Factors influencing the length of the interproximal dental papilla between maxillary anterior teeth

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Received: Apr 17, 2009
Accepted: Jul 22, 2009

KEY WORDS:
contact area;
interdental distance;
interproximal dental papilla;
keratinized gingiva;
radiography

Background/purpose: The presence of interproximal dental papillae in maxillary anterior teeth is a key esthetic factor and a great concern for dentists and patients. The aim of this study was to determine the factors associated with the length of the interproximal dental papilla in anterior teeth.

Materials and methods: In total, 102 interproximal sites of maxillary anterior teeth in 30 patients were examined.

Results: TempBond mixed with barium sulfate was applied to the tip of the interproximal dental papillae and mucogingival junction using a periodontal probe. Periapical films using a parallel technique were then taken. The presence of the interproximal dental papilla was determined on the radiographs. If the tip of the interproximal dental papilla was at the base of the contact point, the papilla was recorded as being present. If not, the papilla was considered to be recessed. The radiographs were transferred to a computer and analyzed using ImageJ software. Age, sex, and the following parameters were measured: the length of the interproximal dental papilla, the distance between the base of the contact point and bone crest, the width of keratinized gingiva, and the interdental distance. Results showed that the length of the interproximal dental papilla was significantly and individually related to the distance from the contact point to the bone crest, the width of the keratinized gingiva, and the interdental distance.

Conclusion: The width of the keratinized mucosa was the predominant factor affecting the length of the interproximal dental papilla.

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Introduction

In addition to maintaining dental and periodontal health, dental esthetics has become a great concern for both dental practitioners and patients. Increasing numbers of doctors and patients demand the eradication of dental and periodontal diseases and also the restoration of dental esthetics, for which the gingival plane, gingival outline, and gingival and interproximal dental papilla recession in the anterior teeth are particularly important. The presence of interproximal papillae between the maxillary anterior teeth is a key esthetic component, and the contour of the interdental tissues, and the color and texture of keratinized tissues are essential for esthetic anterior protheses. The various problems associated with the recession of interproximal dental papillae such as food impaction, esthetics, and phonetics, known as the “black hole” problem, pose a great challenge for dental treatment.

The form and volume of interdental tissues are determined by the morphology of the adjacent teeth. Cohen first described the col as non-keratinized or parakeratinized tissue in the interproximal area with buccal and lingual peaks of keratinized tissue. The interdental papillae between the incisors are usually pyramidal-shaped or a slight gingival col, depending upon the location of the contact area and the height of the gingiva. Matherson and Zander reported that the col took the shape of the contact area of the adjacent teeth but not the underlying alveolar bone. The shape of the interproximal dental papilla is also determined by the proximal crown forms and the course of the cementoenamel junction (CEJ). The contour and shape of the interproximal dental papilla is also affected by the periodontal biotype. There are two periodontal biotypes: thin scalloped and thick flat types. Thin scalloped periodontium is characterized by thin gingival tissue and long interproximal dental papilla, while the thick flat type is characterized by thick gingival tissue and a short, wide papilla.

Tarnow et al. reported that when the distance from the contact point to the bone crest is ≤5 mm, the papilla is present almost 100% of the time. Other studies showed similar results. The principle is widely used in clinical prevention and management of loss of the interproximal dental papilla, including surgical rebuilding of the interdental papilla. However, the relationship between the presence of the interproximal dental papilla and its length remains unclear, and there is no study in the literature investigating factors related to the length of the interproximal dental papilla.

The purpose of this study was to evaluate, by a noninvasive method, the factors that are related to the length of the interproximal dental papilla. The factors investigated included: (1) the distance between the contact point and the bone crest, (2) the width of the keratinized gingiva, and (3) the interdental distance at the level of the bone crest.

Materials and methods

The study protocol was approved by the local institutional review board. Patients who visited the periodontal department at Chang Gung Memorial Hospital and received supportive periodontal therapy from September 2007 to February 2008 were enrolled in this study. All patients were older than 20 years, with no systemic compromising problems including pregnancy. They had no history of taking medications known to increase the risk of gingival enlargement. All had healthy gingiva with periodontal probing depths of <5 mm and plaque and gingival index (Loe and Silness) grades of 0–1. The sites selected for the measurements were the interproximal dental papillae from the maxillary right to left canines. The interproximal dental papillae between teeth with dental implants, artificial crowns, proximal/cervical restorations or abrasions were excluded.

