This retrospective analysis was undertaken to evaluate the effect of immediate implant restoration using a computer-assisted technique in partially edentulous sites on interimplant and intertooth bone level stability and papilla formation. Nine partially edentulous patients received a total of 23 implants that supported immediately placed implant restorations. Planning was accomplished using a radiographic guide, which allowed visualization of the emergence profile from the platform of the implant to the cervical of the planned restoration. Guided implants were placed according to the manufacturer’s instructions, and restorations were screw retained directly to the implant. Multiple implants were splinted at surgery with autopolymerizing resin. Measurements were made at a mean of 545 days (range 288–958) postoperatively on the basis of radiographs and photographs. Measures were: (1) distance from bone crest to platform, (2) bone crest to contact point, (3) interimplant distance at the outer diameter of the platform, and (4) papilla from highest point to a reference line. At follow-up time, the bone ridge was located higher than the implant platform (mean 0.57 mm) compared to implants whose interimplant distance was less than 3 mm (mean 0.27 mm). Mean increase of the bone level between insertion and approximate 1-year follow-up was 0.047 mm. The mean distance from the contact point to bone was 2.39/3.93 mm postoperatively, resulting in 91/71% papilla fill between implants and between implant and adjacent tooth, respectively. Computer-assisted surgery with the preplanned immediate restoration seems to be an effective method to minimize bone loss at the implant platform resulting in support for papilla.

Key Words: papilla formation, guided surgery, implant, partially edentulous, immediate loading

INTRODUCTION

Since the introduction of osseointegrated dental implants in 1981 the field has evolved from possibility to refinement.1 Today, ideal implant placement is thought to result in high esthetic outcome.2 Black triangle has been a major esthetic problem.3 Restoratively driven implant placement can result in optimized emergence profile and may create the environment necessary to preserve and enhance the peri-implant soft tissue and papilla,4 yet its effect on soft and hard tissue is not well understood.

Tarnow et al described that when the interimplant distance is greater than 3 mm, papilla was 100% present, and when the interimplant distance was less than 3 mm, tissue loss was significant.5 Choquet et al demonstrated that when the distance between contact point to the crest of bone was less than 5 mm, papilla was present.6 Furthermore, three case reports by Elian et al showed the presence of interimplant papilla.7 These three papers were based on submerged and not immediately restored implants. In 2004, Kan et al reported that the immediate restorations resulted in a good papilla formation between teeth.8 In all of these reports, implants were all placed using freehand techniques.

In recent implant dentistry, computer-assisted surgery (CAS) is becoming more popular and achieves prosthetically driven implant placement.9 CAS was first introduced by Van Steenberghe et al.10,11 The key to computer planning is transferring the planning to the patient using a surgical template that allows placement of the implant directly through the tissue without the reflection of the flap.12 Furthermore, immediate restoration is possible because of precise fit, excellent primary stability achieved, and the ability to make a pre-implant model.13 This procedure allows restoratively driven implant placement and restoration to provide a more natural environment for soft tissue formation.14

In this paper, we are reporting a unique technique to create emergence profile in the computer program preoperatively and delivery of immediate restorations, incorporating the predetermined profile at implant placement. The overall objective of this analysis was to evaluate the effect of immediate implant restoration using the CAS in partially edentulous healed sites on peri-implant bone level stability and papilla formation at 1 year postimplantation and restoration.

MATERIALS AND METHODS

Twenty-three implants in 9 consecutively presenting patients with partially edentulous healed sites of 1–3 teeth requesting immediate loading were treated using the CAS technique and analyzed retrospectively (Figure 1). Patients were analyzed for papilla formation and bone remodeling around implants.
Following the planning, a surgical template was produced containing a sleeve at the arrow (Figure 2). For those implants to be immediately loaded, pre-implant models were made using the surgical template (Figure 3). Using these models, the pre-implant restorations were fabricated in the laboratory; the surgical template contained all the planning information, and replicas could be inserted into them. Preimplant casts with soft tissue could be fabricated and mounted against the opposing dentition. The replicas were exposed and, using titanium cylinders, acrylic resin was processed to the cylinders using matrices prepared from the preimplant-planning waxed crowns. The formation of the emergence profile of the crowns was carried through from the initial waxup for the radiographic guide for planning to the preimplant temporary immediate load temporary crowns.

