

Small-Diameter Implants: A 7-Year Retrospective Study

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Oral implantology has become a major discipline within the field of dentistry. Small or mini dental implants have demonstrated success in the retention of removable and fixed prostheses. Small-diameter implants (SDI) and mini-diameter implants (MDI) describe a group of implants that demonstrate a diameter less than 3 mm. This retrospective study reports on 335 SDI placed during a 7-year period. All implants were placed in healed sites (>6 months) and loaded immediately or after waiting 3 months. A total of 321 implants were restored and functional within the study's time interval. A total of 14 implants failed, resulting in a 96.1% implant success rate. Treatment plan considerations should include prosthetic design, specific arch, and immediate load. Overall, SDI can be utilized as an alternative implant treatment option for patients with atrophic bone, compromised medical histories and financial constraints.

Key Words: *small-diameter implant, mini dental implant, 1-piece, auto-advance*

INTRODUCTION

Implant dentistry has become a well-recognized discipline of dentistry by oral care practitioners. The field has demonstrated predictable long-term outcomes while meeting patient expectations.¹ Although conventional diameter implants (3.3–6.0 mm) remain the primary choice, SDI or MDI (1.8–3.0 mm) have emerged as an alternative option for patients with minimal bone.^{2,3}

Small-diameter implants received US Food and Drug Administration (FDA) approval for long-term usage for complete dentures, removable partial dentures, and multi-unit fixed prosthetics.⁴ Histological and clinical studies confirmed that osseointegration was achieved, similar to conventional diameter implants in regards to bone-to-implant contact (BIC) values.^{5,6} Small-diameter implants are characterized as 1-piece and a diameter size range of 1.8 to 2.9 mm. The implant is manufactured from Ti alloy (Ti AL VN), which provides strength from fracture. The threads are blasted and acid is used to etch and increase roughness, and a transgingival collar with micro threads facilitates soft tissue adherence (3M ESPE, St Paul, Minn).⁷ An o-ball or square head prosthetic design serves as the retentive feature.

The body of evidence-based research associated with conventional diameter size implants is vast; however, SDI studies are limited.⁸ This paper is a retrospective study of 335 implants placed in a private office by a single clinician between April 2009 and June 2016. The implants were utilized as retentive features in removable and fixed prosthesis. The main objective of the retrospective study was to evaluate success and failures and its relationship to various clinical conditions.

METHODS AND MATERIALS

A total of 80 patients were involved in small-diameter implant therapy receiving 335 implants fabricated by a single implant

manufacturer (3M ESPE). A diagnostic evaluation consisted of a medical history, diagnostic models, periapical or panoramic radiographs, intraoral examination, and photographs. At consultation, treatment options were provided, consent reviewed, signed, and a time for treatment completion given.

All hopeless teeth were atraumatically extracted and grafted with a mineralized irradiated bone allograft (Puros, Zimmer Inc, Carlsbad, Calif) and contained with a d-PTFE barrier (Cytoplast, Osteogenics, Biomedical, Lubbock, Tex). The surgical sites were allowed to heal 6 months prior to SDI surgery.

Patients were prepped, draped, and asked to rinse with a chlorhexidine mouthwash for 30 seconds. Platelet-rich plasma (PRP) and fibrin (PRF) were developed after a 20-mL blood draw from the median cubital vein using a standard phlebotomy technique. Platelet-rich plasma preparation was initiated after a 10-mL whole-blood draw with a yellow-top vacutube containing tris-sodium citrate with dextrose and PRF was developed after a 10-mL whole-blood draw into a red-top vacutube (silicone coated glass tube with no additives). The blood was placed in a single spin (Clinseal model, Salvin Dental, Charlotte, NC) centrifuge for 12 minutes at 3100 RPM for separation of whole blood into PRP and PRF.^{9,10} Two percent lidocaine with 1:100 000 epinephrine was administered in a buccal and lingual/palatal infiltration technique. A surgical guide was placed, bleeding points established with an endodontic explorer, and a #2 round bur created a "dimple" on the bony crest. The vacuum-formed surgical guide was fabricated on a stone model from an irreversible hydrocolloid impression. The surgical guide delineates the mesial distal position of the implant sites and the relationship of the distal implant site with regards to the mental foramen or anterior wall of the maxillary sinus. A midcrestal incision was made with a 15c blade and the flap reflected with a periosteal elevator. A 1.1-mm drill was utilized to create a shallow osteotomy at a depth of one-third to one-half of the implant length. The appropriate size implants were auto-advanced with a finger driver, thumb wrench, and ratchet. The flap was closed with 4.0 polyglactin (Vicryl, Ethicon, Sommerville, NJ) interrupted sutures.

