A Retrospective Survival Study of Trabecular Tantalum Implants Immediately Placed in Posterior Extraction Sockets Using a Flapless Technique

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A retrospective review of patient records was conducted in a single private practice to evaluate the efficacy of immediately placing a novel implant design in posterior jaw locations using a flapless technique. Forty-two patients (22 males, 20 females) with a mean (SD) age of 60.2 (7.6) years (range = 31–68) presented with 1–2 nonrestorable molar (maxillary = 14; mandibular = 8) or premolar (maxillary = 20; mandibular = 1) teeth compromised by periodontal disease, endodontic failure, root resorption, root fracture, or severe caries. Most patients (78.6%) had moderate (66.7%) or severe (11.9%) periodontitis. Other comorbidities included smoking (14.3%) and controlled diabetes mellitus (11.9%). After atraumatic extraction, teeth were immediately replaced with a total of 44 trabecular tantalum implants (Trabecular Metal Implants, Zimmer Biomet Dental) (diameter = 3.7–4.7 mm; length = 10–13 mm). Sites requiring augmentation were treated with 3 types of small-particle (250–1000 μm), mineralized, solvent-dehydrated, allografts (Puros) based on location: cortical for crestal sinus grafts, cancellous for peri-implant voids in thick tissue biotypes, or cortical-cancellous (70:30) mix for peri-implant voids in thin tissue biotypes. Cortical particulate was used when slower resorption would help maintain graft volume for esthetics or implant support. Grafts were covered with resorbable bovine pericardium membranes (CopiOs, Zimmer Biomet). Cumulative implant survival and success rates were 97.7%, respectively, with a mean (±SD) follow-up time of 25.0 ± 12.1 months (range = 4–48). One asymptomatic implant failed to osseointegrate. Within the limitations of this study, implants achieved outcomes comparable to conventionally placed and restored single-tooth implants in anterior jaw locations.

Key Words: trabecular metal, immediate placement, posterior implant placement, immediate temporary loading, grafting, sinus crestal elevation

INTRODUCTION

Implants placed in molar and premolar locations have traditionally exhibited slightly lower survival rates than have implants placed in anterior sites.[1] This may be attributable, in part, to the greater occlusal forces,[2] lower bone density[3,4] and limited vertical bone volume typically found in the posterior jaw.[1] Significant reductions in alveolar bone dimensions can also occur from tooth extraction,[5–8] maxillary sinus pneumatization, smoking,[9] long-term use of a conventional tissue-supported prosthesis,[10] and such diseases as periodontitis, diabetes, or osteoporosis.[11]

Although various grafting techniques[12–15] and distraction osteogenesis[16] have been successfully used to augment posterior jaws,[17] it is important to note that the low-density bone characteristically found in these regions may still predominate after grafting. Thin to poorly differentiated cortical bone[18,19] and trabecular bone volume that ranges from approximately 24% in males to 18% in females have been reported.[20–22] Histologies of sinus grafts taken from the same regions after 6–8 months of healing have also demonstrated approximately 25% vital bone.[20,23] Consequently, long-term implant survival rates in augmented posterior jaws have widely varied in the dental literature.[24–27]

In recent years, a novel, hybrid, titanium-tantalum implant (Trabecular Metal Implants, Zimmer Biomet Dental, Palm Beach Gardens, Fla) was developed and preliminarily evaluated in human[28–35] and animal[36–38] models. Briefly, the titanium implant body is a conventional tapered screw design with an unthreaded midsection of highly porous (~80%) trabecular tantalum (Trabecular Metal Material, Zimmer Biomet TMT, Parsippany, NY), which is fabricated by coating a vitreous carbon matrix (~2%) with elemental tantalum (~98%) through a chemical vapor deposition process.[28] The finished biomaterial has a mean (±SD) compressive strength of 60 ± 18 MPa, tensile strength of 63 ± 6 MPa, bending strength of 110 ± 14 MPa, and a modulus of elasticity (2.5–3.9 GPa) that more closely approximates that of natural bone (6.8–17 GPa) than titanium (106–115 GPa) and other common surgical metals (210–230 GPa).[28,30,31] Internally, trabecular tantalum forms a 3-dimensional network of interconnected pores in highly regular sizes (~430 μm) and shapes designed for osseoincorporation,[28] an expanded healing model for secondary implant fixation.[20,28–38]

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TABLE 1

Patient selection and implant outcome criteria*

Patient Selection Criteria
Inclusion
Patients who completed all treatment
Implant-supported single-tooth restoration or FPD: implant splinted to neighboring tooth
Immediately placed implant without significant grafting
Implant placed in molar or premolar location
Nonadjacent implant or recent graft placement
Exclusion
Patients currently undergoing treatment
Multiple implants supporting a single tooth or FPD: implant splinted to another implant
Implant placed in healed extraction site
Implant placed in central, lateral, or cuspid area
Implant adjacent to the treatment site
Healing bone graft adjacent to the treatment site
Implant placed with significant grafting
Implant Outcome Criteria
Implant survival
Clinical and radiographic evidence of osseointegration
Functioning according to its prosthodontic purpose
Absence of peri-implant radiolucency
Absence of infection/suppuration
Absence of pain
Absence of mobility when tested
Implant success
Meets all criteria for implant survival
Esthetically pleasing to the patient and the clinician
All implants accounted
Clinically healthy soft and hard tissues
Bone loss $<$1.0 mm after first year of function
Annual bone loss $<$0.2 mm after the first year
Width of keratinized tissue $>$1.5 mm
Functionally comfortable for the patient

*FPD indicates fixed partial denture.

