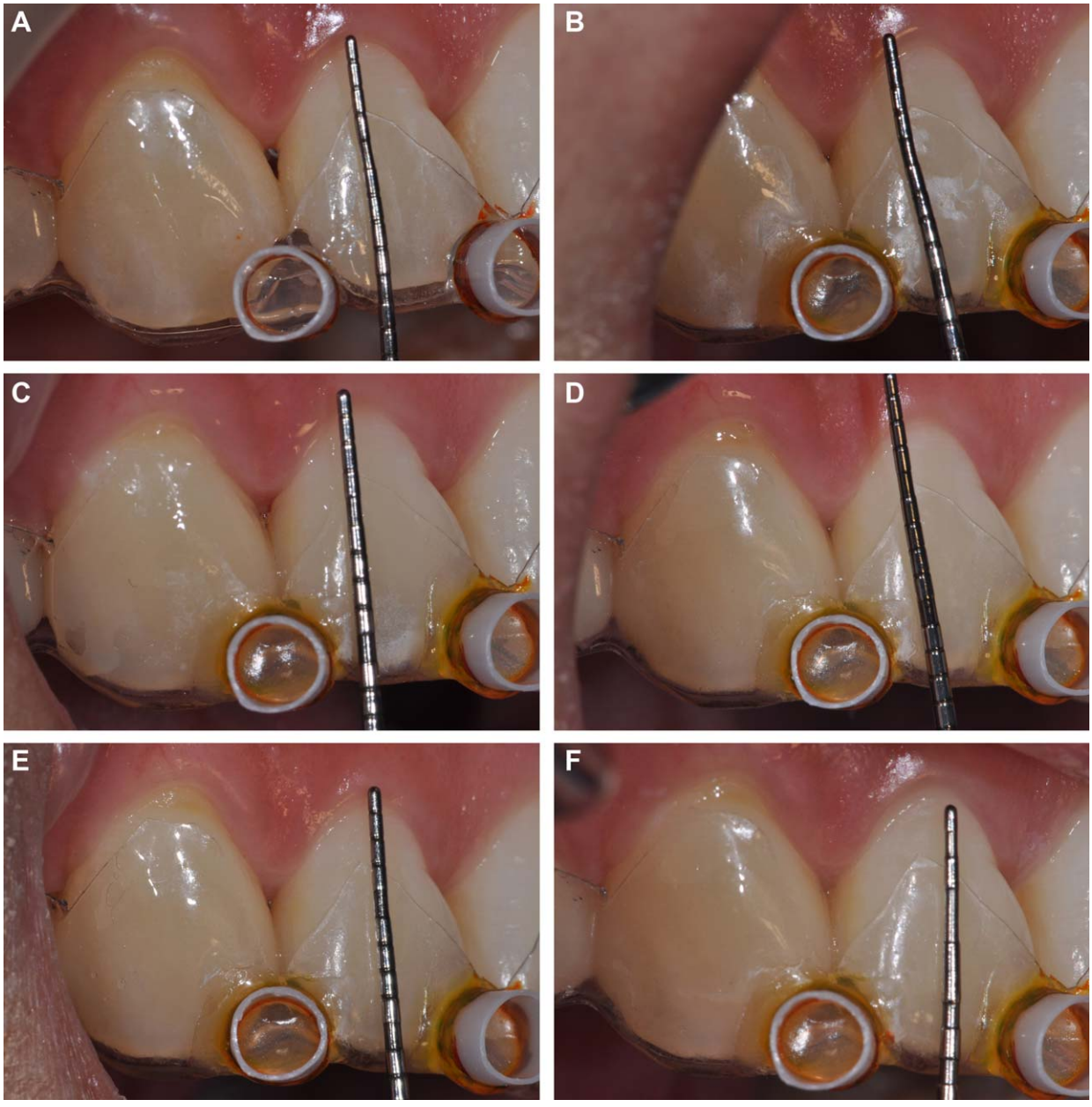

FIGURE 3. Representative case of CIPR. A, Before 1st gel application at baseline. B, Before 2nd gel application at 3 weeks. C, Before 3rd gel application at 6 weeks. D, Before 4th gel application at 9 weeks. E, Before 5th gel application at 12 weeks. F, At 6 months following gel application.

