Initial Clinical Efficacy of 3-mm Implants Immediately Placed Into Function in Conditions of Limited Spacing

Michael S. Reddy, DMD, DMSc[1]/S. Jean O'Neal, DMD, MS[2]/Sandra Haigh, RDH, MS[3]/
Ruth Aponte-Wesson, DDS, MS[4]/Nico C. Geurs, DDS, MS[5]

Purpose: *The objective of this study was to determine changes in interdental papillae, alveolar bone loss, esthetics, and initial healing survival when 1-piece narrow-diameter implants were immediately loaded in sites with limited tooth-to-tooth spacing.* ***Materials and Methods:*** *One-piece titanium alloy implants with a maximum diameter of 3.0 mm and a resorbable blast surface texture on a square-thread form were evaluated. Digital photographs were made at each clinical visit to assess soft tissue healing. Interproximal soft tissue fill of the embrasure was assessed with a modified Jemt index. Standardized radiographs were made at baseline (implant placement) and at 6 and 12 months post-surgery. Radiographic bone height was measured from a consistent landmark on the implant. A 1-sided t test was used to determine statistical differences of bone height.* ***Results:*** *Thirty-one implants were placed in 17 subjects. One implant had clinical mobility and was removed, for an overall survival rate of 96.7%. Mean bone height on the day of placement and restoration was 2.33 + 0.73 mm above the first thread. Mean bone height was 1.75 ± 0.78 mm at 6 months postrestoration and 1.63 ± 0.81 mm at 12 months postrestoration. There was a statistically significant loss of bone support over the initial 6 months (0.58 mm; P < .01), with no significant progression thereafter (0.12 mm; NS). Complete fill of papillae was found in 92% of maxillary lateral incisor sites and 60% of mandibular incisor sites.* ***Conclusion:*** *The use of 1-piece narrow-diameter immediately loaded implants appears to be an effective prosthetic treatment for areas of limited space.* (Case Series) INT J ORAL MAXILLOFAC IMPLANTS 2008;23:281–288

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[1]Professor and Chair, Department of Periodontology, University of Alabama at Birmingham School of Dentistry, Birmingham, Alabama.
[2]Professor and Chair, Department of Prosthodontics, University of Alabama at Birmingham School of Dentistry, Birmingham, Alabama.
[3]Clinic Coordinator, Department of Periodontology, University of Alabama at Birmingham School of Dentistry, Birmingham, Alabama.
[4]Assistant Professor, Department of Prosthodontics, University of Alabama at Birmingham School of Dentistry, Birmingham, Alabama.
[5]Associate Professor, Department of Periodontology, University of Alabama at Birmingham School of Dentistry, Birmingham, Alabama.

Correspondence to: Dr Michael S. Reddy, Department of Periodontology, UAB School of Dentistry, 1530 3rd Avenue South, SDB 412, Birmingham, AL 35294-0007. Fax: +205 934 7901.
E-mail: mreddy@uab.edu

Dental implants have, in many cases, become the treatment of choice for replacing teeth lost because of disease or trauma. In some cases, the tooth-to-tooth spacing is limited due to the drifting or migration of the remaining teeth; the resulting space after orthodontic therapy can also be limited. The problem is compounded in patients with congenitally missing maxillary lateral incisors or mandibular incisors, where loss of space is a common complication. In addition, these teeth, which have the smallest width (mesiodistal dimension), are also the most commonly missing.

The incidence of congenitally missing lateral incisors is estimated at 5% of the population and represents a significant clinical problem.[1–3] A fully developed lateral incisor ranges from 4.5 to 6.7 mm wide, with a mean of 5.5 mm.[4] When the lateral incisor is congenitally missing there is a tendency toward space loss; thus, the tooth-to-tooth space may be at the lower limits for a maxillary lateral

incisor. Conventional 2-piece dental implants with a diameter of 3.5 to 4.0 mm at the margin are too wide for a 4.5-mm space and compromise the space for the interproximal bone and gingival papilla volume. The potential problem is even more pronounced for mandibular incisors given the width of the teeth relative to conventional implants.

