Case Series

Influence of the Tooth- and Implant-Side Marginal Bone Level on the Interproximal Papilla Dimension in a Single Implant With a Microthread, Conical Seal, and Platform-Switched Design

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Background: *The purpose of the present study was to investigate whether bone level on the tooth side was the single dominant factor on the dimension of an interproximal papilla around single-tooth restorations made on a microthread, conical seal, and platform-switched design implant.*

Methods: *Periapical radiographs were taken of 17 patients, each of whom was treated with a single implant. The bone levels on the tooth (Dt) and implant (Di) sides were recorded. The dimension of the papilla (Ph) was measured as the shortest distance from the top of the papilla to the crestal bone. The marginal bone levels of the implants were also measured. The Pearson correlation coefficient was used to correlate the variables, and a regression analysis was used to determine whether Di or Dt had a significant (P <0.05) influence on Ph.*

Results: *A positive correlation existed between Ph and Di (r = 0.413; P = 0.023) and between Ph and Dt (r = 0.830; P <0.0001). However, only Dt had a significant influence on Ph.*

Conclusion: *Dt is the dominant factor that influences the interproximal soft tissue dimension between a natural tooth and a single implant with a microthread, conical seal, and platform-switched design.*
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KEY WORDS

Dental esthetics; dental implants; interdental papilla; tooth.

To achieve esthetic success with implant restorations, crown restorations should be in harmony with the existing dentition in terms of color, shape, and surface structure.[1,2] In addition, the preservation or creation of harmonious soft tissue contours of the peri-implant mucosa, with distinct papillae, might be another important factor in obtaining favorable esthetic results after implant treatment.[3,4] Most previous studies[3-10] on the interproximal papilla around a single-implant restoration used flat-topped implants. It is unclear if the relationship found in flat-top designs, i.e., that the tooth-side bone level is the determining factor for the interproximal papilla level,[5,8,9] is applicable to implants of other designs. The implant design may affect the extent of marginal bone loss, and less marginal bone loss could contribute to maintenance of the interproximal papilla. Implants of a conical seal and platform-switched design with microthread are known to have less bone loss than the flat-top implants.[11,12]

The purpose of the present study was to investigate whether the tooth-side bone level remains the dominant factor affecting the interproximal papilla dimension around a single implant with a microthread, conical seal, and platform-switched design.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of Yonsei University. All patients were informed of the study procedures and provided written informed consent.

Study Population

Subjects were selected from those who were treated with single-implant restorations at the Department of Periodontology, Gangnam Severance Dental Hospital, and participated in periodic follow-up studies between November 2006 and March 2007. The patients were selected according to the following inclusion criteria: prosthesis functioning for >12 months,

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Table 1.

Age and Gender Distribution of Patients

	Age (years)					
Gender	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	Total
Male	1		3		3	7
Female		1	2	7		10
Total	1	1	5	7	3	17

Table 2.

Distribution of Implants

	Tooth Number/N Implants														Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	1	3		2					1		2	2	1		12
	31	30	29	28	27	26	25	24	23	22	21	20	19	18	
		2	1								1			1	5
Total	1	5	1	2					1		3	2	1	1	17

all implants had microthread on the coronal portion of the fixture,§ no history of surgical reconstruction of the interproximal papilla, and no history of peri-implant mucosal complications. Seventeen patients (seven males and 10 females; mean age: 50.2 years; range: 21 to 65 years; Table 1) fulfilled the inclusion criteria. Two of the 17 single-implant restorations were placed at the most posterior teeth (Table 2), providing a total of 32 papillae formed by the single implants.

Each implant was placed using a two-stage protocol. An uncovering surgery was performed 3 months after fixture placement for the mandible and 6 months after fixture placement for the maxilla. There was no temporary prosthesis used on the implant site during the healing period. Two weeks after the uncovering surgery, an impression was taken at the fixture level, and the prosthesis was set a week later. Patients were instructed on proper oral hygiene before implant surgery and after prosthetic placement. Patients were followed up every 6 months for professional plaque control and oral hygiene instructions.