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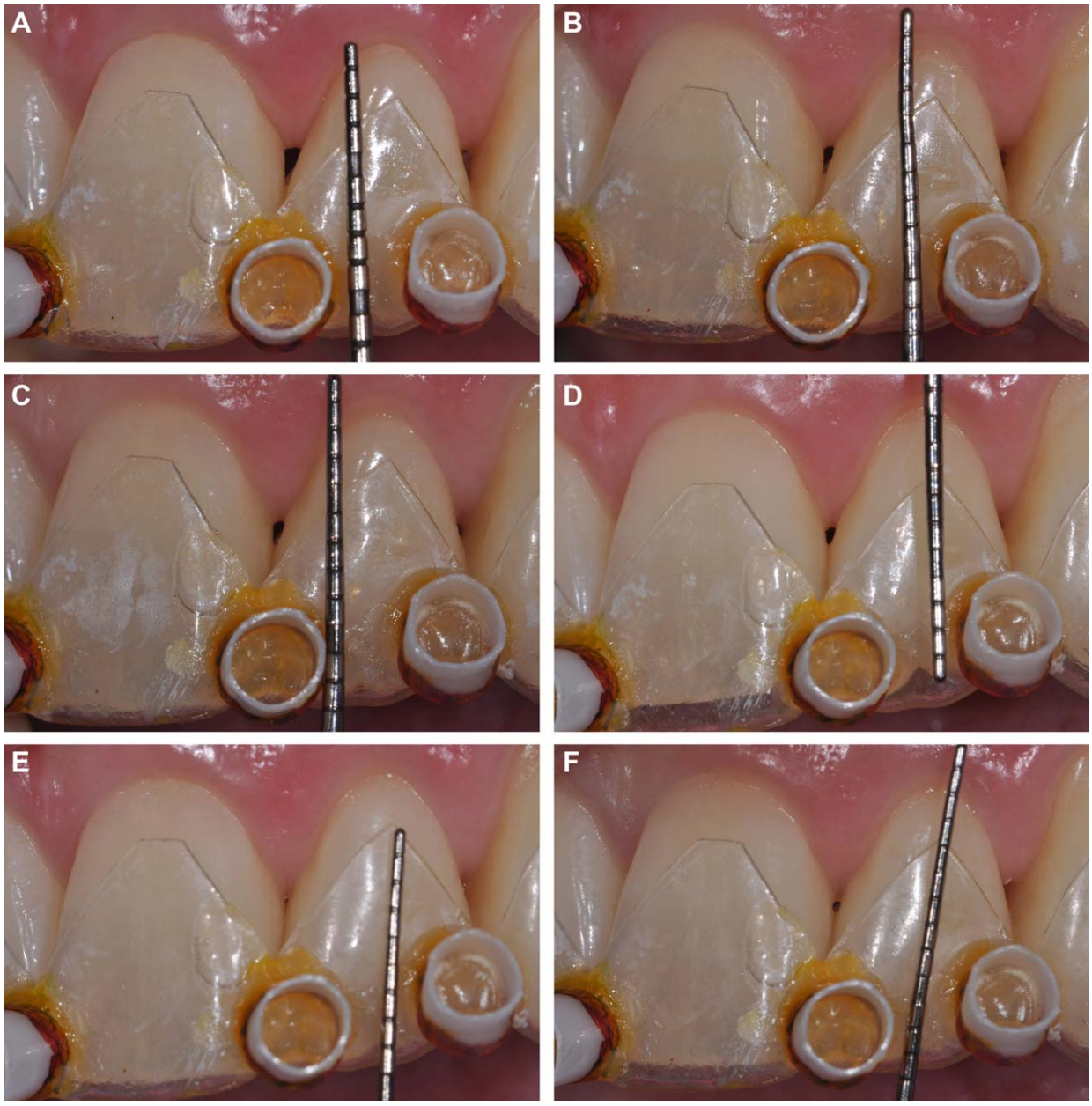

FIGURE 4. Representative case of PIPR. A, Before 1st gel application at baseline. B, Before 2nd gel application at 3 weeks. C, Before 3rd gel application at 6 weeks. D, Before 4th gel application at 9 weeks. E, Before 5th gel application at 12 weeks. F, At 6 months following gel application.

a higher BTA, BTH, and BTW at the initial examination resulted in a statistically significant increase in the number of injectable hyaluronic acid gel applications required to achieve a CIPR (Table 4). In the PIPR group, an increase in the number of applications correlated to a statistically significant increase in IPRR but the slope of increase showed a decrease for each treatment interval (Figure 5).