The authors established the experimental procedures and made the measurements. A technician took all periapical radiographs. Radiopaque material consisting of a 2:1 (v/v) mixture of TempBond (Kerr Corp., Orange, CA, USA) and barium sulfate was placed on the tip of the papilla with its coronal margin at the mucogingival junction (MGJ) using a periodontal probe (Fig. 1). Only a minimal amount of radiopaque material was needed, because the radiopacity was greatly enhanced by the contrast media. Working time of TempBond was less than 90 seconds.

Three periapical radiographs of the test sites in each patient were taken using a parallel technique with a film holder (XCP; Rinn, Elgin, IL, USA). The available radiographs were of good quality and had no overlap. All radiographs included a ruler and were digitized using a digital camera (Nikon Coolpix 4500; Nikon Inc., Melville, NY, USA) with 2272 × 1704 input pixels at the same time; the image format was JPEG. After digitization, all images were transferred to a personal computer and examined using the same monitor. In a dark room, measurements of the digital images were undertaken using ImageJ freeware from the National Institutes of Health (http://rsb.info.nih.gov/ij).

The variables measured on the periapical radiographs included: (1) the length (L) of the interproximal dental papilla, i.e., the distance from the
Interproximal dental papilla

Fig. 1 TempBond and barium sulfate placed with a probe on the tip of the papilla (PT) and mucogingival junction (MGJ).

Fig. 2 Measurements taken on the radiographs. L = the length of the interproximal dental papilla, the distance from the papilla tip (PT; radiopaque material) to the bone crest (BC); D1 = the distance between the contact point (CP) and BC; D2 = the distance from the PT to the mucogingival junction (MGJ; radiopaque material); D3 = the interdental distance at the bone crest level.

top of the papilla to the bone crest; (2) the distance (D1) from the base of the contact area to the bone crest; (3) the width (D2) of keratinized gingiva, i.e., the distance from the tip of the papilla to the MGJ; and (4) the interdental distance (D3) between two natural teeth at the bone crest level paralleling the CEJ (Fig. 2). Every measurement was repeated 10 times, and the average was recorded. All measurements were rounded to the nearest 0.01 mm.

Statistical analysis

Owing to the clustered data structure in this study, generalized estimating equations (GEEs)\textsuperscript{23,24} were employed to account for clustering of multiple teeth within individual patients. The dependent variable was the length of the interproximal dental papilla measured in millimeters. Associations between the dependent variable and the explanatory variables of age, sex, D1, D2, and D3 were first tested separately. When two or more explanatory variables significantly influenced the length of the interproximal dental papillae, those factors were combined in the GEE analysis. Those with significant results were the predominant factors associated with the length of the interproximal dental papilla.

Results

In total, 30 patients (13 males and 17 females) who met the selection criteria were included in the study. Patients had a mean age of 53.8 ± 11.5 years (range, 28–78 years). Of the 150 interproximal sites of the maxillary anterior teeth from the left to the right canine, 48 sites were excluded; only 102 sites were investigated in this study. The mean value of the length of the interproximal dental papilla was 3.80 ± 0.72 mm, that of the distance from the contact point to the bone crest was 5.26 ± 1.59 mm, that of the width of the keratinized gingiva was 4.41 ± 1.29 mm, and that of the interdental distance was 1.65 ± 0.66 mm (Table 1).