Clinical Evaluation and Radiographs

The mesial, distal, buccal (labial), and lingual (palatal) modified plaque index scores and modified sulcus bleeding index scores[13] were recorded for implant restorations. The width of the keratinized mucosa was measured with a periodontal probe,‖ to the nearest 0.5 mm, at the mid-buccal site of the implant restoration.

Radiographs¶ were obtained using a previously described method.[14-16] Briefly, a liquid radiopaque material, consisting of a 2:1 mixture of an endodontic sealer# and barium sulfate, was placed on the tip of the papilla with a probe. A metal ball bearing (5 mm diameter) was attached to the crown with utility wax for use as a calibration reference. A periapical radiograph was taken (70 kilovolt [peak], 10 mA) using the parallel-cone technique with an extension cone-paralleling device. All films were developed using the same automatic processor** following the manufacturer's instructions. The radiographs were digitized using a computerized scanner†† at 2,400 dots per inch and 256 grayscale.

The following procedure was performed with a 1,280 × 1,024 resolution monitor and software‡‡ in a darkened room. A virtual horizontal line (Lp) was drawn perpendicular to the axis of the implant fixture, passing through the papilla top. The distance between Lp and the most coronal point of the alveolar bone contacting the implant surface was measured (Di); the corresponding dimension on the natural tooth side (Dt) was also measured. The soft tissue dimension of interproximal papilla (Ph) was determined by measuring the shortest distance from the top of the papilla to the alveolar bone (Figs. 1 and 2). The papilla fill was recorded as 1 if the radiopaque material reached the contact point; otherwise, it was recorded as 0. The distance from the contact point to the crestal bone was also measured. The marginal implant bone level was determined from the reference point to the lowest point of contact of the bone with the fixture. The reference point was the border between the rough and machined fixture surfaces.

All measurements were performed by a single operator. Prior to the investigation, intraobserver variability was tested under the supervision of the director. Computer-assisted measurements of 50 periapical films with natural teeth and implants, in which radiopaque material was placed on the papilla tips, were performed twice, 1 week apart. A paired *t* test revealed no significant difference between the first and second measurements, with a standard deviation of 0.15 mm between them. Pearson correlation

§ MicroThread, Astra Tech, Mölndal, Sweden.
‖ Williams PW, Hu-Friedy, Chicago, IL.
¶ Kodak Insight, film speed F, Kodak, Rochester, NY.
# Tubli-Seal, Kerr Dental, Orange, CA.
** Periomat, Dürr Dental, Bietigheim-Bissingen, Germany.
†† Expression 1680 Pro, EPSON, Nagano, Japan.
‡‡ Photoshop 7.0, Adobe, San Jose, CA.

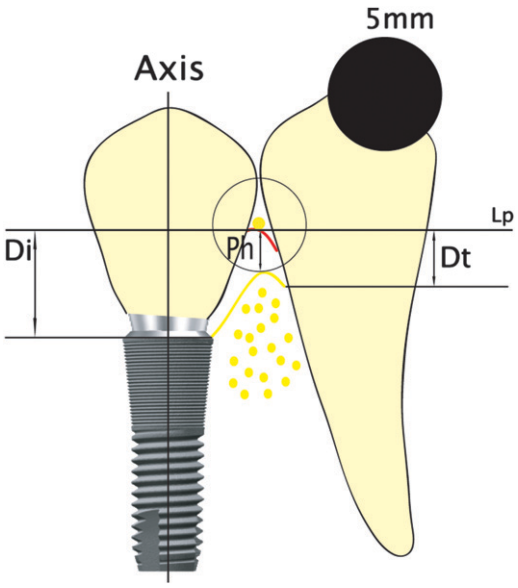

Figure 1.
The relationship between the implant and the natural tooth. Axis = the axis of the fixture; Lp = line perpendicular to the axis of the implant fixture passing through the lowest point (papillary top) of the radiopaque material; Dt = distance from the highest point of the alveolar bone contacting the adjacent tooth surface to Lp; Di = distance from the highest point of the alveolar bone contacting the implant surface to Lp; Ph = papilla height; shortest distance from the top of the papilla to the alveolar ridge.