The maxillary lateral and mandibular incisors represent more than 20% of tooth sites that may potentially be replaced with dental implants. Until recently the majority of the clinical solutions were too large for many of the sites, resulting in compromised esthetics. Studies of the tooth-to-implant spacing have indicated that the implant-to-tooth distance needs to be at least 1.5 mm to predictably maintain the interdental papillae in anterior esthetic areas.[5–7]

To make an implant of smaller size than the conventional implants available, an alternative design needed to be employed for biomechanical strength. One-piece construction has several potential advantages. A test implant with a diameter of 3 mm was manufactured from a Ti-6Al-4V alloy in a single piece. Since it was fabricated in one piece there was no coupling attachment or screw that could be a likely fracture point. One-piece construction eliminates the potential microgap between the abutment and implant and may help preserve interproximal bone and papillae.[8,9] The thread pattern used, a modified square thread geometry, may lead to more bone-to-implant contact and higher reverse torque values than alternative designs.[10–12] This may be a potential design advantage for a narrow implant with a decreased surface area, since the implant used in this study has a minimal profile, with a maximum diameter of 3 mm. The gold hue of the abutment portion of the implant may be advantageous for tissue esthetics in patients with a thin biotype.[13] The 1-piece design has the additional benefit of decreased treatment time, since it is placed with a single-stage protocol.

The disadvantage of this approach stems from the requirement that the implant be placed in a single-stage protocol. This creates a demand for exacting implant placement and leaves minimal ability to prosthetically correct for implant placement. The 1-piece construction requires immediate provisional restoration of the site at the time of surgery. Furthermore, the narrow implants are under an immediate functional load during healing, which may adversely influence success.

Therefore, the goal of this study was to evaluate the functional and esthetic performance of implants in areas of limited tooth-to-tooth spacing. A 1-piece transmucosal 3-mm implant design was evaluated for implant survival, bone loss, and fill of interdental papillae over the initial 12 months of function.

MATERIALS AND METHODS

This study was a consecutive case series of subjects followed for a period of 12 months. Participants who met the following inclusion/exclusion criteria were invited to participate.

Inclusion criteria:

- Missing maxillary or mandibular lateral incisors
- Good health
- More than 19 years old
- Willingness to give informed consent to participate and comply with protocol

Exclusion criteria:

- Significant medical conditions or habits expected to interfere with bone healing
- Pregnancy (because the dental treatment was elective)
- A history of drug or alcohol abuse, which was considered an indicator of increased risk of noncompliance

All participants signed a University of Alabama at Birmingham and Western Institutional Review Board–approved informed consent. The study included a baseline visit for treatment planning, an implant surgery visit, and follow-up evaluations at 2 weeks, 3 months, 6 months, and 12 months post-surgery. Implants were restored with definitive restorations 4 to 6 months after surgery.

Implant Surgery

Each subject received 1 or more 1-piece titanium alloy implant with a maximum diameter of 3 mm. The implants had a resorbable blast-surface texture and square threads (BioHorizons, Birmingham, AL; Maximus 3.0).

As part of presurgical treatment planning (Fig 1), a surgical stent was fabricated and then used to guide the drill for the initial osteotomy preparation. Implant surgeries were performed under local anesthesia alone.

A course of antibiotics (2 g cephalexin) was dispensed one hour before surgery. Participants rinsed for 1 minute with a chlorhexidine mouthwash. After the treatment area was sufficiently anesthetized, a small crestal incision was made, and a full-thickness flap was elevated to reveal the bony architecture or, at the surgeon's discretion, a punch incision was made at the crest of the ridge. The initial osteotomy was prepared with a 2-mm-diameter drill corresponding to the length of the implant to be placed. The osteotomy was enlarged with a 2.5-mm-diame-

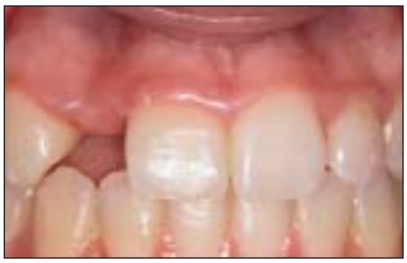
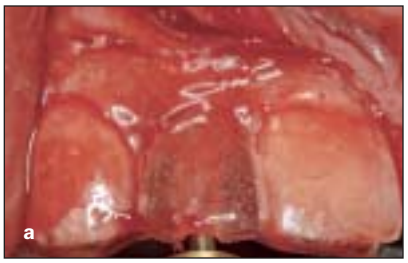


Fig 1 Preoperative appearance. *(a)* Unsatisfactory esthetics due to loss of papilla, uneven gingival margins, and ridge deformity at missing tooth site.



