The Role of Implant-Tooth Distance on Marginal Bone Levels and Esthetics

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Purpose: The peri-implant bone and mucosa architecture contribute to the health and esthetics of single-tooth dental implants. The implant-tooth distance (ITD) has been regarded as a key determinant of their outcomes. This study was conducted to determine the relationship between ITD and peri-implant bone, mucosa, and pink esthetic scores (PES) for anterior single-tooth implants. Materials and Methods: For 44 dental implants with a microthread conical abutment interface design placed in 38 participants, periapical radiographs and photographs were evaluated at 1 and 4 years to assess interproximal bone levels and PES. Results: Mean mesial and distal marginal bone level change over 4 years was 0.20 ± 1.00 mm and 0.20 ± 0.74 mm, respectively. In this cohort, there was no relationship between ITD and interproximal bone changes or papilla fill at 4 years; however, marginal bone changes influenced PES score—the smaller the ITD, the lower the PES (P < .001). Alone, ITD did not influence marginal bone levels or papilla in this cohort. Conclusion: These results imply a complex relationship between ITD, marginal bone levels, and PES scores for single-tooth implants. Int J Oral Maxillofac Implants 2019;34:499–505. doi: 10.11607/jomi.6809

Keywords: implant-tooth distance, marginal bone loss, pink esthetic score, single tooth dental implant

A missing anterior tooth has a profound effect on the social and psychologic health of an individual.1–3 Fixed tooth replacement in the esthetic zone is not only important for self-esteem but also associated with social perceptions of an individual’s well-being.4–7 The esthetic value of an anterior single-tooth implant is a critical factor in determining treatment success. There are, however, unintended esthetic complications associated with implant placement including alterations in buccal mucosal and interproximal papilla form.8 The measurement of single-tooth implant esthetics has been quantified using several different objective clinical rating scores including the Implant Crown Aesthetic Index (ICAI) and the pink esthetic score (PES).9,10 Both the ICAI and the PES highlight the importance of the peri-implant mucosal architecture upon the esthetic outcome of single-tooth implant restorations. While clinicians appear to be harsher judges of the objective clinical esthetic ratings for implants, patients and laypeople do recognize limitations in appearance related to peri-implant mucosal form11 and loss of papilla leading to “black triangles.”12 The clinical management of peri-implant soft tissues is of importance in esthetic anterior dental implant success.

Control of peri-implant mucosal responses is especially important when dental implants are immediately placed and restored. Risk factors for immediate placement single-tooth implant esthetics include the absence of buccal bone supporting facial mucosal height, loss of connective tissue attachment at adjacent teeth, facial implant position, and thin biotype. Regarding the facial mucosal height that ultimately determines implant crown form and establishes harmony with adjacent teeth, facial implant position or buccal...
and the PES13; and
esthetic outcome using digital dental photographs
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terproximal bone dimensions in relationship to objec-
tissues/papillae.14–16 Several investigations indicate that the implant-tooth distance (ITD) is a second, ma-
jor determinant of the interproximal tissues/papillae.17

Earlier studies showed that the ITD influenced the horizontal component of bone loss around im-
plants.18,19 However, in a previous study involving early
loading of dental implants, the acknowledged proximity
of implants and teeth was not associated with inter-
proximal bone loss.20 Using the same implant system,
Chang and Wennström21 determined that for 32 ante-
rior single-tooth implant restorations, there was no re-
lation between the ITD and marginal bone loss or
papilla fill. In their study, the mean horizontal ITD was
1.8 mm at the bone level. Thus, disagreement exists
among reports on the influence of ITD on interproxi-
tissue responses. Because previous reports that in-
dicate that 3 to 5 mm ITD space is needed to preclude
loss of interproximal tissues, it may be deduced that it
could be virtually impossible to prevent interproximal
tissue loss at anterior implants where the mesiodis-
tal bound edentulous space is less than 10 mm and a
4-mm-diameter implant would be placed. This seem-
ing impossibility prompted the inquiry into outcomes
related to peri-implant tissue responses at the level of
bone and soft tissue with respect to the ITD.