Relationship Between BTA, BTH, and BTW at Initial Examination and IPRR

The results showed that BTA and BTH values up to 0.25 mm^2 and 1 mm, respectively, during the initial examination, largely resulted in 100% IPRR for both parameters. However, when the BTA and BTH values exceeded 0.25 mm^2 and 1 mm, respectively, the

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TABLE 3. Comparison of variables of complete and PIPR groups (mean ± SD)

Variables	CIPR (29 sites)	PIPR (14 sites)	*p* value
Baseline BTA (mm^2)	0.15 ± 0.09	0.42 ± 0.20	$P < 0.001$*
Baseline BTH (mm)	0.71 ± 0.30	1.37 ± 0.41	$p < 0.001$*
Baseline BTW (mm)	0.34 ± 0.15	0.56 ± 0.13	$p < 0.001$*
6 months ΔBTA (mm^2)	0.15 ± 0.09	0.31 ± 0.12	$p < 0.001$*
6 months ΔBTH (mm)	0.71 ± 0.30	0.70 ± 0.20	$p = 0.717$
6 months ΔBTW (mm)	0.34 ± 0.15	0.29 ± 0.10	$p = 0.436$
6 months IPRR (%)	100.00 ± 0.00	77.07 ± 14.90	$p < 0.001$*
No of App	2.66 ± 1.08	5.00 ± 0.00	$p < 0.001$*

CIPR = complete interdental papilla reconstruction group; PIPR = partial interdental papilla reconstruction group; BTA = black triangle area; BTH = black triangle height; BTW = black triangle width; ΔBTA = reduction in BTA; ΔBTH = reduction in BTH; ΔBTW = reduction in BTW; IPRR = interdental papilla reconstruction rate; No of App = number of gel applications; SD = standard deviation.
*Mann–Whitney U test; statistically significant at $p < 0.05$.

increases in both BTA and BTH showed statistically significant negative correlations with the IPRR (Figures 6 and 7, respectively). Furthermore, a BTW of up to 0.5 mm at the initial examination resulted mostly in 100% IPRR but values exceeding this led to a negative correlation between the BTW and IPRR, albeit without statistical significance (Figure 8).

DISCUSSION

Currently, numerous studies have reported the use of image analysis programs for the evaluation of clinical photographs. Sin and colleagues[18] used an imaging tool to analyze clinical photographs used for investigating changes in gingival shrinkage based on gingival biotype 3 months after scaling and root planing. In addition, Kerner and colleagues[19] analyzed clinical photographs using an image analysis program to calculate the root coverage rate and reported that the results were reliable when compared to those obtained using a conventional periodontal probe. However, clinical photographs of the same area taken at different times using these methods have shown that errors can be introduced if the shooting angles are not identically reproduced. Furthermore, Ricci[20] emphasized the importance of reproducing the same shooting angle when performing a comparative analysis of clinical photographs from different time points. In addition, this study reported that using a camera fixed in the same position on a plaster model enhanced the reproducibility of the shots, which enable vertical changes in soft tissue margins to be accurately measured to an error range within 0.1 mm. In the present study, a photographic standardization device was developed in-house to increase the reproducibility of clinical photographs taken of the interdental papilla areas. We ensured that the same up-down and left-right shooting composition was reproduced by making sure that the brown strip on the cylindrical post was not visible on each clinical photograph acquired. In addition, we reduce errors based on magnification

TABLE 4. Variables comparison in relation to four groups subdivided based on number of applications in complete papilla reconstruction group (mean ± SD)

Variables	G1 (4 sites)	G2 (9 sites)	G3 (11sites)	G4 (5sites)	J-T	*p* value
Baseline BTA (mm^2)	0.03 ± 0.04	0.13 ± 0.07	0.16 ± 0.07	0.24 ± 0.11	3.419	$p = 0.001$*
Baseline BTH (mm)	0.23 ± 0.12	0.69 ± 0.24	0.80 ± 0.24	0.93 ± 0.20	3.146	$p = 0.002$*
Baseline BTW (mm)	0.18 ± 0.12	0.32 ± 0.10	0.36 ± 0.14	0.44 ± 0.19	2.176	$p = 0.030$*

G1 = group with complete interdental papilla reconstruction after 1st application; G2 = group with complete interdental papilla reconstruction after 2nd application; G3 = group with complete interdental papilla reconstruction after 3rd application; G4 = group with complete interdental papilla reconstruction after 4th or 5th application; BTA = black triangle area; BTH = black triangle height; BTW = black triangle width; J-T = standardized J-T statistic; SD = standard deviation.
*Jonckheere-Terpstra test; statistically significant at $p < 0.05$.