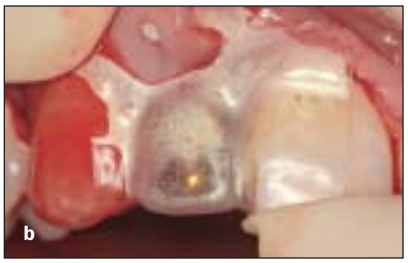


Fig 2 Implant surgery. *(a)* A stent was used to serve as a guide during implant placement. *(b)* After placement, the stent was used to verify abutment position.

ter finishing drill. The 1-piece 3-mm-wide implants were inserted without tapping threads in the osteotomy. The abutment position was verified with a stent (Fig 2). The flap was closed palatally or lingually with synthetic mattress sutures (Vicryl 4.0; Johnson & Johnson/Ethicon, Somerville, NJ) to maintain papilla height.

Postsurgery analgesics (600 mg ibuprofen and/or 500 mg acetominophen with 7.5 mg of hydrocodone) and antimicrobial mouthwash (0.12% chlorhexidine gluconate) were prescribed.

The implants were evaluated for implant survival, alveolar bone loss, and fill of interdental papillae.

Prosthetic Restoration

Immediately following implant placement, minimal preparation was performed as needed on the abutment to ensure adequate clearance on the facial surface to achieve an esthetic temporary restoration and occlusal clearance. A clear vacuum-formed matrix of ideal tooth contour was used to evaluate facial and occlusal reduction. At initial temporization, no definitive margin was prepared on the implant abutment. Provisional restorations were fabricated from temporary acrylic resin (Jet Acrylic; Lang Dental, Wheeling, IL) with the addition of orthodontic resin powder. The provisional restorations had no centric or eccentric occlusal contacts. Brushing contact (minimal shared contact) was achieved on some restorations in protrusive excursions to achieve acceptable esthetics. After polishing, provisional restorations were cemented with temporary cement (Tempbond NE; Sybron/Kerr Dental, Orange, CA) following application of petroleum jelly to the external surface to facilitate cement removal.

The patient was seen at 1 week postoperatively, and the sutures were removed 2 weeks postoperatively (Fig 3). After a healing phase of 4 months in the mandible and 6 months in the maxilla, the abutments were prepared with a gingival curettage bur (5878K-016, Brassler, Savannah, Georgia). A small chamfer (0.5 mm) was placed around the circumference of the abutment. All preparations had a minimum of 1 mm of occlusal clearance. Braided cord (Ultradent no. 1; Ultradent, South Jordan, UT) was used to obtain gingival retraction prior to an impression with a vinyl siloxane impression material (Aquasil LV and Monophase; Dentsply International, York, PA). Due to the small abutment size, epoxy dies were utilized for restoration fabrication. All crowns were porcelain-fused-to-metal crowns fabricated using a high noble alloy. Definitive restorations were adjusted to have slight occlusal contacts in centric occlusion (ability to pull shim stock between teeth) and appropriate distribution of forces in all excursive occlusal movements.

Alveolar Bone Loss

Standardized radiographs were obtained at implant placement and 6 and 12 months postsurgery (3 radiographs). Radiographs served to document implant placement and restoration, to monitor bone healing, and to document any postoperative and/or postloading complications. An independent investigator digitized the radiographs and measured change in bone height relative to a consistent landmark on the implant.