Results in Table 2 show that the lengths of the interproximal dental papillae varied from 3 to 6 mm, with the majority at 4–5 mm. The percentage of the presence of interproximal dental papillae was

Table 1. Demographic characteristics and interdental area data of the study population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD (range), yr</td>
<td>53.8 ± 11.5 (28–78)</td>
</tr>
<tr>
<td>Measurements, mean ± SD (range), mm</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>3.80 ± 0.72 (2.3–5.7)</td>
</tr>
<tr>
<td>D1</td>
<td>5.26 ± 1.59 (2.3–9.4)</td>
</tr>
<tr>
<td>D2</td>
<td>4.41 ± 1.29 (1.6–7.5)</td>
</tr>
<tr>
<td>D3</td>
<td>1.65 ± 0.66 (0.4–3.9)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13/30 (43.33)</td>
</tr>
<tr>
<td>Female</td>
<td>17/30 (56.67)</td>
</tr>
<tr>
<td>Papillary presence*, n (%)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>45/102 (44.12)</td>
</tr>
<tr>
<td>No</td>
<td>57/102 (55.88)</td>
</tr>
</tbody>
</table>

*If the tip of the papilla was at the base of the contact point, the papilla was defined as being present; if not, the papilla was defined as being not present. SD = standard deviation; L = length of the interproximal dental papilla; D1 = distance between the contact point and bone crest; D2 = distance from the papilla tip to the mucogingival junction; D3 = interdental distance at the bone crest level.
similar in each group of lengths of the interproximal dental papillae. Relationship between the presence of the interproximal dental papilla and its length was not significant ($P = 0.58$) according to the GEE analysis.

Results from the GEE models are presented in Table 3. In the univariate analysis, the length of the interproximal dental papilla was significantly related to two factors: the distance from the contact point to the bone crest, and the width of the keratinized gingiva ($P < 0.05$). In the multivariate analysis, both were put in a GEE to test their independent associations after adjusting for other variables in the model. Both the distance from the contact point to the bone crest and the width of the keratinized gingiva were significantly influencing the length of the interproximal dental papilla ($P < 0.05$). However, the width of the keratinized gingiva was the strongest determinant factor.

**Discussion**

Previous studies by Tarnow et al.\textsuperscript{4} and Cho et al.\textsuperscript{15} showed that when the distance from the contact point to the bone crest is $\leq 5$ mm, the interproximal dental papilla is always present. However, they used a sounding technique under anesthesia on the facial aspect of the contact point, and verified these measurements by reflecting the gingiva. Some points should be considered. First, sounding with a probe might cause a certain degree of compression of the interproximal dental papilla. Second, the measured points on the facial aspect of the contact point might fail to reveal the apical tip of the contact area and crestal bone resorption. In addition, surgery always leads to discomfort and fear in patients and may even cause unfavorable recession of the interproximal dental papilla or trauma of supporting tissues.\textsuperscript{4,25}

A simple, convenient and repeatable method to study the interproximal dental papilla is, therefore, desirable. The thickness of the masticatory mucosa and gingiva can be determined ultrasonically, but this does not apply to interproximal dental papillae.\textsuperscript{26,27} Olsson et al.\textsuperscript{28} introduced a method of measuring the length of the interproximal dental papilla with the aid of clinical photographs. Others have developed an index for assessing the contour of the interproximal dental papilla.\textsuperscript{29,30} Use of radiographs as a noninvasive method\textsuperscript{14,16−19,31−33} was also developed. Lee et al.\textsuperscript{14} tested the accuracy of periapical films for measuring the length of soft tissue from the top of the interproximal dental papilla to the crestal bone. They compared periapical films using a parallel technique and bone probing method under local anesthesia. Results suggested that the noninvasive method using a radiopaque material and periapical radiographs could be utilized to measure the length of interproximal dental papillae with high accuracy.

Several radiopaque materials are used to increase the contrast. Lee et al.\textsuperscript{14,31,33} used an endodontic sealer plus barium sulfate as an indicator of the MGJ. However, endodontic sealer (Tubli-Seal; Kerr Corp.) flows and does not set. It is not easy to apply to test sites, especially when saliva is not isolated, and it is too sticky to be easily removed from the mucosa. Chang\textsuperscript{17−19} used Caviton (GC Corp., Tokyo, Japan) to block the interdental space due to recession of interproximal dental papillae.