External hex implant placement was performed according to the manufacturer’s instruction for guided implant placement without reflection of flap (Biocare USA, LLC, Yorba Linda, Calif). Implants were placed 0.5 mm below the crest (Figure 4a). Primary stability of all the implants was confirmed by using of insertion torque value, implant stability quotient, and Periotest value. The immediate screw-retained provisional prostheses were fabricated preoperatively in the laboratory and immediately inserted at implant placement (Figure 4b). Restorations were immediately splinted using autopolymerizing polymethyl methacrylate (PMMA). These immediately loaded crowns were replaced after the 3–4 month osseointegration period with ceramic screw-retained restorations. The patients were asked to return every 3 months for maintenance. All of the patients were followed up for at least 1 year.

At follow-up at least 1 year after the implant and restoration placement, Plaque Index\textsuperscript{15} and modified Gingival Index\textsuperscript{16} were graded. Radiographic measurements were

FIGURE 1. (a) Prosthesis waxup radiographic guide (b) was made from the waxup. (c) Actual radiographic guide was scanned and converted in the program to a virtual image in which the cervical area is visible. (d) Combining computerized tomography scan and the radiographic guide (outlined in black) allows the creation of natural emergence profile shown in yellow.
FIGURES 2 AND 3. **FIGURE 2.** Stereolithographic surgical template generated from the computer program with the sleeve. **FIGURE 3.** Surgical template was used to create preimplant model. (a) Specialized components implant replicas are placed into the template. (b) Original model is cut away in area of replica. (c) Template with replica is placed on original cast, and stone is poured around replica. (d) The soft tissue is reproduced using a matrix of the precut ridge.

FIGURES 4 AND 5. **FIGURE 4.** (a) Implants were placed 0.5 mm below the bony crest without a raising flap. (b) Implant crowns were placed immediately after the implant placement and were connected at arrows using autopolymerizing PMMA resin. (c) Postoperative radiograph shows definitive restoration at 1 year. **FIGURE 5.** Radiographic interimplant and bone to contact measurement. (a) Radiographic measurement between implant and tooth. Most apical extent of bone on the tooth, implant platform, most coronal extent of bone on implant, and contact point were identified; the distances between those were measured. (b) Contact point, implant platform, and bony crest were identified; interimplant distance and the distances between contact point to bony crest were measured. Purple circle = most coronal point of the bone level contacting the implant. Solid red line = fixture abutment junction. Blue circle = most coronal point of the bone level contacting the tooth. Yellow circle = contact. Pink circle = bone crest. Green circle = coronal extent of papilla transferred from intraoral photo. (c) Distance from bone level on implant to platform. (d) Distance from bone level on tooth to the platform. (e) Distance from contact to the bone level on tooth. (f and g) Lateral distance (bone loss) from the implant to bone crest. (h) Vertical crestal bone loss. (i) Distance between implants at the implant-abutment interface. (j) Contact to bone crest.
made from the implant platform to the most apical extent of bone adaptation on the mesial and distal sides of the implant. Radiographic measurements were then performed using the method described by Tarnow et al⁵ and Choquet et al⁶ (Figure 5).