A clinical study was conducted to evaluate the clinical efficacy of immediately placing trabecular tantalum implants in posterior jaws using a flapless technique. This current article reports on the clinical outcomes of the study.

Materials and Methods

Study design

This single-center, private-practice study was a retrospective clinical evaluation of patients previously treated with tooth extraction and immediate placement of a novel implant design in molar or premolar locations using a flapless technique. The study objective was to determine the survival and success rates of the test implant under immediate conditions in posterior jaw locations. Implant survival was defined as a dental implant that was functioning in accordance with its prosthodontic intent and was free of adverse clinical manifestations, including lack of peri-implant radiolucency, suppuration, pain, or mobility when manually tested. A successful implant was defined as a surviving implant that met the needs and expectations of the patient and also exhibited appropriate clinical esthetics based on a consensus of the clinician and the patient. The study was conducted in accordance with the ethical and patient privacy provisions of the Declaration of Helsinki (2013) and the Health Insurance Portability and Privacy Act (HIPAA, 1996). These safeguards to patient care and privacy—combined with the study's retrospective design—did not necessitate additional external ethical approvals. Patient records were carefully reviewed to identify all subjects who had been treated with extraction of at least one nonrestorable posterior tooth, immediate placement of a dental implant into the fresh extraction socket, and restoration of the implant prior to chart review. Treatment data from the patient records were entered on a spreadsheet in a password-protected computer.

Patients

All subjects met the inclusion criteria (Table 1) and were treated according to the same standard office protocol (Table 2). Prior to surgery, patients were thoroughly evaluated through detailed clinical and radiographic examinations, assessment of their oral hygiene and clinical habits, and review of their dental and health histories. During the clinical interview, patient questions were answered and a determination was made of their ability to commit to a long-term treatment plan. Oral hygiene procedures were also reinforced at that time. Only patients deemed by the clinician as acceptable candidates for implant placement were scheduled for surgery after informed consent was obtained. Before implant placement, periodontal clinical attachment levels were evaluated and surgical or nonsurgical periodontal therapy was performed, if necessary. Maintenance recall visits every 3 months were scheduled for the patient throughout the treatment and follow-ups. Bleeding on probing and plaque index[39] were monitored at all maintenance visits, and implant placement was initiated only if signs of gingival inflammation were absent and patient plaque control deemed as acceptable.

A diagnostic workup was performed for each patient to evaluate the volume and location of available bone as well as the esthetic and functional needs of each case. Radiographic imaging was done—including periapical radiographs and computed tomography—to analyze the anatomy of the planned surgical site. Diagnostic casts were fabricated and mounted on semi-adjustable articulators utilizing a face bow transfer and vertical registration to determine interarch relationships, available occlusal dimensions, proposed implant position, crown-to-root ratios, and potential complications. This allowed the creation of prosthetic wax-ups and the fabrication of a surgical template to guide implant placement relative to the planned prosthesis.

Treatment Planning Protocol

Prior to tooth extraction, a cone beam computerized tomography (CBCT) scan was taken to determine if the patient was a candidate for an immediate posterior implant placement. For each case, the available bone width and height, buccal plate thickness, and furcation defect were evaluated using the CBCT. When evaluating ridge height, the maxillary sinus served as the superior limit for the maxillary arch, and the inferior alveolar canal served as the inferior limit in the mandible. A minimum distance of 2 mm from the inferior alveolar canal was maintained when placing implants in the posterior mandible.