The purpose of this study was to investigate the in-
terproximal bone dimensions in relationship to objective
measures of esthetics. In this retrospective analysis
of a cohort of participants receiving a single anterior
dental implant and crown, this study (7) measured the
crestal bone changes and distance between the im-
plant and adjacent tooth at 4 years; (2) assessed the
esthetic outcome using digital dental photographs
and the PES13; and (3) determined the statistical associ-
between the proximity of the implant to the tooth vs the vertical interproximal bone changes, the
proximity of the implant to the tooth vs the soft tissue papilla fill, and the vertical interproximal bone chang-
es vs the PES.

**MATERIALS AND METHODS**

**Participant Selection**

This study included participants who were enrolled in
a longitudinal prospective clinical trial at the University
of North Carolina School of Dentistry. The study was
approved by the University of North Carolina Institu-
tional Review Board (IRB), and informed consent was
obtained from all participants. All participants were
nonsmokers and healthy (without systemic disease).
The inclusion/exclusion criteria, treatment modal-
ities for implant placement (Astra Tech, Osseospeed),
provisionalization, and definitive crown delivery are
described in detail in a previous publication.22 A to-
tal of 44 participants with 56 implants were assessed
for inclusion in this observational radiographic and
photographic study. Due to poor image quality or in-
complete data, 38 participants with 44 implants were
included for the final analysis.

**Analysis of Radiographs**

Periapical radiographs were taken immediately fol-
lowing implant and abutment placement, and at
1-year and 4-year follow-up visits using the long cone
parallel technique to evaluate the interproximal mar-
ginal bone level. Measurements of digital radiographs
were made using ImageJ image processing software
(National Institutes of Health). Each radiograph was
calibrated using the known implant diameter as a ref-
ence. The implant-abutment interface (IAI) was cho-
sed as a readily identified reference point. The vertical
distance from the reference point to the interproximal
bone level (My, Dy) and adjacent tooth (Mx, Dx) was
measured in millimeters at the mesial and distal as-
pects of each implant using magnification (×7) to the
nearest 0.01 mm (Fig 1). Two independent examiners
not related to the participants’ treatment analyzed all
radiographs.

**Analysis of Photographs**

Intraoral digital photographs were used to assign PES
at the 1-year and 4-year follow-ups.13 PES is composed
of seven parameters that can be scored 0, 1, or 2, with 2
being the best and 0 being the worst score. Papillae are
evaluated for completeness (2 = complete, 1 = incom-
plete, 0 = absent), and the other variables are assessed
by comparison with a reference tooth. Cosyn and col-
leagues23 defined a PES score of equal or less than 7 to
be an esthetic failure, greater than 8 to be acceptable,
and greater or equal to 12 to be almost perfect. PES
was recorded by two calibrated independent examiners not involved in any treatment. All photographs were scored twice with an interval of 1 week.

Statistical Analysis

Interexaminer and intraexaminer reliability was tested by computing Cronbach Coefficient Alpha with 0.70 as an acceptable reliability coefficient. Mesial and distal bone loss around the implant was calculated, and the relationship between bone loss and the distance between the implant and the tooth was tested by general linear model regression. PES at the 1-year and 4-year follow-ups was calculated and compared by paired t test. The associations between radiographic bone level measurements and PES were further explored using the Pearson Chi-square test and linear regression modeling. SAS ODS (output delivery system) statistical graphics were used to generate the plots. All statistical analyses were performed using SAS version 9.2 (SAS) with .05 as the significance level.

RESULTS

In total, 56 implant sites in 44 participants were eligible for evaluation. Two participants were lost to follow-up, and 16 were not included due to incomplete data or poor image quality. Forty-four implant sites in 38 participants provided complete data sets for analysis. There were no implant failures or complications reported in these participants.

Interexaminer agreement was confirmed using the Cronbach Coefficient Alpha test for the radiographic measurements (α = .98). PES also demonstrated high interexaminer and intraexaminer agreement using the Cronbach Coefficient Alpha test (α = .98).

Mesial and distal bone loss measured from radiographs over 3 years was 0.2 mm (SD = 1.00) and 0.2 mm (SD = 0.74), respectively. Regression analysis failed to reject the null hypothesis that there is no relationship between proximity of tooth to implant and change in crestal bone level (Figs 2 and 3).