Sixteen papilla between implant and tooth and 12 papilla between implants were analyzed. The mean observation period was 545 days (range 288–958). Papilla height and distance between contact to baseline were measured with the modification of the technique used by Kan et al⁸ (Figure 6). Calibration was performed on the height of the teeth adjacent to implants using models (Figure 7), and the Jemt papilla index score³ was recorded¹⁷ (Figure 8). Implants were considered successful when there was absence of pain, mobility, suppuratation, and the marginal soft tissue recession with the bone level relative to the implant platform was less than 2 mm at a minimum of 1-year follow-up.¹⁸

Statistical analysis

Retrospective data were analyzed using the the Kruskal-Wallace test and Spearman’s rank correlation.
**RESULTS**

Mean age of the patients was 65.0 years old (range 34–85). Implant survival and success was 100% for these patients. Twenty patients (87.0%) had plaque index 0, and 3 patients (13.0%) had plaque index 1 (Table 1). Nineteen patients (82.6%) had gingival index 0, and 4 patients (17.4%) had gingival index score 1 (Table 1). Total number of papilla observed was 28 (Table 2). Sixteen papilla were between implant and tooth, and 12 were between implants. The Jemt papilla index score was used to evaluate papilla fill; the higher number, the more fill, 3 being a complete fill. Between implants, 4 papillae were scored 2, and 8 papillae scored 3. Between implant and tooth, 56% of papillae were scored as 2 (Table 2). The mean papilla height was $3.00 \pm 1.30$ mm, and mean soft tissue height was $1.58 \pm 0.63$ mm (Table 3). This measurement resulted in a mean papilla vertical fill percentage between implants at 91.4%, whereas between implant and tooth, 71.4% vertical papilla height was observed (Table 3).

The most notable finding between the implant and tooth was the slight correlation (correlation coefficient $-0.46$, $P = .08$ Pearson’s correlation) between the implant platform and the most coronal extent of bone on the tooth and papilla vertical height. When the distance between the crest of bone and platform increased, papilla vertical height was less (Figure 9).

Between-implant distance between contact to bone was shorter when papilla vertical fill was less (Table 4). Between-implant mean distance from the bone ridge to platform was 0.45 mm. When the interimplant distance was less than 3 mm, the mean distance between bone ridge to platform was 0.27 mm. When interimplant distance was more than 3 mm, the mean distance between bone ridge to platform was 0.57 mm (Table 5). There was a trend that the longer the distance, the higher the bone level from the platform (Figure 10). It is interesting to note that in all but one implant, the bone level was above the platform (Figure 10). In this study, flapless guided implant surgery with premade immediate provisionalization resulted in a good papilla formation between implants and between implant and tooth (Figure 11).

**Discussion**

In the present study, immediate restoration was applied, and all implants were successful. The emergence profile of these immediate restorations was planned in the computer planning software (Nobel Guide, Nobel Biocare). This allowed us to form the ideal emergence profile on the implant crowns, which also contributed to create the natural environment for the peri-implant tissue. Together with the precise drilling using the CAS implant placement and the placement without disruption to the blood supply to the soft tissue complex, the bone and soft issue complex around the implant platform were well preserved at least 1 year after the implant and immediate restoration placement. From our analysis, when the bone level was higher, the papilla vertical fill was greater.

Between-implants papilla vertical fill percentage was 91%, which was greater compared to the papilla vertical fill between the implant and tooth at 71% (Table 3). Actual measurement of papilla fill was greater between implant and tooth (3.00 mm) compared to 1.58 mm between implants. This may have resulted because it is easier to modify contact point of final restorations between implants compared to the modification of contact point between implant and tooth. Thus, between implants moving the contact point apically might have resulted in higher papilla fill percentage.

It is interesting to note that regarding the papilla measurements compared to the bone level, the majority of

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**Table 1**

<table>
<thead>
<tr>
<th>Plaque Index (n = 23)</th>
<th>Gingival Index (n = 23)</th>
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<tbody>
<tr>
<td>0</td>
<td>20 (87.0%)</td>
</tr>
<tr>
<td>1</td>
<td>3 (13.0%)</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
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<tr>
<td>3</td>
<td>0</td>
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**Table 2**

