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## Comparison of interproximal soft tissue height for single implants and contra-lateral natural teeth

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**Key words:** contra-lateral, interproximal papilla, non-invasive papilla measuring, periodontitis, single implant, soft tissue thickness

### Abstract

**Objective:** To compare the interproximal soft tissue dimensions adjacent to single implant restorations in the premolar–molar position with those adjacent to the contra-lateral natural teeth.

**Material and methods:** Twenty-five patients with a single-tooth implant in premolar–molar position and healthy contra-lateral teeth were enrolled in this retrospective cross-sectional study. The reason for the extraction was periodontitis. Radiographs were used to measure the shortest distance from the tip of the papilla to the crestal bone in single implants and contra-lateral teeth. A Wilcoxon's signed-ranks test was used to examine the differences between the interproximal soft tissue dimensions adjacent to the single-tooth implant restorations (IS-STI) from those of the contra-lateral natural teeth (IS-NT).

**Results:** We found no significant difference between the mesial IS-STI and the mesial IS-NT ( $3.28 \pm 0.83/3.31 \pm 0.62$ ;  $P=0.861$ ), or between the distal IS-STI and the distal IS-NT ( $3.09 \pm 0.72/3.3 \pm 0.63$ ;  $P=0.263$ ).

**Conclusions:** The interproximal soft tissue height adjacent to single-implant-supported restorations in the premolar–molar position is similar to that adjacent to the contra-lateral natural teeth.

A previous study (Chang et al. 1999) compared interproximal soft tissue dimensions adjacent to single implants with those of the contra-lateral teeth in the anterior maxilla. The vertical dimension of the interdental papilla was determined by measuring the distance between the coronal tip of the papilla and a line connecting the most apical points of the gingival margin at the mid-buccal points of the adjacent teeth (Olsson et al. 1993). A non-invasive alternative to this measurement technique has been proposed by Lee et al. (2005a), who used radiography to measure the distance from the tip of the papilla to the crestal bone.

The height of alveolar bone at the extraction site, instead of at adjacent teeth, has been reported to confine the level of bone fill after an extraction (Schropp et al. 2003). Therefore, in cases of extraction due to periodontitis, the level of bone fill in an extraction socket would be apical to the height of alveolar bone level of the adjacent teeth. A lower bone level in edentulous areas would naturally lead to the apical position of an implant, in cases where no vertical bone augmentation is performed. Although vertical differences in the implant positions do not affect bony changes between the implant and the adjacent teeth (Cardaropoli et al. 2003), an apically

### Date:

Accepted 15 March 2009

### To cite this article:

Lee D-W, Huh J-K, Park K-H, Chai J-K, Kim C-K, Moon I-S. Comparison of interproximal soft tissue height for single implants and contra-lateral natural teeth. *Clin. Oral Impl. Res.* 20, 2009; 1320–1325.  
 doi: 10.1111/j.1600-0501.2009.01737.x

positioned implant might affect the dimensions of the interproximal soft tissue in this region. This is because the position of the soft tissue margin is determined by alveolar height and the thickness of the supra-crestal soft tissue (Bengazi et al. 1996).

This study compared interproximal soft tissue height, defined as the distance from the tip of the papilla to the crestal bone, at single implants with that at the contra-lateral natural teeth among patients with an apically placed implant.

## Material and methods

### Patient selection

The participants in this study were patients diagnosed with chronic periodontitis, who had received periodontal flap operation and implant surgery to the premolar and molar areas at the Department of Periodontology, Gangnam Severance Dental Hospital (College of Dentistry, Yonsei University, Seoul, Korea), between February 2001 and November 2005. In total, 12 males and 13 females with a mean age of 53.2 years (range 39–69 years) were enrolled in this study. The study protocol was approved by the Yonsei University Institutional Review Board, at the Yonsei University Health System Clinical Trial Center. Informed consent was obtained from all subjects.