The data suggest that the closer the implant is to the tooth, the higher the PES is. Table 1 demonstrates the mean PES subcategories at 1 year and 4 years. Mean PES was largely unchanged from 10.80 (SD = 1.79) at 1 year to 10.88 (SD = 2.14) at the 4-year follow-up. From the 1-year photographs, 30% of participants scored high (> 12), 68% were considered acceptable (> 8), and only 2% were considered esthetic failures (≤ 7). Evaluation of the 4-year photographs revealed that 45% of participants scored high (> 12), 48% were considered acceptable (> 8), while only 7% were considered esthetic failures (≤ 7). The aggregate PES changes were not statistically significant.

The proximity of the implant to the tooth at the mesial and distal sites is associated with PES (P < .0001). The data suggest that the closer the implant is to the

Table 1 PES Subcategory Mean ± SD Scores at 1 Year and 4 Years

<table>
<thead>
<tr>
<th>PES subcategories</th>
<th>1 year</th>
<th>4 years</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesial papilla</td>
<td>1.48 ± 0.64</td>
<td>1.4 ± 0.63</td>
<td>–0.08 ± 0.62</td>
</tr>
<tr>
<td>Distal papilla</td>
<td>1.60 ± 0.55</td>
<td>1.4 ± 0.67</td>
<td>–0.20 ± 0.46</td>
</tr>
<tr>
<td>Level</td>
<td>1.78 ± 0.48</td>
<td>1.73 ± 0.45</td>
<td>–0.05 ± 0.45</td>
</tr>
<tr>
<td>Contour</td>
<td>1.55 ± 0.50</td>
<td>1.58 ± 0.55</td>
<td>0 ± 0.51</td>
</tr>
<tr>
<td>Alveolar bone</td>
<td>1.78 ± 0.42</td>
<td>1.78 ± 0.42</td>
<td>0 ± 0.51</td>
</tr>
<tr>
<td>Color</td>
<td>1.20 ± 0.46</td>
<td>1.43 ± 0.50</td>
<td>0.23 ± 0.48</td>
</tr>
<tr>
<td>Texture</td>
<td>1.43 ± 0.50</td>
<td>1.58 ± 0.50</td>
<td>0.15 ± 0.62</td>
</tr>
<tr>
<td>Total PES</td>
<td>10.80 ± 1.79</td>
<td>10.88 ± 2.14</td>
<td>0.08 ± 1.82</td>
</tr>
</tbody>
</table>

PES = pink esthetic score.
Fig 4 (Left) Mesial proximity of implant to tooth vs PES ($P < .0001$). Mx = horizontal ITD at mesial location.

Fig 5 (Right) Distal proximity of implant to tooth vs PES ($P < .0001$). Dx = horizontal ITD at distal location.

Fig 6 (Left) Mesial change in bone level vs PES ($P = .0515$). PES = pink esthetic score; My = mesial vertical bone change.

Fig 7 (Right) Distal change in bone level vs PES ($P = .0040$). PES = pink esthetic score; Dy = distal vertical bone change.

Fig 8 (Left) Mesial change in bone level vs mesial papilla score ($P = .6317$). My = mesial vertical bone change.

Fig 9 (Right) Distal change in bone level vs distal papilla score ($P = .1842$). Dy = distal vertical bone change.

Fig 10 (Left) Mesial proximity to tooth (Mx) vs mesial papilla score ($P = .9042$).

Fig 11 (Right) Distal proximity to tooth (Dx) vs distal papilla score ($P = .0545$).
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tooth, the lower the PES (Figs 4 and 5). It is of further interest that the change in bone level over 3 years on the distal side of the implant is significantly associated with PES ($P = .004$). A suggested relationship ($P = .515$) was noted at the mesial aspect of the implant (Figs 6 and 7). Regression analysis showed that more bone loss on the distal side of the implant correlated with a lower PES.

In contrast to the association of ITD and total PES, regression analysis revealed no association between the proximity of the ITD and individual papilla scores (Figs 8 and 9). The changes in bone level ($\Delta y$) did not show a correlation with individual papilla scores (Figs 10 and 11). Although the total PES is significantly related to the proximity of the implant to the tooth, this relationship is not found at the subcategory level for papilla score. Other subcategories in PES may have contributed to the result. Thus, the relationship between the proximity of the implant to the tooth and esthetic result is still unclear.