Table 2

Protocol for immediate implant placement in posterior jaws

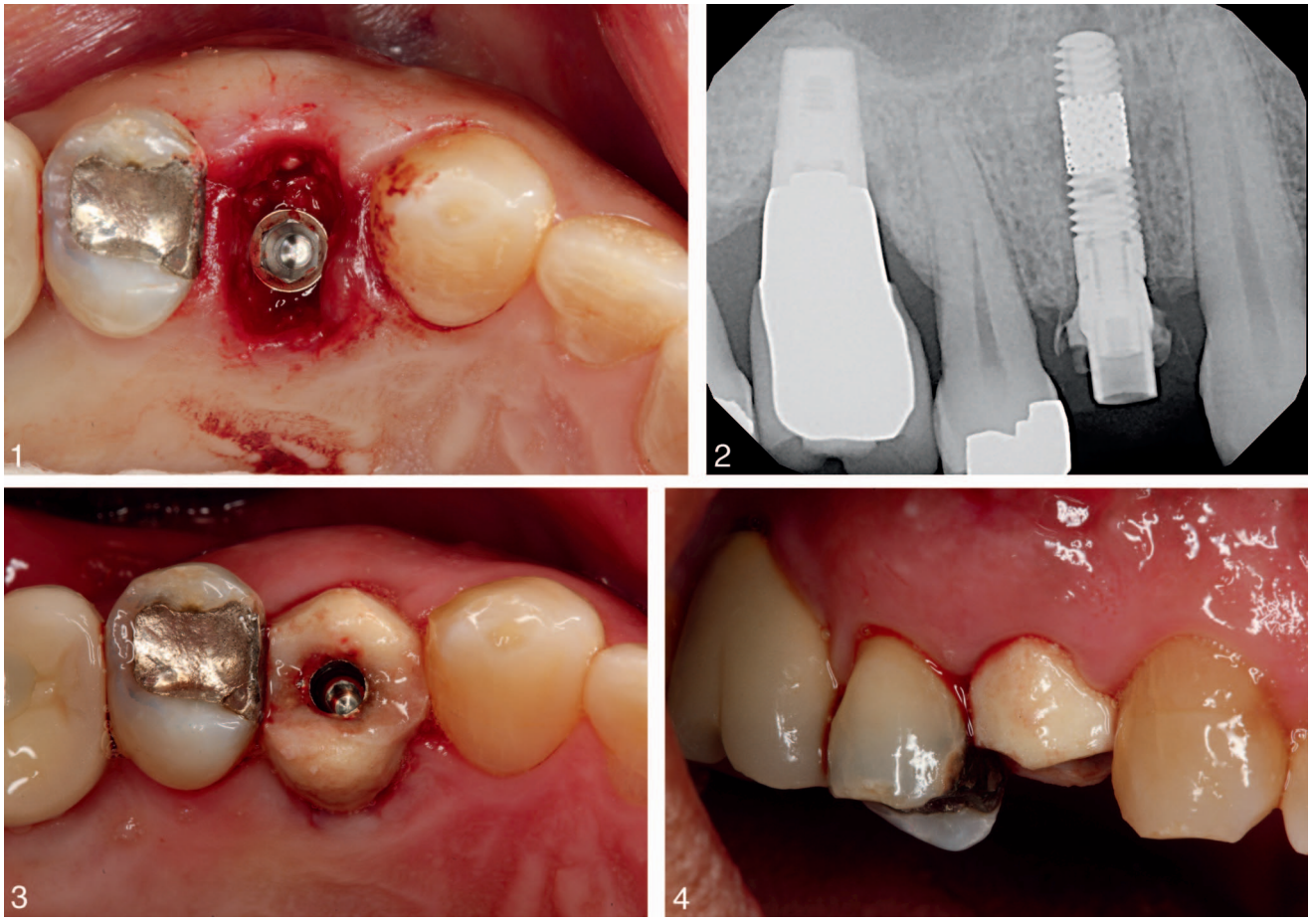
Step	Procedure	Indication	Details
1	Determine the patient's gingival biotype	Thin gingival biotype	Patients with <1.5 mm of gingival thickness
		Thick gingival biotype	Patients with ≥2 mm of gingival thickness
2	Evaluate the preoperative anatomy of the extraction site	Cone beam computerized tomography	Identify available bone width and height Determine buccal wall thickness Identify the furcation bone width (if applicable)
3	Extract the tooth	Nonrestorable tooth	Use an atraumatic extraction technique
4	Prepare the extraction socket for immediate implant placement	Single-rooted tooth	Engage the lingual aspect of the extraction socket during osteotomy preparation Drill 3–4 mm past the apex of the extracted tooth to form a primary stability rectangle. Place the implant at a minimum of 2 mm away from the lingual aspect of the facial socket wall Select an implant diameter that results in at least 0.5 mm between the implants
		Multi-rooted tooth	Engage the center of the furcational dome Drill 3–4 mm past the apices of the extracted tooth.
5	Place the implant relative to the patient's anatomy	Optimal position of the implant's prosthetic platform	0.5 mm subcrestal 3–5 mm below the free gingival margin
6	Graft residual peri-implant voids	Indication for thin gingival biotype	Composite cortical-cancellous (70:30) allograft Bovine pericardium membrane
		Indication for thick gingival biotype	Cancellous allograft Bovine pericardium membrane
7	Graft the maxillary sinus	Inadequate bone volume for implant placement	≥4 mm vertical subantral space required Cancellous, cortical or composite particulate allograft
8	Determine the optimal implant loading time	Immediate loading Delayed loading	≥40 Ncm of implant insertion torque <40 Ncm of implant insertion torque

For maxillary implant sites, a minimum of 4 mm vertical height from the tip of the furcation dome in multirooted teeth (or the most apical aspect of the socket for single root teeth) to the floor of the maxillary sinus was deemed necessary for use of crestal sinus elevation simultaneous to immediate implant placement. A minimum of 3–4 mm apical to the top of the furcation dome or the most apical limit of the socket was maintained for achievement of primary stability. A buccal plate thickness of at least 2 mm and a buccal wall height that allowed placement of the implant platform both 0.5 mm subcrestal and no more than 3–5 mm from the anticipated free gingival margin were considered desirable. If there was not enough bone to place the implant within the anatomic limitations of the required prosthetically driven position, a two-stage surgical approach was followed, which involved grafting the extraction site and then placing the implant at a later time. If the patient was deemed a surgical candidate based on the CBCT results, the implant size was selected based on the bone height, width and prosthetic needs.

Surgery

Patients were administered antibiotic prophylaxis (amoxicillin 1 g or Clindamycin 150 mg if sensitive to penicillin) 1 hour prior to surgery and rinsed intraorally with 0.2% chlorhexidine gluconate 2 minutes prior to the start of the procedure. Antibiotic (amoxicillin 500 mg or Clindamycin 150 mg t.i.d.) and antiseptic (0.2% chlorhexidine gluconate 15 mL 30-second rinse t.i.d.) medications were prescribed for 1 week. Acetaminophen/hydrocodone (Vicodin) 5 mg/500 mg and diflunisal (Dolobid) 500 mg were also prescribed for analgesia and to help control swelling during the first 24 hours after surgery, respectively.