Patients received postoperative instructions with emphasis on extraoral cold packs adjacent to the surgical site and soft

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DOI: 10.1563/aaid-joi-D-16-00098

TABLE 1
Implant success in 321 cases

Diameter/Length (mm)	Numbers
1.8 × 10	76
1.8 × 13	62
1.8 × 15	2
2.1 × 10	4
2.1 × 13	37
2.4 × 10	35
2.4 × 13	101
2.4 × 15	4

food for 24 hours. Warm salt H₂O rinses after 24 hours were advised and continued until suture removal in 14 days. Medications were prescribed, consisting of amoxicillin (500) TID, ibuprofen (600) q6h and chlorhexidine BID for 5 days. The restorative stage was initiated at 6 months postoperatively for maxillary SDIs and 3 months postoperatively for mandibular SDIs. Implants with a lack of mobility or pain on percussion were incorporated into the final prosthesis, including an overdenture, fixed bridge, or a single crown.

RESULTS

Eighty patients in the age range of 30 to 94 received a total of 335 SDIs between April 2009 and April 2016. Three hundred and twenty-one implants were functional within the time span of our study, exhibiting a resultant success rate of 96.1%. Of the 80 patients, 25 were male and 55 were female. Of the implants, 52.2% (175) were placed in the maxilla and 47.2% (158) in the mandible. A diameter width of 1.8 mm, 2.1 mm, and 2.4 mm with lengths of 10, 13, and 15 mm were utilized in the study (Table 1). The most common size implant used in the maxilla was a 2.4 × 13 mm (101/321) and 1.8 × 10 (76/321) in the mandible. Of the 333 total implants, 88.3% (296) served as retentive features for removable overdentures, 9.9% (33) as fixed bridge abutments, and 1.2% (4) were single unit crowns.

A low percentage of implant failures were demonstrated in relation to survival rates (Table 2). Fourteen implants (11 patients) demonstrated failure of the 335 implants (80 patients) placed. The results showed a failure rate of 4.2%. A gender breakdown within the failure group was 7 females and 4 males within an age range of 50 to 76 years old. Eleven implants in the failed category were placed in the maxilla (78.6%) with 3 in the mandible (21.4%). A removable prosthetic design accounted for 13 of the failures (92.9%). Only 1 failure was seen in the fixed prosthesis group.

A diameter width of 2.4 mm accounted for 78.6% (11/14), while 2.1 mm and 1.8 mm exhibited 21.4% (3/14) of the failures, cumulatively. The most common length, 13 mm, demonstrated a failure rate of 64.3% (9/14). Varied lengths accounted for the remaining failures (Table 3).

The statistical mean for time of implant failure was 10.8 months with the median at 8.0 months. The results suggest that the majority of SDI failure occurs within the first year of placement. Two patients accounted for 5/14 (35.7%) failures. More specifically, all failed implants were placed in the maxilla and 3 immediately loaded. Of the failures, 11/14 (78.6%) were placed in the anterior aspect while 3/14 (21.4%) were in the posterior segment of the mouth.

DISCUSSION

Implant dentistry has evolved into a predictable discipline over the last 4 decades. Conventional, 2-stage diameter implants are the most utilized type of system employed.¹¹ Small-diameter implants or MDIs have emerged as an alternative option.¹² Osseointegration has been demonstrated through histological studies.¹³ FDA approval for usage in the retention of overdentures, removable partial dentures, and fixed multi-unit bridges has increased incorporation in treatment plans. The minimally invasive nature in surgical placement, lack of bone grafting, and simplistic prosthetic options have contributed to their growth. Small-diameter implants are categorized as a single-stage, 1-piece implant with a diameter size less than 3.0 mm. The prosthetic design is an o-ball for removable or a square head for fixed applications. The implant is manufactured

TABLE 2
Data used in the statistical analysis of 14 failed small-diameter implants*

Name	Age	Sex	Site	Placement Date	Failure Date	Time Interval	Implant Size	Prosthesis
LF	66	F	#12	November 17, 2012	July 13, 2013	8 mo	2.4 × 10	OVD
NJ	79	M	#11	April 21, 2009	February 10, 2010	10 mo	2.4 × 13	OVD
			#11	March 30, 2010	July 10, 2010	4 mo	2.4 × 13	OVD
DC	59	F	#11	March 30, 2010	August 13, 2010	5 mo	2.4 × 13	OVD
			#6	March 5, 2015	March 12, 2015	1 wk	2.4 × 13	OVD
BG	50	F	#10	August 22, 2014	October 7, 2014	2 wk	2.4 × 13	OVD
CB	65	F	#7	August 9, 2011	May 1, 2015	3 y 9 mo	2.4 × 13	OVD
			#12	August 9, 2011	May 1, 2015	3 y 9 mo	2.4 × 10	OVD
FM	72	M	#8	November 14, 2012	July 9, 2013	9 mo	2.4 × 13	OVD
DR	88	M	#22	June 10, 2014	August 1, 2014	6 wk	1.8 × 10	OVD
GF	76	F	#9	May 8, 2013	April 14, 2014	11 mo	2.4 × 13	OVD
EB	67	M	#21	August 23, 2013	September 28, 2013	1 mo	2.1 × 13	OVD
DB	55	F	#9	July 17, 2012	May 6, 2013	10 mo	2.4 × 15	OVD
MM	75	F	#25	January 12, 2010			2.4 × 13	Single crown