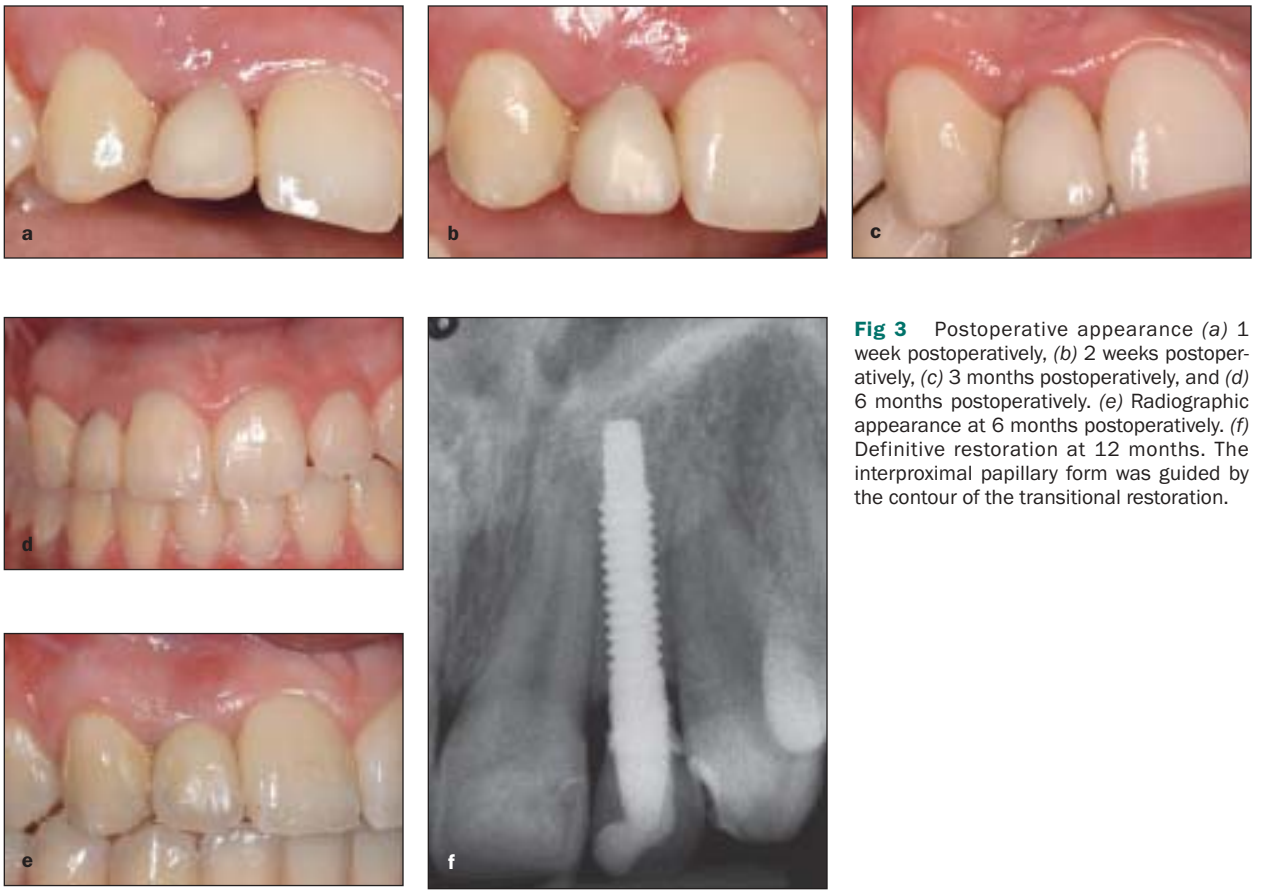


Fig 3 Postoperative appearance *(a)* 1 week postoperatively, *(b)* 2 weeks postoperatively, *(c)* 3 months postoperatively, and *(d)* 6 months postoperatively. *(e)* Radiographic appearance at 6 months postoperatively. *(f)* Definitive restoration at 12 months. The interproximal papillary form was guided by the contour of the transitional restoration.

Interdental Papillae Fill

A modified Jemt index[14] was used to assess the soft tissue fill of embrasure space. Tissue height was assessed by determining the distance in the embrasure space between contact points and the gingival height of contour of the crown. No papilla in the present study was scored as 0. Papillae less than half the height between gingival margin and the contact point were scored as 1. Papillae that extended farther than half the height between the gingival margin and the height of contour but not completely filling the embrasure were scored as 2. Papillae completely filling the embrasure space were scored as 3. Digital photographs were made at each clinical visit to document soft tissue healing.

Esthetic Assessments

Esthetics were subjectively evaluated by trained dental professionals based on smile form, tooth structure, incisal edge, surface contours, line angles, contact area, embrasure form, surface texture, and color and tissue contour.

Outcomes Analyses

Life table analysis was used for evaluation of the cumulative success and survival rate. A 1-sided *t* test was used to determine statistical differences in alveolar bone support between baseline, 6, and 12 months. Papillary fill data was categorized with nonparametric methods, and esthetics were subjectively evaluated by trained dental professionals.

RESULTS

Thirty-one implants in 17 subjects were followed for an initial healing period of 12 months. The age range of the subjects was 19 to 74 years.

The implant survival at 12 months was 96.7% (30/31). One mandibular incisor implant exhibited clinical mobility at 4 months and was removed and subsequently replaced without complication. Because of the limited number of failures, differences in surgical protocol (full-flap versus flapless), bone-grafted sites, or immediate extraction sites could not

Table 1 Radiographic Results: Radiographic Bone Level Above the First Thread

	Bone level	Change from baseline
Baseline	2.33 ± 0.73 mm	
6 months	1.75 ± 0.78 mm	−0.58 mm*
12 months	1.63 ± 0.81 mm	−0.70 mm*

*$P < .01$.