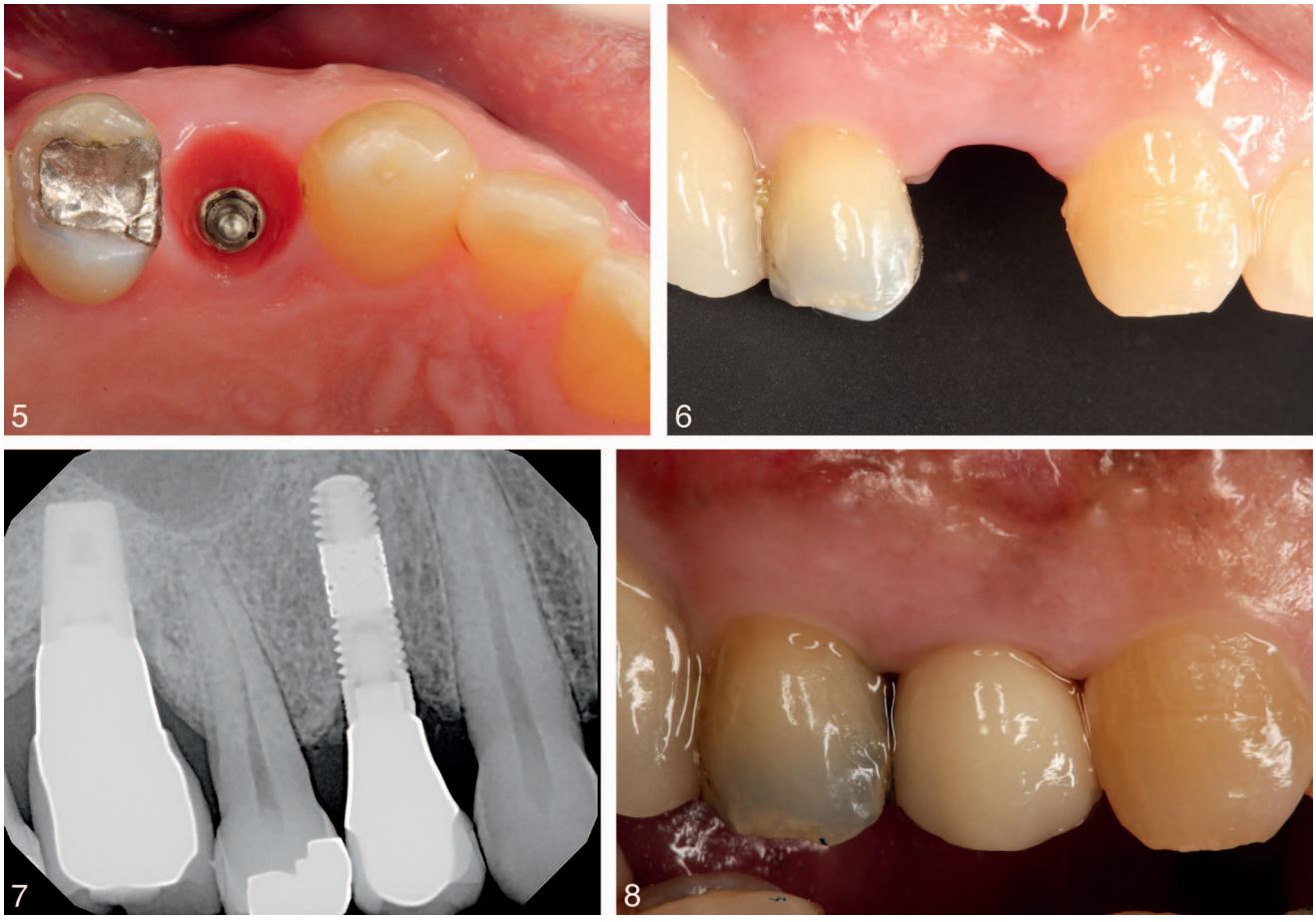
An intrasulcular incision and circular fibrotomy were performed, and the tooth was extracted with minimal trauma to the alveolar bone (Figures 1 through 17). The residual alveolar socket was thoroughly debrided to remove the periodontal ligament and all necrotic tissue, then irrigated with sterile saline solution. Next, a second careful evaluation of the socket was performed to determine if the remaining bony anatomy was sufficiently intact to proceed with osteotomy preparation.



Figures 1–4. Figure 1. Case No. 1: After atraumatic flapless extraction of the nonrestorable maxillary right first premolar (#5), an implant was placed according to the manufacturer's protocol. The lingual aspect of the extraction socket was engaged during osteotomy preparation, which extended 3 to 4 mm past the apex of the extracted tooth to form a "primary stability rectangle." Note that the distance between the walls of the implant and the adjacent osseous crest allows for the minimum 0.5 mm of space to prevent resorption of the interproximal bone during remodeling and healing. The peri-implant voids are filled with small-particle MSDBA. **Figure 2.** Case No. 1: Postoperative periapical radiograph shows the implant, graft and provisional prosthesis in place. **Figure 3.** Case No. 1: Occlusal view of screw-retained acrylic provisional prosthesis fabricated chairside. Note the screw access hole in the center of the occlusal surface and the reduced marginal ridges. **Figure 4.** Case No. 1: Buccal view shows that the cusp have been reduced to eliminate contacts in centric protrusive and excursive movements.

An osteotomy was prepared at the site via sequential graduated drills under copious irrigation according to the manufacturer's protocol. In single-rooted or merged-root extraction sockets, the osteotomy was positioned away from the buccal socket wall as to engage the lingual/palatal aspect of the extraction socket. In molar extraction sites, the furcation dome was engaged as the initial site for the osteotomy. The study implants were placed into the prepared sites per the manufacturer's protocol. Specific implant length and diameter were selected according to the individual needs of the case. An implant diameter was selected that allowed for a minimum of 0.5 mm between the implant and the adjacent crestal bone to prevent pressure on and resorption of the interproximal crestal bone during remodeling and osteointegration. During implant placement, the cervical collar of the implant was positioned 0–0.5 mm apical to the buccal alveolar bone margin and 3–5 mm from the free gingival margin. In the maxillary posterior jaw, if a crestal sinus elevation was needed, the osteotomy was prepared up to 1 mm from the sinus and prepared at that height to the last drilling bur that corresponded to the intended diameter of the implant to be placed. At this point, the floor of the sinus was perforated using a reamer (Sinus Crestal Approach Kit, Zimmer Biomet Dental) that corresponded to the length and diameter of the last bur used to prepare the osteotomy for implant placement. Once the Schneiderian membrane was exposed and elevated, small-particle (250–1000 μm) cortical mineralized solvent-dehydrated bone allograft (Puros Cortical Particulate Allograft, Zimmer Biomet Dental) was delivered and compacted in the sinus cavity using osteotomes (Summers Osteotomes, Zimmer Biomet Dental).