*OVD indicates overdenture.

TABLE 3
Implant failures in 14 cases

Diameter/length (mm)	Numbers
1.8 × 10	1
1.8 × 13	0
2.1 × 13	1
2.4 × 10	2
2.4 × 13	9
2.4 × 15	1

in titanium alloy to enhance strength.¹⁴ The dental implant surface is treated for increased roughness and surface area with a process that includes sandblasting with aluminum oxide followed by cleaning and passivation with an oxidizing acid. A moderate roughness (1–2 microns) is achieved with this process.

Surgical and prosthetic protocols are critical in enhancing long-term success rates.¹⁵ A surgical template assists in the delineation of the mental nerve or maxillary sinus. The surgical/radiographic template incorporates radiopaque markers positioned to approximate these anatomic structures. The surgical guide's primary objective is to aid in the location of the most distal osteotomy site and the mesial-distal location of additional implant sites. A full mucoperiosteal or partial thickness flap is recommended because it enables direct visualization of the bony crest, enhancing implant placement. The flapless approach can be utilized in areas of abundant bone or when 3-D imaging is employed. This approach can reduce postoperative pain, edema, bleeding, and morbidity. The surgical protocol is initiated with a shallow osteotomy created with a 1.1-mm drill, followed by implant placement with a finger driver and thumb wrench. A ratchet may be needed in dense bone. The auto-advancement implant placement is a manual procedure, not exceeding 12 rpm. The rate of implant insertion is based on the quality of bone, implant length, and diameter. Denser bone dictates a greater time interval between revolutions of the implant. A slow advancement of the implant, with various instrumentation, allows for accurate placement. A shallow osteotomy—no greater than half of the implant length—increases the probability of rigid fixation. The auto-advanced technique is based on bone expansion principles to gain initial stability and osseointegration.¹⁶ The implant must demonstrate a lack of mobility at placement. The prosthetic protocol for the removable aspect is placement of an o-ring housing over an o-ball, secured in the overdenture with an auto polymerizing resin. Various o-ring housings are available depending on retentive needs and interocclusal clearance.¹⁷ The fixed prosthetic aspect consists of a square head transfer and corresponding implant analogue. A commercial laboratory creates a model by which a final prosthesis is fabricated utilizing standard protocols.

Small-diameter implants present with limitations due to surgical protocols and design. The shallow osteotomy, auto-advanced technique may lead to errors in implant placement in regards to angulation. A focus is critical on maintaining a path that is parallel to adjacent implants or roots of teeth. An implant angulation greater than 30° can impact retention due to its 1-piece design. The o-ring may not engage the ball or an

undercut preventing a path of insertion for fixed prosthesis. Immediate placement for mandibular cases can be utilized if implant torque values exceed 35 Newton centimeters. However, this study employed a staged approach in the majority of cases; in fact, immediate load in the maxillary arch demonstrated the highest failure rates.

This retrospective study illustrates that SDI failures occur; therefore, several factors should be considered in the development of a treatment plan. Place implants in healed sites (>6 months). Stage prosthetic loading in a conventional manner of 3 and 6 months in the mandible and maxilla, respectively. Incorporate growth factors via concentrated platelets through PRP and PRF. If immediate load is considered in the mandibular arch, then evaluate patient age, opposing occlusion, torque, and periotest values. Immediate load in the mandible can be utilized when a torque value of at least 35 Newton centimeters is present upon SDI insertion plus a negative periotest value and no clinical evidence of bruxism. Several studies have demonstrated higher failure rates associated with implants placed in the maxilla. It has been the author's experience that torque values of 35 Newton centimeters and negative periotest values are not predictable in the maxillary arch. A 6-month nonloaded osseointegration period is recommended. Long-term studies beyond 10 years do not exist to support success rates, suggesting special consideration with regards for SDI use in the young patient. Implant occlusal schemes should be factored into the prosthetic design to minimize crestal bone loss. Crestal bone stress levels can be reduced by increased implant numbers, diameter, and length.¹⁸ Small-diameter implants are indicated only in type I, II, and III bone. Type IV bone is a contraindication.