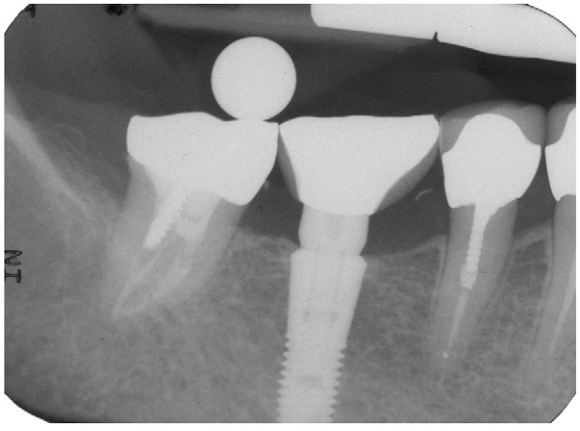

Figure 2.
Radiograph showing radiopaque material on the tip of the papilla.

coefficients revealed that measurements 1 and 2 were significantly correlated with each other (Pearson correlation coefficient = 0.97; $P<0.001$). The intraobserver variability and correlation coefficients are comparable to those of previous studies.[17,18]

Distances were measured in pixels and converted into millimeters by measuring the known diameter of the metal ball in the radiograph in pixels. The diameter of the ball was measured parallel to the implant axis to minimize horizontal distortion.

Statistical Analyses

A pilot study using periapical radiographs from 10 patients showed a mean difference between Di and Dt of 1.1 mm, with standard deviations of 2.0 (Di) and 0.5 (Dt) mm. Using a statistical program,[§§] these data revealed a required sample size ≥28. After collecting all data (30 pairs), the normality was tested using the Kolmogorov-Smirnov test, which revealed normal distributions for Di, Dt, and Ph. Because Di and Dt showed unequal variance (F test; $P<0.001$), the Welch test was used for mean comparisons.

Statistical analyses included descriptive statistics for clinical/radiographic parameters; comparisons of the Di and Dt means using the Welch test; correlations among Dt, Ph, and Di using the Pearson correlation coefficient; and multiple linear regression analyses to determine whether Di or Dt had a significant influence on Ph. Linear models were constructed with Ph as the dependent variable and Di and Dt as explanatory variables. All calculations were performed on a personal computer with a statistical program.[||||]

RESULTS

The mean mesial, distal, buccal (labial), and lingual (palatal) plaque and sulcus bleeding index scores are summarized in Table 3. The mean width of the keratinized mucosa on the buccal side of the crown was 3.60 ± 1.52 mm. The data from one patient whose sulcus bleeding index score was 2 at the proximal surface were discarded. In 16 of 17 sites, the width of the keratinized mucosa was >2 mm. The width of the remaining site was 0.5 mm, but there was no sign of inflammation. The mean marginal bone loss of 16 implants was 0.16 ± 0.17 mm (Table 4). The mean values for Di, Dt, and Ph were 5.41 ± 1.62 mm, 3.26 ± 0.78 mm, and 3.45 ± 1.11 mm, respectively (Tables 5 and 6; Fig. 3). Perfect papilla fill was observed in nine of 30 papillae (30%). The mean distance from the contact to the crestal bone in cases of perfect papilla fill was 4.88 ± 0.95 mm. In cases of imperfect papilla fill, the mean distance was 6.15 ± 1.29 mm. There were statistically significant positive correlations between Di and Ph (r = 0.413; $P = 0.023$) and between Dt and Ph (r = 0.830; $P<0.0001$; Table 7). However, multiple regression analysis showed that only Dt had a significant influence on Ph ($P = 0.0001$ versus $P = 0.538$; Table 8).