Immediately after placement, the implants' primary stability was evaluated. Implants were noted as stable only if they resisted rotation and rocking under applied manual manipulation. If an implant did not achieve primary stability, the implant was removed and the patient was immediately treated with a wider diameter implant and a traditional two-stage surgical



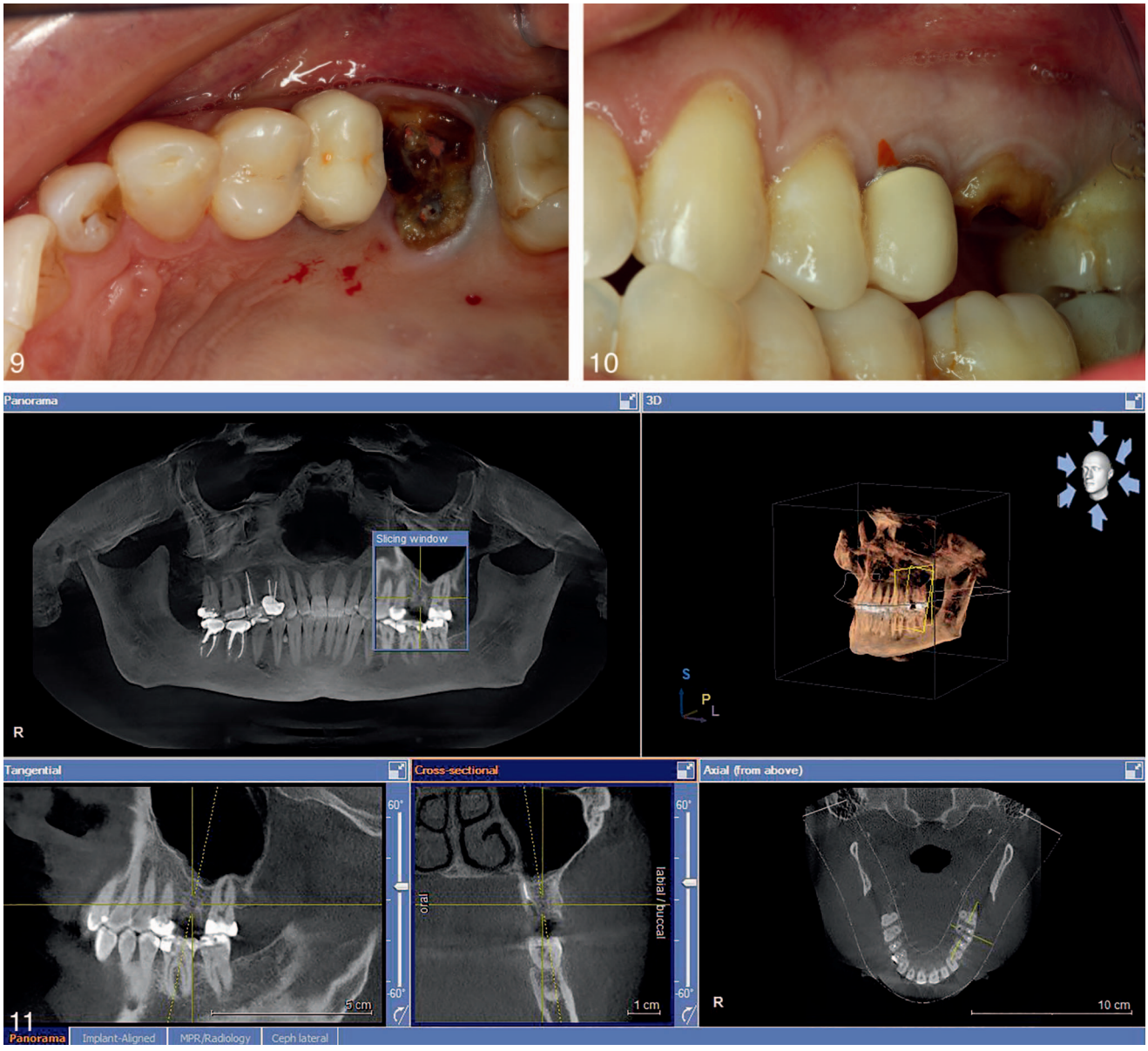
Figures 5–8. Figure 5. Case No. 1: Occlusal view shows the soft tissue contour of the healed extraction site after removal of the provisional prosthesis. **Figure 6.** Case No. 1: Buccal view of the healed extraction site shows the preserved papilla. **Figure 7.** Case No. 1: Periapical radiograph after delivery of the definitive screw-retained prosthesis. Note that the interproximal bone levels remained stable throughout healing and osseointegration of the implant. **Figure 8.** Case No. 1: Clinical buccal view of the definitive screw-retained, porcelain-fused-to-high-noble metal, implant-supported crown in place.

procedure, as stipulated by the treatment protocol. In the premolar areas, implants that achieved an insertion torque value of at least 40 Ncm were immediately provisionalized with a provisional acrylic crown that was fabricated chairside and cemented to a temporary titanium cylinder abutment, attached to the implant body with a retention screw. The occlusion was adjusted to prevent centric contacts as well as any contact in lateral excursions or in protrusion. In the molar areas, provisional healing abutments were immediately delivered to all other implants deemed as clinically stable.