The exclusion criteria were as follows: (1) need for extraction of contra-lateral teeth; (2) use of any medication known to affect the periodontal soft tissues; (3) a history of soft tissue graft on the implant or contra-lateral side; and (4) an over-contoured crown on the contra-lateral side.

At the time of selection, the patients showed good general health, and had been treated for existing moderate to severe chronic periodontal disease. The diagnostic criteria followed the 1999 classification standards for periodontal disease (Armitage 1999). The patients received initial therapy including oral hygiene instruction, scaling and root planing and subsequent corrective therapy including extraction and periodontal flap surgery.

Implantation was performed at least 3 months after corrective therapy, and was dependent on patient demonstration of good self-performed plaque control. The participants had a single-implant-supported, fixed prosthesis for more than



Fig. 1. Panoramic radiograph of a patient in this study.

**Table 1. Distribution of the installed implants**

Jaw	Placed site														Total
	7	6	5	4	3	2	1	1	2	3	4	5	6	7	
Maxilla	1	3	1	2							1	2	1	1	12
Mandible		4									2		2	5	13
	1	7	1	2							3	2	3	6	25

12 months ( $2 \pm 0.73$  years). On the contra-lateral side of the implant, the natural teeth were also treated using a periodontal flap procedure (Fig. 1).

### Treatment procedure

The implants (17 AstraTech ST™, 8 Astra-Tech Fixture Microthread™, Astra-Tech AB, Mölndal, Sweden) were installed in the premolar and molar regions (Table 1). No vertical bone augmentation procedures were performed. A second surgery procedure was performed after a healing period of 3 months for mandibular and 6 months for maxillary implants. Crestal incisions were used to uncover the fixtures. No additional soft tissue grafting was performed. Prostheses were placed 4 weeks after the second surgery. All patients received oral hygiene instructions for the individual implant prosthesis and natural teeth, which included education on the use of interproximal brushes of various sizes. The patients were recalled every 3 months for thorough professional plaque control and repeated oral hygiene education.

### Follow-up parameters

The following clinical variables were recorded at the baseline examination (placement of the prosthesis) and at annual follow-up examinations (Lee et al. 2007): (1) pain from the implant region; (2) implant stability; (3) plaque accumulation [modified plaque index (mPI), Mombelli et al. 1987] at four aspects on the implant

and adjacent teeth and on the contra-lateral and adjacent teeth; (4) gingival inflammation [modified sulcus bleeding index (mBI), Mombelli et al. 1987] at four aspects on the implant and adjacent teeth and on the contra-lateral and adjacent teeth; and (5) suprastructure complications.

Clinical examinations were performed at least 1 year after prosthesis delivery. Patients with inflamed mucosa around the implants showing a bleeding tendency and plaque accumulation were excluded (mPI and mBI > 2). The excluded patients were re-instructed on proper oral hygiene and reexamined during another session. They were included in the data sets if these symptoms had subsided.

The dimension of the interproximal soft tissue can be affected by the plaque accumulation as well as the gingival status of the mesial and distal aspects of the examined papilla. Therefore, the mPI and mBI (Mombelli et al. 1987) were recorded for the mesial and distal sides of the examined interproximal soft tissue. The highest index scores were selected to represent each patient in a statistical comparison between the implant side and the contra-lateral side (Table 3).

### Radiographic examination

A previously described (Lee et al. 2005a, 2005b, 2006) non-invasive method for measuring the distance from the tip of the papilla to the crestal bone was applied to both the natural teeth and the implants.

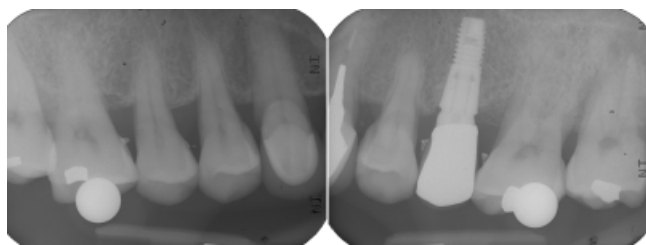


Fig. 2. Periapical view with radiopaque material applied at the tip of the papilla.