DISCUSSION

We examined the influence of the tooth and implant-side marginal bone levels on the vertical dimension of

§§ MedCalc 9.3, MedCalc Software, Mariakerke, Belgium.
|||| SPSS for Windows, release 13.0, SPSS, Chicago, IL.

Table 3.

Frequencies of Surfaces With Plaque Accumulation and Bleeding on Probing and Plaque Index Scores and Sulcus Bleeding Index Scores

Examined Implant Surface	Plaque Accumulation (%)	Bleeding on Probing (%)	Plaque Index Score (mean ± SD)	Sulcus Bleeding Index Score (mean ± SD)
Mesial	11.8	29.4	0.12 ± 0.33	0.35 ± 0.60
Distal	11.8	29.4	0.12 ± 0.33	0.35 ± 0.60
Buccal	23.5	29.4	0.29 ± 0.59	0.41 ± 0.71
Lingual	35.3	17.6	0.41 ± 0.62	0.24 ± 0.56
Average	20.6	26.5	0.24 ± 0.49	0.34 ± 0.61

Table 4.

Marginal Bone Loss of Implants in Examined Subjects

Subject	Mesial (mm)	Distal (mm)
1	0	0.13
2	0.5	0
3	0.1	0.1
4	0.1	0.1
5	0.2	0.2
6*	0.3	
7	0	0
8	0.4	0.5
9*	0.2	
10	0.1	0.3
11	0.1	0.1
12	0	0
13	0	0
14	0.6	0.3
15	0	0
16	0.4	0.06
Mean	0.16	
Median	0.10	
SD	0.17	

* Implants at second molar, thus no distal interproximal papilla was present.

the interproximal soft tissue in single-implant restorations. Although the implant-side bone level showed a simple correlation with the interproximal soft tissue dimension, the tooth-side bone level was the dominant factor.

Subjects enrolled in the present study had plaque indices that were comparable to those in previous studies.[19,20] Except for one restoration with high indices, for which the data were discarded, the oral hygiene indices of the proximal surfaces were fairly good. Thus, the possible effect of inflammatory mucosal deformation on the proximal sites could be ruled out when measuring the dimensions of the peri-implant soft tissue. Furthermore, we observed that plaque accumulated more on the lingual surfaces than on the proximal surfaces. This seemed to stem from good patient compliance with regular follow-up visits and the strict usage of interdental brushes that fit the individual spaces.

The use of radiographic analysis can lead to a false diagnosis when analyzing small peri-implant bone-level changes.[21] The accuracy of using the thread pitch distance as an internal reference is reported as being within 0.3 mm.[22] However, because the difference between Di and Dt was ~2 mm, periapical radiographs could be used for analysis with confidence.

The mean value of Ph was 3.45 mm. This value seems to be short for a papilla next to a natural tooth compared to that reported previously for maxillary anterior teeth (3.76 to 4.46 mm).[6] However, the present study measured the shortest distance from the interproximal crestal bone tip to the papilla tip, whereas the previous study measured the distance from the tooth-side marginal bone to the interproximal papilla tip. This methodologic difference might have caused discrepancies between the values. Additionally, the implants in the present study were mostly in premolar and molar positions (Table 2). Only one implant was in the anterior sextant. In contrast, the implants in the previous studies[5,6,8] were at maxillary anterior sites. Also, we recommended the strict use of an interproximal brush, which might have caused limited and restricted papilla formation after prosthesis delivery.[7]

Perfect papilla fill was observed in 30% of the subjects. The mean distance from the contact to the crestal bone in cases of perfect papilla fill was 4.88 ± 0.95 mm. To the contrary, in cases of imperfect papilla fill, the mean distance was 6.15 ± 1.29 mm. This

Table 5.