Immediate implant placement in fresh extraction sockets resulted in peri-implant voids at the bone-implant interface or vertical buccal wall defects. The decision of whether or not to graft a defect was based on its size, as measured on CBCT scans according to the criteria of Le and Borzabadi-Farahani.[40] Defects <2 mm were allowed to heal without grafting, while larger defects (≥ 2–<3 mm = small; 3–5 mm = medium; >5 mm = large) were grafted according to patient's biotype. In cases of a thin biotype, residual extraction socket defects were filled with a 70:30 mixture of small particle (250–1000 μm) cancellous and cortical mineralized allograft (Puros Cancellous-Cortical Mix [70:30] Allograft, Zimmer Biomet Dental). This mixture was selected because the slowly resorbing cortical particulate would help maintain the graft volume for esthetics. In patients with a thick biotype, residual peri-implant defects were grafted with small-particle (250–1000 μm) cancellous allograft (Puros Cancellous Particulate Allograft, Zimmer Biomet Dental). Graft materials were isolated with a resorbable bovine pericardium membrane (CopiOs Pericardium Membrane, Zimmer Biomet Dental). These augmentation materials were selected because of their documented efficacy in hard and soft tissue regeneration.[40–45] The wound was stabilized with 5.0 polyglactin dyed vicryl sutures and careful soft tissue management.[46]

Follow-up

Patients were reappointed at 1 week, 4 weeks, and 2 months for postoperative follow-up, and implants were definitively restored with screw-retained, porcelain-fused-to-noble-metal restorations at an average of 8 months after implant placement. Patients were reappointed 1 month after delivery of the definitive restoration and then placed on a 3-month maintenance program. At all monitoring appointments, soft tissue status and plaque indices were evaluated and recorded.



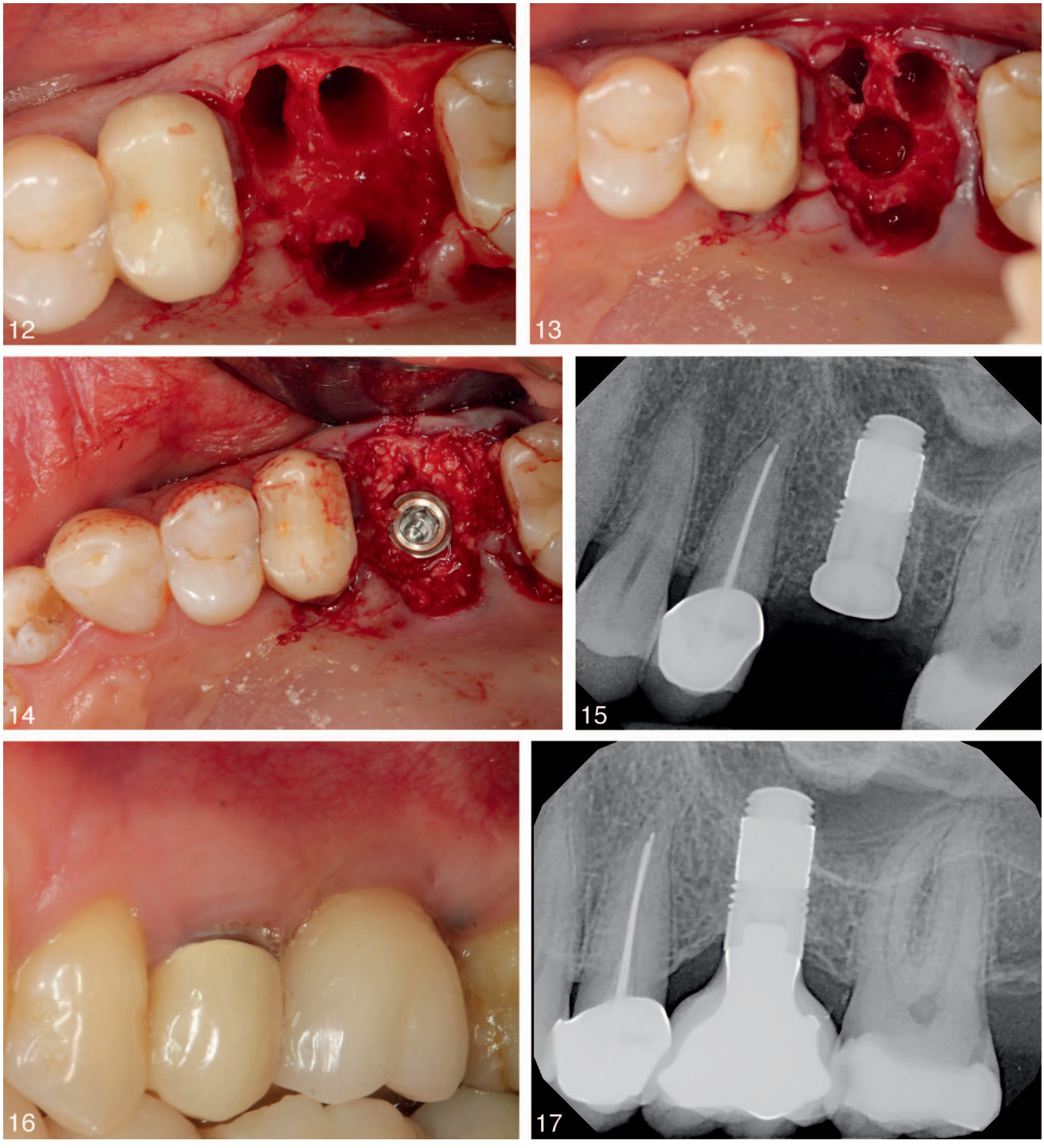
Figures 9–11. Figure 9. Case No. 2: Occlusal view of a nonrestorable maxillary left first molar (#14). **Figure 10.** Case No. 2: Buccal view of the nonrestorable tooth. **Figure 11.** Case No. 2: Sagittal view on the cone beam computerized tomography (CBCT) image sliced through the center of tooth #14. Note the furcal bone width and height appears adequate for immediate implant placement. The maxillary sinus area is also free of any notable pathology if crestal sinus elevation is needed. Axial view of the CBCT image sliced through the center of tooth #14. Note the height of the furcal dome and the adequate bone apical to the root tips. The distance from the top of the furcal dome to the floor of the maxillary sinus is adequate for achievement of primary stability, but vertical sinus augmentation via the crestal approach will needed.