Table 2 Papillae and Esthetic Outcomes

Tooth site	Jemt 0	Jemt 1	Jemt 2	Jemt 3
Maxillary lateral	0%	0%	8%	92%
Mandibular incisor	0%	4%	36%	60%

be retrospectively assessed. In addition, differences between prosthesis types (individual crowns, splinted crowns, fixed partial dentures) and differences between implant lengths could not be determined.

The radiographic results indicated that a statistically significant amount of bone loss (0.58 mm) occurred between baseline and 6 months (Table 1). There was no significant progression in alveolar bone loss (0.12 mm) between 6 and 12 months.

The maxillary lateral sites demonstrated excellent fill of the interproximal papillae, with 92% of the sites completely filling the embrasure space (Table 2). The mandibular incisor sites were more highly variable, with 60% of the sites completely filling the embrasure space.

Overall, the esthetic results were determined to be very good to excellent by a subjective assessment of the patients and clinicians.

DISCUSSION

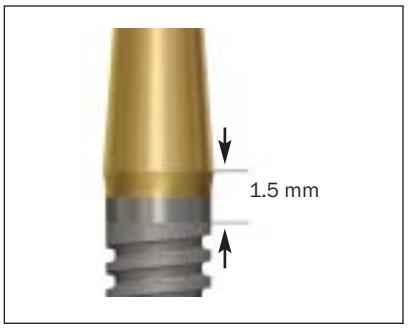
This study assessed the functional and esthetic efficacy of 3-mm-diameter dental implants as tooth replacements in areas of limited tooth-to-tooth spacing. Within the limits of the study, the initial healing response appears promising. The implant survival rate observed in the study (96.7%) precluded further analysis of factors that may affect the success rate in immediate-function 3-mm implants. This case series was not a randomized clinical trial powered to assess differences between treatment protocols; therefore, the absence of differences observed here should not be interpreted to indicate that differing clinical approaches will have no bearing on implant success. The implant placement and restoration in this study was carefully planned and orchestrated with a team approach to limit potential complications. In addition, the transitional restorations were not in occlusal lateral excursions, the patients were instructed not to incise food with the teeth during the first 3 months, and the postoperative healing was carefully monitored.

The narrow 3-mm, 1-piece implants showed statistically significant bone loss during the first 6 months compared to the bone level at baseline. At 12 months the alveolar bone level was also significantly different from baseline but not from 6 months. The statistically significant bone loss during the first 6 months (0.58 mm) may not be highly clinically significant since there was minimal bone loss (0.12 mm) during the subsequent 6 months.

Numerous lines of evidence exist to support the efficacy of placing restored implants in immediate function. The prognosis for longitudinal success appears favorable. A review of the literature on postrestorative survival rates of single and multitooth replacements, some for periods extending up to 8 years, lends credence to the value of early loading.[15–22] These investigations assessed early versus delayed loading and found collective success rates of 90% to 100%. Data from these studies show some additional saucering of crestal bone and a slightly increased risk of implant failure. Even so, overall conclusions indicate wide acceptance of early loading as a viable treatment option.

The observed results for alveolar bone loss in the present study are also comparable to those of other investigations. Both clinical trials and case series reports indicate a mean bone loss ranging from 0.82 mm in after 1 year of follow-up[23] to 1.2 mm after 3 years.[23,24] Similar studies measuring peri-implant osseous architecture following immediate function report marginal bone loss ranging from 0.7 after 10 months[25] to 1.5 mm following an 18-month evaluation.[26]

Some authors have suggested that the observed initial bone loss in immediate and delayed-load implants relates to the formation of a biologic width.[27] In a study of 2-piece roughened and machined-surface implants placed in the anterior region of the jaw, the initial bone loss was found to be approximately 1.3 mm.[28] This represented bone loss approximately to the roughened surface of the implant. The implant protocol for the placement of the 3-mm implants utilized in the present study called for the implant to be placed so that the roughened surface was 0 to 1.5 mm below the bone crest (Fig 4a). The implants in this study were positioned with the bone level at the junction of the gold-colored abutment and the machined surface. Figure 4b illustrates the bone loss with a flap reflected at the time of restoration. The bone level appeared to be at the level of the roughened implant surface. The interface of the machined implant surface



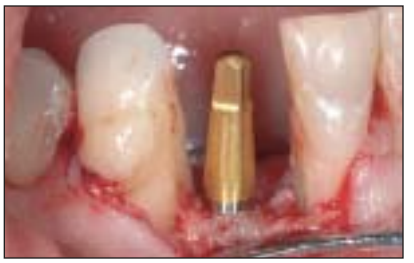


Fig 4a *(Left)* The manufacturer's recommended level of bone in relation to the implant.