**Table 2.** Presence of papilla versus the length (D2) of the interproximal dental papilla

<table>
<thead>
<tr>
<th>Distance from the papilla tip to the crestal bone (mm)</th>
<th>Total</th>
<th>Papilla, n</th>
<th>Present†, n (%)</th>
<th>Recessed‡, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>15</td>
<td>9 (60.00)</td>
<td>6 (40.00)</td>
<td>3 (40.00)</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>20 (39.22)</td>
<td>31 (60.78)</td>
<td>31 (60.78)</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>14 (43.75)</td>
<td>18 (56.25)</td>
<td>18 (56.25)</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>2 (50.00)</td>
<td>2 (50.00)</td>
<td>2 (50.00)</td>
</tr>
</tbody>
</table>

*When the data were categorized, all measurements were rounded to the nearest millimeter; †recorded as present if the tip of the interproximal dental papilla (radiopaque material) was at the base of the contact area; ‡recorded as recessed if a space was visible apical to the contact area.

**Table 3.** Generalized estimating equation multivariable linear regression for papillary length for the 102 papillae

<table>
<thead>
<tr>
<th>Regression coefficient*</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>0.11</td>
</tr>
<tr>
<td>D2</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*Indication of change in the mean papillary length (in millimeters) per unit increase in the potential variables; a positive sign indicates a longer papilla for a unit increase in the potential variable. D1 = distance between the contact point and bone crest; D2 = distance from the papilla tip to the mucogingival junction.
This radiopaque material helps reveal the tip of the interproximal dental papilla on periapical film. Cavition might also cause compression of the interproximal dental papilla, especially when the distance from the contact point to the tip of the interproximal dental papilla is <1 mm. In addition, it is very difficult to apply Cavition to the MGJ.

In this study, a noninvasive method with periapical X-rays and TempBond as the radiopaque material was used. As TempBond flows, it is much easier to apply to test sites. Its working time is 90 seconds, which is decreased by the addition of barium sulfate. When it sets, it attaches to soft tissues and does not detach even in the presence of saliva. It is also easy to remove from the mucosa after the radiographs have been taken.

In this study, the lengths of the interproximal dental papillae varied from 3 to 6 mm, with 80% of them at 4–5 mm. The biologic width, first described by Garguilo et al., consists of 1.07 mm of connective tissue attachment and 0.97 mm of junctional epithelium. Kois described this as the dentogingival complex. It was shown that the average dimension of the dentogingival complex in natural teeth is 3 mm at the facial aspect and 4.5 mm at the interproximal aspect. In this study, the length of the interproximal dental papilla was measured from the tip of the papilla to the bone crest. This comprises the biologic width (connective tissue attachment plus junctional epithelium) and free (marginal) gingiva. The free gingiva forms the soft tissue wall of the gingival sulcus. The histologic sulcular depth was reported to be 1.8 mm, varying 0–6 mm while other studies reported 1.5 mm and 0.69 mm. Therefore, the width of the dentogingival complex (3–4.5 mm) plus the length of the free gingiva (0.69–1.8 mm) is approximately 3.69–6.3 mm. It was similar in this study; the length of the interproximal dental papilla was 3–6 mm (Table 2).

The results of this study revealed that the length of the interproximal dental papilla is significantly and individually related to two factors: the distance between the contact point and the bone crest, and the width of the keratinized gingiva. This means that when the distance from the contact point to the bone crest increases, the length of the interproximal dental papilla also increases. However, when the distance from the contact point to the bone crest is ≤5 mm, the length of the interproximal dental papilla is limited. Tarnow et al. also studied the vertical distance from the crest of the bone to the height of the interproximal dental papilla between adjacent implants. They showed that 2–4 mm (average, 3.4 mm) of soft tissue height can be expected to cover the interimplant crest of bone; however, no interimplant distance was actually defined.

The results also illustrated that the length of the interproximal dental papilla increased when the interdental distance increased. In an implant study, Lee et al. compared two different implant systems, and both showed similar dimensions of interproximal soft tissue (3.3–3.4 mm) between adjacent implants, irrespective of the horizontal distance of the fixtures.