Radiographic monitoring utilizing a Rinn Holder technique (Rinn, Dentsply, York, Pa) was performed immediately after implant placement, and postoperatively at 1 week, 4 weeks, 2 months, 4 months, and 5 months, and then on a yearly basis. Implant survival and success criteria are summarized in Table 1.

Results

Patient demographics and treatment data are summarized in Tables 3 and 4. A total of 42 patients (20 females, 22 males) with a mean (SD) age of 60.2 (7.6) (range = 31–68) years were treated with 44 implants and monitored for a mean (SD) follow-up time of 25.0 (12.1) (range = 4–48) months. A majority of patients (n = 33; 78.6%) had moderate (n = 28; 66.7%) or severe (n = 5; 11.9%) periodontal disease. Other patient comorbidities included smoking (n = 6; 14.3%) and controlled diabetes mellitus (n = 5; 11.9%). Reasons for tooth loss included endodontic failure, root resorption, tooth fracture, chronic periodontal abscess, and severe dental caries.

Of the 44 implants placed, 8 (18.2%) implants in maxillary premolar sites achieved 40 Ncm of insertion torque and were



Figures 12–17. Figure 12. Case No. 2: Atruamatic extraction of tooth #14 following careful sectioning and elevation preserved the thick buccal plate and wide furcal dome. **Figure 13.** Case No. 2: The osteotomy is prepared in the center of the furcal dome and the vertical augmentation via the crestal osteotome technique is performed using small particle cortical MSDBA. **Figure 14.** Case No. 2: After implant placement in the prepared osteotomy, remaining peri-implant voids are filled with small-particle MSDBA. After engaging a cover screw, a pericardium membrane is placed over the site and primary closure is attempted with 5.0 vicryl sutures. **Figure 15.** Case No. 2: An immediate postoperative periapical radiograph of the maxillary left first molar #14. **Figure 16.** Case No. 2: Clinical image shows a buccal view of the definitive, screw-retained, porcelain-fused-to-high-noble-metal, implant-supported crown #14. **Figure 17.** Case No. 2: Periapical radiograph after delivery of the definitive screw-retained prosthesis.

TABLE 3

Distributions of patients and implants

	Patients		Implants	
	n	%	n	%
Patients	42	100	44	100
Males	22	52.4	22	50.0
Females	20	47.6	22	50.0
Diabetics	5	11.9	5	11.4
Smokers	6	14.3	6	13.6
Periodontitis	33	78.6	35	79.5
Moderate periodontitis	28	66.7	30	68.2
Severe periodontitis	5	11.9	5	11.4

provisionally restored immediately after placement. Most implants were placed in the maxillary posterior (n = 34; 77.7%) and all of the remaining implants were placed in the mandibular posterior (n = 10; 22.7%). Of the 34 maxillary posterior implants, 12 (27.3%) were placed in the molar and 22 (50.0%) were placed in the premolar regions. Additionally, 15 (34.1%) of the implants placed in the maxillary posterior required crestal sinus elevation: 11 (25.0%) in molar and 4 (9.1%) in premolar locations. All implants placed with crestal sinus elevation were restored and met the criteria for survival and success (Table 1) at the time of follow-up. No implants placed in the maxillary molar region were immediately temporized, while 8 (18.2%) of the implants placed in the maxillary premolar region were provisionalized, and 1 (2.3%) of the implants placed in the maxillary premolar region had both crestal sinus elevation and immediate provisionalization. All implants that were immediately provisionalized received definitive restorations and were deemed successful at follow-up.

Ten (22.7%) of the 44 implants were placed in the mandibular posterior jaw: 8 (18.2%) in the molar and 2 (4.5%) in the premolar areas. No implants placed in the mandible were immediately provisionalized. All implants placed in the mandibular molar region met the criteria for final restoration and were determined to be successful at time of follow-up. One asymptomatic implant placed in the mandibular premolar region failed to osseointegrate. The implant was listed as a failure before prosthetic loading and was removed from the study. Outside of the study, the failed implant was removed and the respective site was grafted to allow for future implant replacement. After bone healing, a new implant was successfully placed and restored but was not part of the study data. The remaining 43 implants remained stable, in function, and showed no discernible radiographic changes in bone levels during follow-up visits.

Periodontitis was the most common cause of tooth failure in the study and at the time of surgery. A total of 33 (78.6%) subjects had underlying periodontitis and 35 (79.5%) of the implants were placed in patients with underlying periodontal disease. It is important to note, however, that periodontitis and other comorbid conditions did not appear to influence implant survival or implant success. Implants were evenly distributed between male and female patients in the study population. Of the co-morbid conditions at the time of implantation, periodontal disease (n = 33; 78.6%) was most common, followed by smoking (n = 6; 14.3%) and diabetes mellitus (n = 5; 11.9%).