Briefly, a radiopaque material consisting of a 2 : 1 mixture of an endodontic sealer and barium sulfate was placed at the tip of the papilla using a probe. A periapical radiograph (Kodak Insight, film speed F, Rochester, NY, USA) was taken (70 KVp, 10 mA, Yoshida REX 601, Tokyo, Japan) (Wyatt et al. 2001) using a parallel cone technique with an XCP device (XCP Kit, Rinn, Elgin, IL, USA). A 5 mm metal ball bearing (X-ray Distortion Markers, Salvin Dental Specialties, Charlotte, NC, USA) was attached to both the implant and the contra-lateral tooth sides for calibration. All films were developed using the same automatic processor (Periomat, Dür Dental, Bietigheim-Bissingen, Germany) according to the manufacturer's instructions. The radiographs were scanned (Expression 1080 Pro, Epson, Nagano, Japan) at 1200 dpi in an 8-bit gray scale (Fig. 2).

**Measurement of interproximal soft tissue height**

After digitization, the files were transferred to a personal computer (processor, Intel Pentium 2.4 GHz, Santa Clara, CA, USA; operating system: Windows 2000, Redmond, WA, USA) and examined using the same monitor (Flatron LCD, LG, Seoul, Korea), which was set to a resolution of 1400 × 1050 pixels. The room was darkened during the computer-assisted radiographic measurements (Lee et al. 2005a, 2005b).

Calibration was carried out using the known thread pitch of the fixture. The known diameter of the metal ball was used for calibration when the thread was not clearly visible. The shortest length between the crestal bone and the tip of the papilla was calculated using the following procedure. Concentric circles were drawn with their centers on the lowest border of the radiopaque material. The first contact of a circle's diameter with the

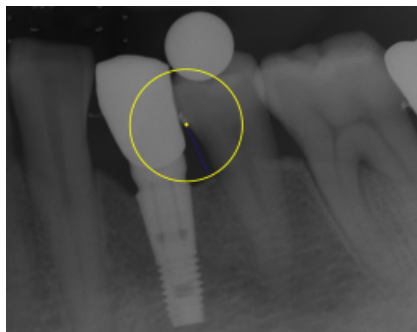


Fig. 3. Computer-aided measurement. Note the circle with its center at the lowest border of the radiopaque material.

crestal bone was marked (Fig. 3). The distance between the lowest border of the radiopaque material and the marked first contact with the crestal bone was measured to the nearest 0.01 mm using Image J (US National Institutes of Health, Bethesda, MD, USA). All radiographic measurements were made by a single calibrated examiner (D.W.L.), and intra-observer variability was tested under the supervision of the director (I.S.M.). Measurements of 30 randomly selected periapical films showing natural teeth and implants were made at times 1 and 2 (interval of 1 week). Paired *t*-tests and Pearson's correlation coefficients were used to assess the statistical significance of the differences between the first and the second measurements. The standard deviation (SD) between the first and the second measurements was 0.12 mm, and paired *t*-tests showed no significant difference. There was a significant correlation between the measurements at times 1 and 2 (Pearson's correlation coefficient = 0.94, *P* < 0.001). The intra-observer variability and correlation coefficients were comparable to those reported elsewhere (Weber et al. 1992; Wyatt et al. 2001).

The length between the crestal bone and the tip of the papillae was measured on the mesial and distal sides of the