This study showed that a wider zone of keratinized gingiva had a longer interproximal dental papilla. The GEE analysis also indicated that the width of the keratinized gingiva was the predominant factor associated with the length of the interproximal dental papilla. This was similar to the study by Lee et al. on dental implants, which revealed that the dimension of keratinized gingiva between two adjacent implants might be related to the dimension of the interproximal dental papilla. However, the relationship between the width of keratinized gingiva in the interproximal region and the dimension of the interproximal papilla between two natural teeth was not investigated until now.

Keratinized gingiva is composed of attached gingiva and free gingiva. The width of the attached gingiva on the facial aspect differs in different areas of the mouth. The attached gingiva functions as a barrier to penetration into the deeper tissue by microbes and noxious agents. It is generally greatest in the incisor region (3.5–4.5 mm in the maxilla and 3.3–3.9 mm in the mandible). Usually about 1 mm wide, the marginal gingiva forms the soft tissue wall of the gingival sulcus. After complete tooth eruption, the free gingival margin is located on the enamel surface approximately 1.5–2 mm coronal to the CEJ.

Wennström et al. studied the dimensions of the gingiva in beagles. They found that gingival units with a wide zone of keratinized gingiva were more voluminous than units with a narrow zone. Olsson et al. also found a strong relationship (P=0.001) between the width of keratinized gingiva and the thickness of the gingiva. In orthodontic treatment, an increased buccolingual thickness of tissue at the facial aspect of the teeth results in coronal migration of the soft tissue margin.

Chang showed a positive relationship between age and interdental distance and a negative relationship between age and papilla height. Those results differed from this study, which revealed that age did not significantly influence the presence or length of the interproximal dental papilla. Wara-aswapati et al. found that the palatal mucosa became thicker with an increase in age. Other studies found no age-related differences in the gingival epithelium of humans or dogs. However, Vandana and Savitha found
that the gingiva was thicker in younger than older individuals.

Wara-aswapati et al.46 and Vandana and Savitha49 revealed that the gingiva and palatal mucosas of males were thicker than those of females. However, in this study, the univariate analysis revealed that sex did not significantly influence the presence of the interproximal dental papilla or its length, which was similar to studies by Chang.18,19

Nowadays, patients have increasing esthetic demands for dental treatments; the principle of the distance of contact point to the bone crest being ≤5 mm indicates that the interproximal dental papilla is almost always present. Alterations in the position of the contact point with the ceramic veneer or crown can induce creeping loss of papillae. In addition, orthodontic treatment in conjunction with tooth stripping to relocate the contact point more apically can be performed to reduce the “black triangle”.50

However, in severe alveolar bone resorption cases, usually in periodontal patients, the prosthetic method fails to recover the papilla recession. Recent advances in periodontal plastic surgery have enhanced the periodontist’s ability to address these concerns. Nemcovsky51 used an advanced papillary flap combined with a gingival graft to augment the soft tissue in the interdental area. Han and Takei52 proposed an approach based on using a semilunar incision and a subepithelial free gingival connective tissue graft which is placed beneath the coronally positioned interdental tissue, to attain the goal of papilla reconstruction. Azzi et al.53,54 reconstructed the interdental papilla using a buccal and palatal split-thickness flap and a connective tissue graft in cases including Miller Class IV recession. However, the blood supply is the key element for success. As previously stated, the keratinized gingival width is the strongest determinant of papillary length, so surgical procedures to increase the dimension of the keratinized gingiva might be helpful in reconstructing the papilla. Although the length of the interproximal dental papilla is not significantly associated with the presence of the interproximal dental papilla, and even if the interdental papilla cannot be completely rebuilt, the black triangle problem can be minimized to achieve patients’ demands. Future research focused on the effectiveness would be clinically significant.

The main limitation of this study is that the periodontal biotype was suggested to affect gingival recession.10−13 However, it is impossible to define the biotype in a radiographic way.

In summary, a newly designed noninvasive method was shown to facilitate the study of the interproximal dental papilla and provides accurate and repeatable measurements. The width of the keratinized mucosa was the predominant factor associated with the length of the interproximal dental papilla. Determining interrelationships of each factor that influences the length of the interproximal dental papilla requires further studies. Additional studies on the interproximal papilla between implants are also necessary.

References

Interproximal dental papilla