TABLE 4

Distribution of implant placement by location, technique and clinical results

	Location					Technique				Clinical Results			
	Implants Placed					Crestal Sinus Elevation		Immediate Loading		Implant Survival		Implant Success	
Category	Cumulative n	Implants n	Diameter (mm)	Length (mm)	%	n	%	n	%	n	%	n	%
All implants Placed	43				100	15	34.1	8	18.2	43	97.7	43	97.7
Maxillary Posterior	34				79.1	15	44.1	8	23.5	34	100	34	100
Molar sites	14	2	4.1	10	32.6	11	91.7	0	0	14	100	14	100
		10	4.7	10									
		1	4.7	11									
		1	4.7	13									
Premolar sites	20	3	3.7	10	46.5	4	18.2	8	36.4	20	100	20	100
		3	3.7	11.5									
		1	3.7	13									
		6	4.1	10									
		3	4.1	11.5									
		1	4.1	10									
		2	4.7	13									
		1	4.7	11.5									
Mandibular Posterior	9				20.9	N/A	N/A	0	0	9	90	9	90
Molar sites	8	4	4.7	10	18.6	N/A	N/A	0	0	8	100	8	100
		4	4.7	11.5									
Premolar sites	1	1	3.7	10	2.3	N/A	N/A	0	0	1	50	1	50

Discussion

To analyze the osseoincorporation process, Arriba et al.[20] placed 24 cylinders of trabecular tantalum in the posterior jaws (14 maxillary, 10 mandibular) of 23 human volunteers. At 2, 3, 6, and 12 weeks postoperative, cylinders ($n = 6$ per time interval) were retrieved for histologic analysis.[20] The surrounding host tissue formed a direct structural link with the external surface of the cylinders (osseointegration).[20] In addition, angiogenesis and bone ingrowth from the host tissues were increasingly evident in the peripheral pores of the biomaterial over time.[20] Cellular migrations deep inside the cylinders and the neoformation of blood vessels and bone were observed as early as week 3.[20] Mean (SD) percentages of calcified bone tissue inside the cylinders were evaluated at depths of 0.5 mm and 1.0 mm from the external surfaces of the cylinders and then in the entire cylinder as a whole.[20] After 12 weeks of healing, mean ($\pm$SD) percentages of calcified bone tissue were 22.74 $\pm$ 11.91% at a depth of 0.5 mm, 16.77 $\pm$ 9.84% at depth of 1 mm, and 14.94 $\pm$ 8.21% in the entire cylinder.[20] The finding of approximately 23% calcified bone penetration at a depth of 0.5 mm inside the cylinders after 12 weeks of healing was consistent with the 18%–24% trabecular bone volume in the first molar regions,[20–22] and the roughly 25% vital bone typically found in sinus grafts after 6 to 8 months of healing.[20,23] The work of Arriba et al.[20] illustrated the three healing pathways that jointly comprise the osseoincorporation process: (1) conventional osseointegration between the host bone and external surfaces of the cylinders, (2) angiogenesis and bone ingrowth through the peripheral pores of the cylinders from the surrounding host tissues, and (3) the neoformation of bone and blood vessels deep inside the highly porous material.[20] Further research is needed to fully understand this tissue neoformation process, which may be attributable to osteoblasts and angioblasts present in the infiltration tissue that filled the internal cells of trabecular tantalum by week 2.[20]

Before undertaking the clinical treatment that served as the basis for the present retrospective analysis, a search of the dental literature revealed no prior studies on the immediate placement of trabecular tantalum implants in fresh extraction sockets using a flapless technique, followed by immediate loading of implant-supported, single-tooth restorations. The lack of historic data on this novel implant design may have slightly elevated clinical risks at the time of treatment because no inherent surgical or restorative challenges could be identified at the time. In addition, the retrospective structure of the current study precluded the ability to randomly assign patients to both experimental and control groups. Results, therefore, should be considered preliminary despite the cumulative mean implant survival and success rates of 97.7%, respectively, after more than 2 years of clinical follow-up. This outcome surpassed a previously reported 95% survival rate for implants placed into healed extraction sites and restored with single-tooth restorations using a conventional delayed loading protocol.[47] Prospective randomized controlled clinical studies are needed to determine how the immediate techniques in the current study compare with conventional delayed implant procedures.

Concerns[28] about the porosity of trabecular tantalum implants possibly posing a risk for plaque attachment and bacterial colonization inside the implant have not been substantiated in animal studies[36,37] or human[35] cases. One reason may be the placement of the porous material in the midsection of the implant and away from the gingival crevice. Other factors that warrant further investigation are the effects of angiogenesis or vasculogenesis observed inside the cells of trabecular tantalum by Arriba et al.[20] If a functioning vascular network actually develops inside the highly porous implants, existing antibiotic therapies may be adequate treatment for eliminating bacterial infections. Further randomized controlled clinical trials are still needed to evaluate the features and benefits of trabecular tantalum implants.

Conclusion

Implants immediately placed into fresh extraction sites and definitively restored with single-tooth restorations no sooner than 4 months after implant placement achieved survival and success outcomes greater than 95%, which is equivalent to reported outcomes for implant-supported, single-tooth restorations subjected to conventional delayed placement and loading protocols. Periodontitis and other co-morbid conditions did not influence the outcome.

Note

The authors have no financial interest in any company or products used in this study, nor have there been any financial contributions made by commercial interests for performing this study.

Abbreviation

CBCT: cone beam computerized tomography
FPD: fixed partial denture

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