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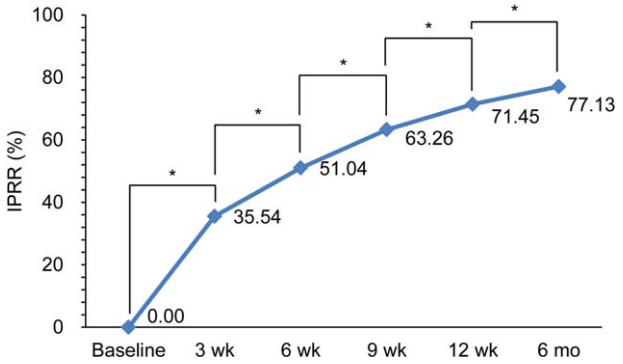

FIGURE 5. Change in mean IPRR of PIPR group. *Wilcoxon signed rank test; statistically significant at $p < 0.05$.

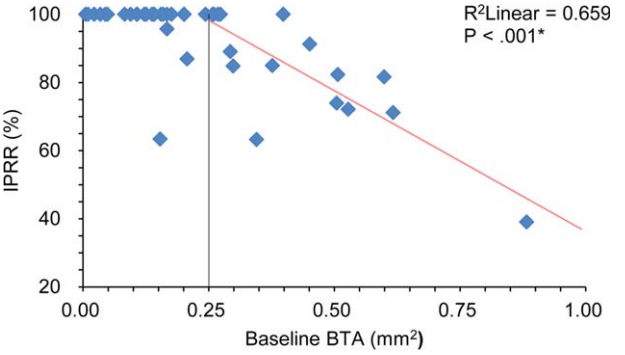

FIGURE 6. Correlation between baseline BTA and IPRR. Two groups were subdivided based on baseline BTA of 0.25 mm^2. Statistically significant negative correlation between baseline BTA > 0.25 mm^2 and IPRR was observed. *The simple regression analysis; statistically significant at $p < 0.05$.

using a 10 mm length of a periodontal probe as a physical scale for calibration.

Becker and colleagues[13] were the first to report that successful outcomes can be achieved on small areas of interdental papilla deficiency using interdental papilla reconstruction with an injectable hyaluronic acid gel. By administering a maximum of 3 injectable hyaluronic acid gel treatments during 3-week intervals, they were able to achieve 100% CIPR in 3 out of 14 sites and 57 to 97% PIPR in the remaining 11 sites. CIPR was observed in 29 out of a total of 43 sites in the present study, which represented a higher percentage than that obtained by Becker and colleagues,[13] while the remaining 14 sites showed various degrees of PIPR from 39 to 96%. We believe that these differences are most likely attributable to the initial deficiencies of the interdental papilla areas. Moreover, the study by Becker and colleagues[13] only reported the final IPRR without providing any data on the BTA, BTH, and BTW at the initial examination for the 14 sites that the procedures were performed on. In contrast, the present study considered the correlations between the deficient interdental papilla areas during the initial examination and the IPRR. Moreover, here, we also showed that the percentage of the completely reconstructed interdental papilla area can be increased using up to five applications. Furthermore, larger deficient interdental papilla area at initial examination required an increase in the number of applications to

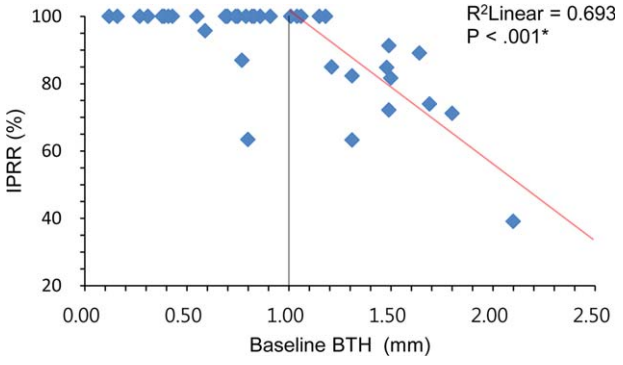

FIGURE 7. Correlation between baseline BTH and IPRR. Two groups were subdivided based on baseline BTH of 1.00 mm. Statistically significant negative correlation between baseline BTH > 1.00 mm and IPRR was observed. *The simple regression analysis; statistically significant at $p < 0.05$.