Radiographic Measurements of All Variables

Papilla	Ph (mm)	Papilla Fill*	Contact Point - Crestal Bone (mm)	Dt (mm)	Di (mm)
1	3.96	1	5.7	3.67	5.02
2	4.29	1	5.1	4.63	4.54
3	2.41	1	3.3	2.5	3.96
4	2.7	1	3.3	2.8	3.09
5	4.17	0	7.13	4.17	6.83
6	4.69	1	5.6	4.36	5.03
7	2.89	0	5	2.89	5.3
8	3.57	0	7.2	3.09	4.05
9	2.56	0	4.7	2.41	5.11
10	2.65	0	3.5	2.8	3.86
11	7.82	1	5.08	4.73	7.52
12	2.37	0	5.7	2.37	4.55
13	2.94	0	6.6	3.03	2.84
14	4.82	1	4.7	4.82	7.72
15	4.92	1	5.5	4.92	6.46
16	3.89	0	5.8	2.8	3.96
17	2.7	0	5.6	2.66	7.59
18	3.89	0	7.7	3.41	6.26
19	2.36	0	5.12	2.7	4.15
20	2.46	0	5.85	2.6	4.25
21	3.04	0	5.8	2.95	6.68
22	2.55	0	5.4	2.55	6.29
23	3.04	0	6.4	2.12	4.44
24	3.38	0	5.6	3.09	4.05
25	3.03	1	5.6	2.84	5.31
26	2.75	0	5.8	3.22	4.17
27	3.44	0	6.8	3.44	6.58
28	3.34	0	6.7	3.34	4.91
29	3.41	0	9.9	3.41	8.63
30	3.6	0	6.8	3.5	9.1

* Papilla fill: 1 = perfect papilla fill; 0 = imperfect papilla fill.

Table 6.

Descriptive Statistics for Ph, Dt, and Di

	n	Mean	SD	Kolmogorov-Smirnov Test	Welch Test
Ph	30	3.45	1.11	$P = 0.373$*	
Dt	30	3.26	0.78	$P = 0.451$*	$P < 0.000$†
Di	30	5.41	1.62	$P = 0.414$*	

* Accept normality of the distribution of data ($P > 0.05$).
† Performed only with Dt/Di.

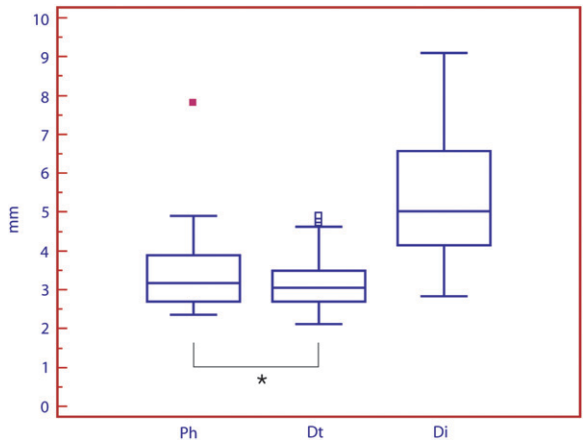

Figure 3.
*Box plot showing the mean values of Di, Dt, and Ph from 16 implants. *P <0.0001 for the influence of Dt on Ph. Small boxes represent the outside value that is defined as a value larger than the upper quartile plus 1.5 times the interquartile range.*

confirmed the previous result that the papilla of the single-tooth implant was present almost 100% of the time if the distance from the contact point to the crest of bone was ≤5 mm.[8]

Of the three bone levels in the proximal area of a single-implant restoration (tooth side, crestal, and implant side), the tooth-side bone level is reported to be the most important factor for the presence of the papilla when flat-top implants¶¶ are used.[5,8] A study[11] showed that, in single flat-top implants,## the presence of the papilla correlated with all three bone levels (the distance from the contact point to the bone at the crest and implant and along the adjacent tooth). However, the distance from the contact point to the tooth bone level was the most discriminating factor.