Fig 4b *(Right)* Clinical appearance of the bone level at the time of restoration. The bone remodeled to the level of the roughened implant surface during the healing period.

and the gold-colored abutment surface was 0.75 mm above the roughened blasted surface. The mean bone loss over the first year was 0.70 mm, which may represent bone loss down to the roughened blasted surface over the first year. Animal studies have indicated that the position of the interface between the roughened and machined surfaces relative to the bone crest may influence alveolar bone loss.[29] The absence of a microgap or junction between the abutment and the implant body may also have helped limit the bone loss observed.[8,9,27] This is consistent with the findings from an animal model in which the biologic width around 1-piece and 2-piece implants was examined.[27] In the aforementioned study it was concluded that the biologic width was smallest when the rough/smooth border was placed at the bony crest. Further, the biologic width was always apical to the microgap, and no bone was formed on the smooth surface of the implants regardless of their depth of placement. The dimension of the biologic width that formed was consistent for all implant types and was similar in dimension to the biologic width around natural teeth.

The papilla fill was better for the maxillary lateral incisor sites than for mandibular incisor sites. Ninety-two percent of the maxillary lateral sites completely filled the embrasure space, whereas only 60% of the mandibular sites had complete papillae fill. Careful review of these data, however, uncovered a possible confounding element. Most of the subjects receiving mandibular implants in this study were older patients who exhibited existing bone loss and gingival recession as well as reduced papillae height on adjacent tooth sites. A study by Schropp et al of interproximal papillae levels adjacent to single-tooth implant restorations found that the papillae height 1.5 years after restoration was inversely correlated to patient age.[30] Some observations suggest that the level of bone support to neighboring dentition may be a more critical factor.[31,32] These investigations found that when bone-to-contact distance on the adjacent tooth was 5 mm or less, papillae were present 100% of the time, whereas when this measurement was 6 mm or greater, the papillae were present less than 50% of the time. In the present study, although the number of subjects was limited, the difference between maxillary and mandibular papillae fill appeared to be more dependent on patient anatomic characteristics than tooth site.

In many of the patients in this series, the implants were in close proximity (< 1.5 mm) to the adjacent tooth surface, indicating the tooth-to-implant distance did not affect papillae fill. This is consistent with an animal study of interimplant distance in dogs which found that implant spacing had no effect on papillae.[33] The difference between these findings and other investigations may be due to the unique design of the narrow implants evaluated. This study examined 1-piece transmucosal implants with tapering abutments as opposed to 2-piece implants in which there is an implant-abutment junction and an emergence profile of the margin that flares toward the adjacent teeth. The tapering design may provide more interproximal volume than a flaring abutment.

No objective evaluation criteria were used to evaluate esthetic outcomes other than evaluation of papilla fill by the modified Jemt index. However, patient satisfaction as judged by verbal comments was very positive. Subjective evaluation by trained dental professionals based on smile form, tooth structure, incisal edge, surface contours, line angles, contact area, embrasure form, surface texture, color, and tissue contour indicated that the esthetic results were excellent. This may reflect the temporization technique used (ie, the contours of the soft tissue were established from the transitional restoration at the time of implant placement.[34,35] As the tissue healed and matured over the initial 3-month healing period, there was progressive soft tissue fill observed coincident with improved esthetics. These findings were consistent with previous studies where well-contoured provisional restorations contributed to the health of interproximal tissues and enhanced the regeneration of papillae.[34,36]

CONCLUSION

Within the limits of this study, the 3-mm, 1-piece dental implant under assessment was an effective prosthetic support for edentulous areas of narrow dimensions. The data show a significant loss of crestal bone during the initial 6 months of healing (ie, the initial 6 months postloading) followed by a stable pattern of bone support after 12 months. The magnitude of the initial bone loss was consistent with the literature and may not be of clinical significance. A high percentage of complete papillae fill was found, especially for maxillary lateral incisors. This result may be related to peri-implant bone support coupled with that of adjacent teeth. In addition, the papillae outcome may have been aided by immediate fabrication of provisional restorations resulting in an improved soft tissue response and enhanced healing.

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