**Table 2** Dimensions from the tip of the papilla to the crestal bone

Subject	mIS-STI	mIS-NT	dIS-STI	dIS-NT
1	3.89	3.37	2.47	3.45
2	3.12	3.97	3.54	4.25
3	3.04	3.41	3.69	3.49
4	2.25	2.77	2.57	4.71
5	3.75	3.58	3.24	3.67
6	3.95	3.73	3.07	2.8
7	3.39	2.94	2.65	3.19
8	2.81	2.7	4.55	3.12
9	3.2	3.24	2.48	2.36
10	3.29	3.06	3.29	2.97
11	3.66	3.82	2.51	2.97
12	3.22	3.01	2.17	3.13
13	2.58	3.12	2.83	3.61
14	4.05	3.91	2.01	2.9
15	2.36	2.27	3.4	2.77
16	2.39	2.97	4.13	2.53
17	2.61	2.55	3.96	4.19
18	2.69	3.63		
19	2.29	3.87		
20	3.01	3.47		
21	2.58	2		
22	2.94	2.91		
23	4.43	3.36		
24	5.16	4.54		
25	5.3	4.49		

mIS-STI, length between the crestal bone and the tip of the papillae on the mesial side of the single tooth implant; mIS-NT, length between the crestal bone and the tip of the papillae on the mesial side of the contra-lateral natural teeth; dIS-STI, length between the crestal bone and the tip of the papillae on the distal side of the single tooth implant; dIS-NT, length between the crestal bone and the tip of the papillae on the distal side of the contra-lateral natural teeth.

implants (mIS-STI, dIS-STI) and contra-lateral natural teeth (mIS-NT, dIS-NT, Fig. 4, Table 2).

**Measurement of vertical distances between the implant and the adjacent tooth and between the contra-lateral and adjacent tooth**

The marginal bone heights at the implant and the adjacent tooth were measured (mesial and distal vertical implant-tooth distance, mV-STI, dV-STI) using the same computer software to determine whether the implants had been installed apically compared with the contra-lateral side. Two virtual horizontal lines were drawn perpendicular to the axis of the fixture passing through: (1) the marginal bone level at the implant and (2) the most coronal bone height of the natural tooth, where the width of the periodontal ligament space was considered normal (Cardaropoli et al. 2003). The shortest distance

**Table 3. Statistical values of the measured variables**

	Mean $\pm$ SD	Median	95% Confidence interval for the median	Non-parametric test ( <i>P</i> -value)
mPI-STI	0.36 $\pm$ 0.49	0	0–1	0.339
mPI-NT	0.2 $\pm$ 0.41	0	0–0	
dPI-STI	0.24 $\pm$ 0.44	0	0–0.68	0.8125
dPI-NT	0.18 $\pm$ 0.39	0	0–0	
mBI-STI	0.16 $\pm$ 0.37	0	0–0	0.547
mBI-NT	0.24 $\pm$ 0.44	0	0–0	
dBI-STI	0.18 $\pm$ 0.39	0	0–0	0.375
dBI-NT	0.35 $\pm$ 0.49	0	0–1	
mV-STI	1.7 $\pm$ 0.69	1.59	1.26–1.88	0*
mV-NT	0.57 $\pm$ 0.32	0.5	0.3–0.77	
dV-STI	1.41 $\pm$ 0.66	1.3	0.82–1.7	0.0001*
dV-NT	0.41 $\pm$ 0.39	0.4	0.13–0.67	
mIS-STI	3.28 $\pm$ 0.83	3.12	2.64–3.72	0.861
mIS-NT	3.31 $\pm$ 0.62	3.36	2.95–3.69	
dIS-STI	3.09 $\pm$ 0.72	3.07	2.49–3.64	0.263
dIS-NT	3.3 $\pm$ 0.63	3.13	2.83–3.65	

\**P* < 0.05 (two-tailed).

mPI-STI(dPI-STI), modified Plaque Index score on the mesial (distal) papilla of the single tooth implant; mPI-NT(dPI-NT), modified Plaque Index on the mesial (distal) papilla of the contra-lateral natural teeth; mBI-STI(dBI-STI), modified Bleeding Index on the mesial (distal) papilla of the single tooth implant; mBI-NT(dBI-NT), modified Bleeding Index on the mesial (distal) papilla of the contra-lateral natural teeth; mV-STI(dV-STI), mesial (distal) vertical implant-tooth distance; mV-NT(dV-NT), mesial (distal) vertical tooth-tooth distance; mIS-STI, length between the crestal bone and the tip of the papillae on the mesial side of the single tooth implant; mIS-NT, length between the crestal bone and the tip of the papillae on the mesial side of the contra-lateral natural teeth; dIS-STI, length between the crestal bone and the tip of the papillae on the distal side of the single tooth implant; dIS-NT, length between the crestal bone and the tip of the papillae on the distal side of the contra-lateral natural teeth.