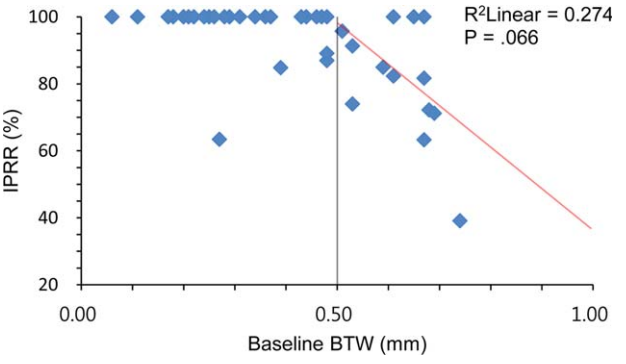

FIGURE 8. Correlation between baseline BTW and IPRR. Two groups were subdivided based on baseline BTW of 0.50 mm. Negative correlation between baseline BTW > 0.50 mm and IPRR was observed. *The simple regression analysis; statistically significant at $p < 0.05$.

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achieve CIPR. Specifically, three and two sites required four and five applications, respectively, to achieve CIPR. In addition, the present study used an injection-assisting device. Lorenc and colleagues[21] reported that in nasolabial folds cosmetic surgery using dermal fillers, the use of injection-assisting devices yielded better aesthetic outcomes than traditional manual injection methods did, by enabling easier and more precise treatment administration. Unlike applying injectable hyaluronic acid gel to the facial area, the interdental papilla region is a very confined space, which requires more effort for precise drug application. Furthermore, in this present study, the injection-assisting device enabled us to continuously administer a small volume of gel (0.002 cc each), which minimized the shaking of the needle and possible counteraction generated by tissue pressure.

We discovered that the number of gel applications was an important influencing factor in the successful reconstruction of deficient interdental papilla. As mentioned previously, the CIPR group, which showed more interdental papilla deficiency on initial examination, required more gel applications to achieve CIPR. The PIPR group exhibited a significant increase in the IPRR even after five applications; however, the increased IPRR per application decreased with an increasing number of injections. Moreover, a higher degree of deficient interdental papilla area at the initial examination tended to lead to a decrease in the IPRR. Therefore, cases that showed large deficiencies in the interdental papilla area at initial examination did not respond as favorably to increasing the number of hyaluronic acid gel injections, which showed limited success in restoring the interdental papilla.

Interestingly, patients with BTA, BTH, or BTW values of up to 0.25 mm^2, 1, or 0.5 mm, respectively, on initial examination, exhibited CIPR following treatment with the hyaluronic acid filler in most cases. This was consistent with the findings of the study by Becker and colleagues,[13] which showed that injectable hyaluronic acid gel can be used to reconstruct interdental papilla of areas with few interdental papilla deficiencies. Therefore, the area, height, and width of the deficient BT can be used as preprocedural diagnostic criteria to predict the effects and possible outcome of interdental papilla reconstruction.

Hyaluronic acid degrades naturally in the body and, therefore, the duration of maintenance of the injectable hyaluronic acid gel is critical. Becker and colleagues[13] reported that the improvement was retained without relapse for up to 25 months in site exhibiting CIPR. In the present study, relapses occurred in 6 out of 14 sites in the PIPR group, whereas all 29 sites that were completely restored were well maintained without any relapses for up to 6 months from the time 100% reconstruction was achieved. Therefore, a long-term follow-up study is definitely necessary.

CONCLUSIONS

Within the limits of this study, we were able to take clinical photographs of the interdental papilla area with adequate reproducibility using photographic standardization devices that were developed in-house. In addition, the reproducible photographs facilitated the reliable assessments of the interdental papilla reconstruction efficiency using an image analysis system. Furthermore, the close association between interdental papilla reconstruction using injectable hyaluronic acid gel and the number of applications was discovered. Moreover, when the BTA, BTH, or BTW were less than 0.25 mm^2, 1, or 0.5 mm, respectively, at the initial examination, a complete reconstruction of the interdental papilla was possible in most cases following the application of hyaluronic acid gel. Therefore, our study demonstrated that interdental papilla reconstruction using an injectable hyaluronic acid gel can be a viable treatment option for interdental papilla deficiencies in small areas.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are included in this article.

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