<table>
<thead>
<tr>
<th>Papilla Score</th>
<th>Overall† (28)</th>
<th>Implant-Tooth Total (16)</th>
<th>Implant-Tooth Single Implants (10)</th>
<th>Implant-Tooth Multiple Implants (6)</th>
<th>Implant-Implant (12)</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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<td>0 (0)</td>
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<td>0 (0)</td>
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<tr>
<td>1</td>
<td>3 (11)</td>
<td>3 (19)</td>
<td>2 (20)</td>
<td>1 (17)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>2</td>
<td>13 (46)</td>
<td>9 (56)</td>
<td>6 (60)</td>
<td>3 (50)</td>
<td>4 (33)</td>
</tr>
<tr>
<td>3</td>
<td>12 (43)</td>
<td>4 (25)</td>
<td>2 (20)</td>
<td>2 (33)</td>
<td>8 (67)</td>
</tr>
<tr>
<td>4</td>
<td>0 (0)</td>
<td>0 (0)</td>
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</tr>
</tbody>
</table>

*Jemt.†Number of papilla observed (%).
the implants shown in Figure 9 had greater than 60% papilla height between implant and tooth. The distance between the platform to the bone on the adjacent tooth was less than 4 mm. Therefore, this may be an ideal platform placement position of the implant adjacent to tooth.

Between-implants bone level was at or above the platform of the implants. Tarnow et al reported the use of Nobel external hex implant with the conventional second-stage implant placement method and then measured the bone level. The level of the bone was below platform at follow-up time. This difference might have been caused by the difference in method, that is, immediate restoration vs 2 stage or CAS vs freehand conventional technique. Further studies are needed to clarify what may have contributed to the bone level preservation that resulted in ideal papilla formation.

It should also be noted that these cases were in the posterior regions of the mouth. Further reports will be needed to see if this phenomenon also occurs in the aesthetic zone where it is especially significant.

Further, there are limitations to the flapless CAS technique: It is not always possible unless there is keratinized tissue around the area where the transmucosal abutment or screw retained crown emerges from the soft tissue. There also needs to be enough buccolingual bone width for implant encase-

**Figures 9 and 10. Figure 9.** Correlation between platform to most coronal point of the bone level contacting the tooth and papilla vertical fill. Correlation coefficient $-0.46, P = .08$ (Pearson’s correlation). **Figure 10.** Relationship between crestal bone level and interimplant distance. Bone level from the platform was measured as $j$, and interimplant distance was measured as $i$ radiographically, as shown in Figure 5a. Each dot represents an individual implant.
ment. If these limitations are present, pre-implant site development to include bone and soft tissue grafting would be indicated.

The notable finding was that the bone level was well preserved at least 1 year after the implant placement. It is not possible to draw specific conclusions on tissue response and bone level stability as the analysis is retrospective, the numbers of patients and implants were small, and the observation period was only 1 year. However, this research has identified a phenomenon of interimplant and interdental papilla formation using CAS and immediate restoration techniques that appear to mimic the natural tooth.

**CONCLUSION**

Use of CAS methods presented in this paper of guided flapless implant surgery and premade immediate prosthetically driven provisional restorations resulted in interimplant and tooth implant papilla formation and fill to varying degrees, but papilla was always present. Therefore, reasons for this observation are worthy of further research, as they may help identify factors that influence soft tissue response between teeth and implants.

**TABLE 4**

<table>
<thead>
<tr>
<th>N Papilla Observed</th>
<th>Mean Distance Between Contact Point to Bone Crest (mm ± SD)</th>
<th>Soft Tissue Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>2.37 ± 0.58</td>
<td>2.07 ± 0.40</td>
</tr>
<tr>
<td>8</td>
<td>2.40 ± 0.77</td>
<td>2.33 ± 0.79</td>
</tr>
<tr>
<td>12</td>
<td>2.39 ± 0.66</td>
<td>2.23 ± 0.64</td>
</tr>
</tbody>
</table>

**FIGURE 11.** Representative clinical papilla formation. Preoperative photo of single (a) and multiple implant sites (c). Postoperative photo of single (b) and multiple implants (d) showing papilla formation at 1-year follow-up.
ABBREVIATIONS

CAS: computer-assisted surgery
PMMA: polymerizing polymethyl methacrylate

REFERENCES