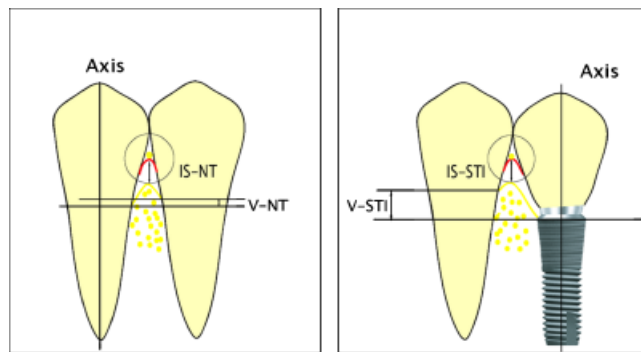


Fig. 4. Schematic presentation of the measurements. IS-NT, length between the crestal bone and the tip of the papilla on the contra-lateral natural teeth; IS-STI, length between the crestal bone and the tip of the papilla on the single tooth implant; V-NT, vertical tooth-to-tooth distance; V-STI, vertical implant-to-tooth distance.

between these two lines was taken. The difference in height between the two marginal bone levels of the contra-lateral and adjacent teeth was also measured (mesial and distal vertical tooth to tooth distance, mV-NT, dV-NT; Fig. 4).

#### Statistical analysis

Statistical analysis included descriptive statistics for the clinical and radiographic measurements of the implants and contra-lateral teeth. The statistical unit to be analyzed was a matched pair of implants

with the contra-lateral tooth (Karoussis et al. 2004).

The results of a pilot study with 10 patients applying the same protocols were used to make a sample calculation. Among them, the IS-NT and IS-STI showed SD of 0.6 and 0.5 mm, respectively. We set  $\alpha = 0.05$  and  $\beta = 0.20$  and hypothesized the mean difference as 0.5 mm. The MedCalc sample size calculating process (MedCalc Software, version 9.3, Mariakerke, Belgium) indicated that 20 samples would be needed to make a non-parametric statistical comparison.

The hypotheses to be tested were: there would be no difference between (1) mPI-STI and mPI-NT, (2) dPI-STI and dPI-NT, (3) mBI-STI and mBI-NT, (4) dBI-STI and dBI-NT, (5) mV-STI and mV-NT, (6) dV-STI and dV-NT, (7) mIS-STI and mIS-NT and (8) dIS-STI and dIS-NT.

The Wilcoxon signed-rank test was used to examine the differences between paired variables (MedCalc Software, version 9.3). A *P*-value < 0.05 was considered statistically significant.

## Results

No notable complications were encountered during the observation period. No patient suffered from pain or implant mobility. Table 3 shows the overall means and medians of the clinical parameters and the results of the non-parametric comparisons of the means. No significant differences were found in the plaque and bleeding indices between the mesial and the distal aspects of the interproximal soft tissue at a single implant and those at the contra-lateral tooth. There was a significant difference between V-STI and V-NT (both mesial and distal sides), indicating that the implants were installed apically compared with the positions of the contra-lateral natural teeth. The interproximal soft tissue dimensions of the single-tooth implant and contra-lateral natural tooth (both mesial and distal sides) were not significantly different.

## Discussion

The peri-implant bone level is known to be positioned more apical, when implants are inserted in an apical to crestal position (Hämmerle et al. 1996; Pontes et al. 2008). However, the height of the peri-implant soft tissue of apically positioned implants has been reported to be similar to that of implants inserted at the crestal bone level (Pontes et al. 2008). Periodontitis was the sole reason for extracting teeth from the patients in the present study. Most implants were positioned rather apically, as indicated by the difference between the V-STI and V-NT. However, the apical positioning of the implant did not result in a significant difference in interproximal soft tissue dimensions compared with that

of the contra-lateral tooth. These results thus confirm those reported by a previous investigation (Pontes et al. 2008).