Platelet-rich plasma and PRF were developed and used for site preservation prior to implant placement. Platelet-rich plasma is mixed with an allograft material and expressed topically over the soft tissues. The allograft is used for its osteoinductive and osteoconductive properties as well as a physical carrier of the PRP and PRF component of the graft. The PRF bioactive membrane is placed under the suture line. The utilization of growth factors contained within platelets has been demonstrated to enhance differentiation, recruitment, and proliferation of cells involved in soft and hard tissue healing. Among the clinical advantages of PRP/PRF have been quicker healing times, less morbidity, and safety.^{19,20} Overdenture removal is recommended at bedtime to reduce deleterious forces caused by nocturnal bruxism.

The quality of bone is a key indicator for long-term implant survival rates. The maxilla exhibits less density of bone, consisting of a thin cortical component with an abundant trabecular core. Small-diameter implants should be placed in adequate bone density to resist occlusal load. Due to reduced surface area, more stress is applied to the crestal bone. A minimum of 4-mm bone width and 10-mm in bone height is desirable for SDI. Scientific studies have documented a high implant loss in maxillary implant overdentures relative to other implant treatment modalities.^{21–23} In the present study, implant failures experienced in the overdentures group translated into 1 patient failure. That specific patient's treatment plan incorporated a total of only 2 implants, both of which were

lost. All other implant failures evidenced in the maxillary overdenture group demonstrated prosthetic success.

A minimally invasive approach to implant surgical placement has advantages.²⁴ The flapless procedure maintains the periosteum, which distributes the majority of blood flow. Less bone and soft tissue loss is evident.²⁵ A limitation to this approach without a CBCT is a possible error in implant placement. Early failures may be due to implant placement partially in soft tissue. Small-diameter implant placement leads to reduced osseous compression necrosis leading to enhanced angiogenesis and osteogenesis.²⁶ The lack of a microgap minimizes surface exposure to pathogenic microorganisms reducing peri-implantitis and subsequent crestal bone loss.²⁷

Implant occlusal principles serve a pivotal aspect for establishing long-term survival rates. A bilateral balanced occlusion exhibiting an anatomical maxillary tooth occluding with a monoline mandibular tooth eliminates interfering excursive movements.^{28,29} Only 1 implant failed in the fixed prosthesis group, accounting for a high survival rate. The fixed group demonstrated prosthetic concerns of poor esthetics and decementations. The predetermined platform, if exposed after hard and soft tissue healing, can result in an unesthetic result. Modification of the manufactured margin with subsequent traditional impression or intraoral scanning and die fabrication can resolve the problem. A fixed prosthesis retained by SDI should be designed with narrow occlusal tables, splinted together and cemented with a permanent adhesive. A resin-modified cement should be utilized for a fixed prosthesis to prevent decementation.³⁰

CONCLUSION

The field of implant dentistry has evolved into a widely accepted dental discipline. Small-diameter implants may be a treatment alternative for some patients. This limited single-site individual private practitioner retrospective study has demonstrated high success rates, suggesting their utilization in specific clinical situations. Small-diameter implant treatment plan considerations should include bone density, prosthetic design, and occlusal factors. Although this retrospective study demonstrates high success rates, additional research focused on SDI is needed prior to wide acceptance by clinicians.

ABBREVIATIONS

BIC: bone-to-implant contact
MDI: mini-diameter implants
PRF: platelet-rich fibrin
PRP: platelet-rich plasma
SDI: small-diameter implants

NOTE

The author has not received financial support in content development or implant materials in the preparation of this manuscript.

ACKNOWLEDGEMENTS

The author wishes to acknowledge Tatyana Lyubezhanina, DA, Caitlin Carparelli, DA, Erin Weigand, RDH, and Judy Hathaway for their assistance in the preparation of this paper.

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ERRATUM

In the 42(5), October 2016, issue of *Journal of Oral Implantology*, the article titled, “Accuracy of Dynamic Navigation for Dental Implant Placement—Model-Based Evaluation,” by Robert W. Emery, Scott A. Merritt, Kathryn Lank, and Jason D. Gibbs was published with an incomplete Acknowledgment. The correct Acknowledgment statement is as follows: “This work was conducted using a grant provided by X-Nav Technologies, LLC. Robert W. Emery is the Chief Medical Officer of X-Nav Technologies, LLC, and has an equity interest in X-Nav Technologies, LLC. Scott A. Merritt is the Chief Optical Engineer of X-Nav Technologies, LLC. Jason D. Gibbs is a Software Engineer at X-Nav Technologies, LLC.”