**DISCUSSION**

The survival rate for the implants included in this study was 100% (44/44) and is consistent with other studies that had utilized an immediate provisionalization protocol. The implant and not the participant was selected as the unit for measure because the local architectural factors greatly influence peri-implant mucosal outcomes. The mean change in bone level (0.20 mm) on both aspects of the implant was consistent with those found in previous studies. An example of the potential maintenance of peri-implant tissues at locations where encroachment of the recommended ITD occurred is presented. Over 10 years, an esthetic tissue architecture was maintained (Fig 12). Clinical photographs and radiographs demonstrate that, as suggested by the present data, it is possible to achieve and maintain esthetic peri-implant tissue architecture stability when the ITD is less than 1.5 mm. This study found no relationship between ITD and marginal bone level changes over 4 years. This is consistent with a previous 3-year retrospective study and very similar to the results obtained using this same implant design in a 12-year report by Chang and Wennström. They suggested that a flat implant-abutment connection design results in greater vertical bone loss that may negatively influence the maintenance of bone levels at adjacent teeth. This speculation has been confirmed in a recent comparative, prospective clinical investigation of different implant-abutment designs.
The present study found no relationship between ITD and papilla scores. In contrast, Lops and colleagues, using an immediate placement protocol, found that when the ITD was less than 2.5 mm, the papilla was absent 70% of the time. In a subsequent study involving premolar sites, these same investigators did not identify a relationship between ITD and papilla fill. The factors defining papilla fill may be more complex than either the ITD or the vertical distance from the bone crest to contact point measures suggest. Chow and collaborators suggest that the subject age, crown width, long proximal contacts, 5 mm from bone crest to the contact point, and thickness of interproximal tissues were associated with the appearance of gingival papilla.

The PES was used in this study and assesses the soft tissue exclusively. Other studies using PES have demonstrated PES with almost perfect scores (≥12) in 19% to 39% of the cases. Ninety-three percent of implants were considered esthetic successes (PES: 8 to 14). An esthetic failure rate of 7% is also consistent with a systematic review suggesting an esthetic complication rate of 7%.

The authors of the present study speculate that the high PES scores reflect the integrity of interproximal soft tissues presented in this study, as others have demonstrated that interproximal tissue loss is a primary factor in esthetic dissatisfaction with implants scored by professionals. This 4-year study suggests that the PES outcomes are stable over time. Other investigators have also demonstrated stable PES scores over time using this implant system. While there are no extensive longer-term data regarding soft tissue esthetics at implants, other reports indicate PES stability over 4 to 12 years. A comparison of baseline and 16- to 24-year PES from photographs demonstrated lower PES scores (reflecting a previous generation approach to treatment) but stability of outcomes at single implants placed in a conventional manner (7.42 ± 2.59 at baseline vs 7.71 ± 2.71 at 16 to 24 years). These reports suggest that medium-term and potentially longer-term stability of soft tissue esthetics is possible.

The present results indicate that ITD at both mesial and distal aspects of the implant and PES were negatively correlated (P < .001). This is an important new observation suggesting that small ITD could represent an esthetic risk factor. Khzam et al reviewed 19 studies of immediately placed and provisionalized implants; however, the role of ITD was not recorded or investigated. The ITD was evaluated in a systematic review of immediate placement of dental implants in the esthetic zone. Buser et al enumerated eight structures to examine in a single-tooth extraction site in the esthetic zone, and while the mesiodistal size of the single-tooth gap is included, ITD was not mentioned.

The role of ITD on esthetics has not been systematically investigated. The reason for this association between bone loss and PES score in the absence of measured soft tissue changes is unclear, and a larger sample size with a comprehensive evaluation of sample characteristics may contribute to an improved understanding of this finding.

CONCLUSIONS

This study failed to demonstrate a relationship between ITD and crestal bone changes at 4 years following single-tooth implant placement by an immediate placement and loading protocol using the designated implant system. Further, the data revealed a statistically significant (P < .001) relationship between smaller ITDs and lower PES. It must be recognized that the ITD was found to be unrelated to papilla fill. In the absence of significant vertical changes in bone level, a relationship to papilla formation could not be interpreted. The results of this study highlight the multifactorial nature of soft and hard tissues surrounding dental implants. Many factors including the surgical procedure, prosthetic management, the choice of implant components, and the quality of the crown may contribute to ultimate esthetic success.

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REFERENCES