Since Chang et al.'s (1999) study compared the interproximal soft tissue of the anterior dentition, direct comparison with the results of the present study would be difficult. While the present study compared the height of the interproximal soft tissue, Chang et al. (1999) compared the clinical dimensions of the papilla, which were measured from the mid-facial margin to the tip of the papilla. In addition, the present study was performed on posterior single-tooth implants, while the previous study (Chang et al. 1999) examined maxillary anterior single-tooth implants. However, both studies confirmed that in single-implant therapy, the interproximal soft tissue between the natural tooth and the single implant appeared to be of similar height as the interproximal soft tissue on the contra-lateral side.

The reason for this result is unclear. However, there are some possible explanations. The transseptal fiber group and other groups of collagen fiber bundles reinforce the gingiva and provide resilience (Lindhe et al. 2008). Although direct fibrous attachment to the titanium surface is rarely observed in the animal studies, the peri-implant fiber bundles originated from the neighboring alveolar crest, gingival papillae and root cementum of the teeth adjacent to the implant surface (Ruggeri et al. 1992, 1994). In addition, transseptal fibers have been observed to regenerate in humans and animals, even after being destroyed by the extraction of a tooth (Chase & Revesz

1944). Therefore, we assumed in this study that transseptal fibers would be present in the case of single-implant therapy, even though they might not be embedded in the implant surface.

The measurement protocol of the interproximal soft tissue recorded the shortest distance from the tip of the papilla to the underlying bone. Therefore, in most situations, soft tissue height at the single implant sites was more similar to the bone level at the adjacent tooth surface. This protocol might be one reason for the dimensional similarity observed in this study.

The legitimacy of using the contra-lateral side as a control relies on the significant degree of symmetry in alveolar bone loss and other clinical parameters found between the left and the right sides of the dentition in patients with current or prior experience of periodontal disease (Mombelli & Meier 2001; Persson et al. 2003). Hence, the contra-lateral side of a single implant site would show similar alveolar bone loss. In addition, the plaque and bleeding index scores for both sides showed similar clinical conditions, ruling out the possibility of localized gingival or peri-implant mucosal inflammation.

The dimensions of the soft tissue near single implants observed in this study were smaller than the results of previous studies (Grunder 2000; Choquet et al. 2001) that investigated single implants in the anterior dentition. The reasons for this difference are: (1) the subjects of the present study were treated with a flap operation before the surgery; and (2) no additional soft tissue grafting procedures were performed. In con-

trast, previous studies (Grunder 2000; Choquet et al. 2001) performed additional soft tissue grafting. In addition, the previous periodontal flap operation in the current study might have reduced the dimension. The effect of surgical intervention on the dimensions of the papilla has been investigated (Velvart et al. 2004). A full raise of the papilla is known to decrease papilla dimensions, even when performed only buccally. Therefore, the dimensions of the subjects in this study would be lower due to a previous periodontal flap operation.

The main limitation of this study was the small sample size. The number of distal papillae analyzed was 17, while the proper sample size was estimated to be 20. This reduced the statistical power of the present study. As all subjects enrolled were patients affected by periodontitis, it was difficult to find patients with periodontally sound contra-lateral teeth. Therefore, increasing the sample size and performing a prospective-comparative study would be necessary for future investigations.

In conclusion, these results suggest that the interproximal soft tissues around a single implant and contra-lateral natural teeth have similar vertical dimensions. Although the origin of the supporting structure for the interproximal soft tissue differs for natural teeth and implants, there was no dimensional disparity between the two parameters.

**Acknowledgements:** This work was supported by the New Faculty Research Grant of Yonsei University (6-2009-0018).

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