We found that Di and Ph were positively correlated with one another (r = 0.413; $P = 0.023$; Table 7). This result seems contradictory to the previous finding that the level of the interproximal papilla of a single

¶¶ Brånemark Implant System, Nobel Biocare, Gothenburg, Sweden.
Steri-Oss, Nobel Biocare, Yorba Linda, CA/Spline, Zimmer Dental, Carlsbad, CA.

Table 7.

Correlation Between Radiographic Parameters

		Dt	Ph
Di	Correlation coefficient	0.426	0.413
	Significance (two-tailed)	0.019*	0.023*
	n	30	30
Dt	Correlation coefficient		0.830
	Significance (two-tailed)		<0.0001*
	n		30

* $P < 0.05$.

Table 8.

Multiple Linear Regression to Determine Factors Influencing Ph

Independent Variables	Coefficient	Standard Error	*P* Value
Di	0.050	0.081	0.538
Dt	1.137	0.168	<0.0001
Coefficient determination $R^2 = 0.6928$			

implant is independent of the proximal bone level next to the implant and relates only to the interproximal bone level next to the adjacent teeth.[5,8] However, despite the positive correlation between Di and Ph, the dominating factor for Ph was Dt ($P = 0.000$; Table 8). Our model explained 69% of the variability, and Di did not significantly influence Ph ($P = 0.538$). Thus, the previous finding that the interproximal papilla dimension is related to the tooth-side bone level was confirmed statistically using a non-invasive soft tissue measuring method with microthread and conical seal designed fixtures.

The simple correlation between Di and Ph in the present study might have been due to a reduced marginal bone loss around fixtures. There were significant differences between the implant system used in the present study and those used in previous studies.[23-27] The marginal bone loss with a flat-top implant is 1.0 to 1.3 mm at 1 year, even with an improved surface.[23-25] In contrast, marginal bone loss with microthread, conical seal, and platform-switched design is 0.11 to 0.24 mm.[26,27] The marginal bone levels of the subjects in this study (0.16 ± 0.17 mm) were comparable to those of previous studies.[26,27]

Also, the position of the implants might have influenced the correlation. The degree of bony scallop is known to be flatter in the posterior regions, and it becomes more convex in the maxillary anterior region.[28] Because most of the subjects had a single implant at the premolar/molar sites, the influence of the tooth-side bone level might be less than in the previous studies.[5,8]

We could not confirm that the Di/Ph simple correlation was due to reduced marginal bone loss because identical statistical analyses for correlation were not performed in previous studies.[5,8,9] Assuming that the marginal bone loss of an implant is minimal, then the difference between the tooth and implant bone levels would be minimized. In extreme cases, where the marginal bone level of the implant is equivalent to the tooth-side level, the correlation between the papilla dimension and the implant or tooth-side marginal bone level would be similar. However, this scenario is unlikely to have occurred in the present subjects because periodontal disease was the primary cause for the extraction (14 of 17 patients). When a tooth is extracted because of periodontal disease, the surrounding bone is destroyed, making it difficult to completely recover the initial preextraction bone level. Therefore, the bone level of the residual dentition is more coronal than the extracted site. Thus, although there is minimal bone resorption of the marginal bone around the fixtures, the inherent difference in the marginal bone level between the natural tooth and the implant is considerable. This could make Dt the dominant factor that influences Ph. However, it is imperative that identical analyses be performed on non-periodontally compromised dentition.

CONCLUSIONS

In the present study, the tooth-side bone level was the dominant factor that affected the interproximal soft tissue between a natural tooth and a single implant with microthread, conical seal, and platform-switched design. Better marginal bone preservation due to implant design features did not have an effect on the height of the interproximal soft tissues in the present study, in which most extracted teeth that were replaced with an implant had been affected by periodontal disease. Thus, preserving the alveolar bone on the tooth side is of utmost importance from an esthetic perspective.

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Drs. Hee-Jun Kwon and Dong-Won Lee contributed equally to the research and should be considered co-first authors. The authors report no conflicts of interest related to this case series.

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