Short Threaded Implants with an Oxidized Surface to Restore Posterior Teeth: 1- to 3-year Results of a Prospective Study

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Purpose: *The aim of this multicenter prospective study was to provide data from a case series supporting the use of short dental implants with oxidized surfaces to treat partially edentulous patients.* ***Materials and Methods:*** *The implants used had an oxidized surface, a tapered design, and a short length (8.5 mm or shorter). All implants were placed in posterior edentulous areas that were affected by high bone resorption (available bone height < 10 mm). Implant success was established according to predetermined criteria.* ***Results:*** *Records were available for 107 implants used to treat 46 patients (69.2% were 7 mm long, and 30.8% were 8.5 mm long); 80.4% were placed in the posterior mandible, and 19.6% were placed in the posterior maxilla. With regard to restorations, 27.1% of implants were restored with single crowns, 16.8% with a single cantilever, and 56.1% with fixed prostheses. After a 1- to 3- year follow-up, 105 implants are still functioning; only 2 implants have been lost, for a survival rate of 98.1%. In all, 4 of the 107 implants placed failed to meet the success criteria, resulting in a success rate of 96.3%. The mean marginal bone loss was 0.6 ± 0.2 mm.* ***Conclusions:*** *The results of this study suggest that short oxidized implants should be regarded as a possible solution for the restoration of posterior teeth in highly resorbed areas.* Int J Oral Maxillofac Implants 2011;26:393–403

Key words: *dental implants, oxidized surface, posterior teeth, short implants*

The loss of one or more teeth has always resulted in bone resorption, which can be influenced by many factors such as age, gender, osteoporosis, diabetes, smoking, previously lost implants, the type of prosthetic rehabilitation, the time that has been allowed to elapse before implant rehabilitation, and others.[1] According to Wolff's law, "bone architecture is modified with load, and bone density is proportional to mechanical solicitation"; therefore, one consequence of the loss of a tooth is a loss of functional stimuli on the alveolar bone.[2] In the case of partial or total edentulism, the jawbone is not subjected to any endosseous demands, which would generate a positive internal stimulus (natural teeth and endosseous implants), but only extraosseous loading (eg, from a mucosa-supported denture), which generates an external compressive stimulus.[3] The more time passes before implant rehabilitation, the less bone volume will be available for the insertion of implants of sufficient length and diameter to ensure a high implant success rate.

It is important to bear in mind that the implant lengths of the original Brånemark et al protocol were established empirically, starting from experimentation on implants with machine-processed smooth surfaces.[4] Today, it is well known that surface characteristics of the implants influence the healing of bone tissues[5]; it has been demonstrated that differently processed surfaces might lead to greater osseointegration and a higher percentage of bone-to-implant contact.

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Undoubtedly, implant surfaces, like implant designs, have undergone a series of evolutions over the years. As a consequence, new kinds of implant surfaces have been developed to improve both the quality of osseointegration and the amount of bone contact at the interface level; one of these is the oxidized surface. This surface is characterized by a highly crystalline and phosphate-enriched titanium oxide that results in a microstructured surface with open pores in the low micrometer range.[6] This kind of surface has repeatedly been found to yield an enhanced bone response compared to machined implant surfaces, and the enhanced bone response to oxidized titanium results in faster and stronger osseointegration and thus better maintenance of implant stability compared to machined titanium implants.[7–9]

New implant designs have also been developed. Some implants retain the conventional tapered shape but incorporate a groove in the implant thread along the entire length of the implant. This feature enables an affinity for bone formation to be obtained within and along the groove, resulting in higher removal torque values.[10,11]

The greater osseointegration resulting from advances in surface and design has enabled implant length to be shortened, as proposed by Albrektsson et al[12] and Brånemark et al.[4] Short implants can be used, which were initially characterized as implants < 10 mm in the mandible and < 13 mm in the maxilla. Recently, Renouard and Nisand[13] redefined the "short implant" as one with a "designed intrabony length" (ie, length of implant meant to support long-term osseointegration) of ≤ 8 mm. However, there are very few reports on the use of threaded dental implants of this length.

The restoration of lost teeth in posterior areas is complicated by loss of permanent teeth at a young age, low bone quality (type III or IV), enhancement of bone resorption caused by mucous stimuli, and the presence of important anatomical structures, such as the inferior alveolar nerves or sinus cavities. Successful management of posterior areas has incorporated surgical techniques for augmentation of bone volume to permit the insertion of long implants to achieve predictable and reproducible results.[14–16] However, as a result of developments in implant dentistry in recent years, short implants can now permit high success rates (95.5% to 100%)[17–22] comparable to success rates seen with longer implants after bone grafting (94.5% to 100%).[14,15]

Different surfaces have been studied by different authors: Friberg et al[17] investigated the survival rates of machined surfaces, Malò et al[18] examined the survival rates of oxidized surfaces, Anitua et al[19] studied the survival rates of acid-etched surfaces, Misch et al[20] considered the survival rates of sandblasted surfaces, Deporter et al[21] researched the survival rates of porous-sintered surfaces, and Griffin and Cheung[22] analyzed the success rates of hydroxyapatite-coated surfaces. In this preliminary study, the authors examined the efficacy of using short threaded implants with oxidized surfaces in treating partial edentulism in posterior areas. The performance of short implants with a length ≤ 8 mm, as a "designed intrabony length" ≤ 8 mm, is reported here after a follow-up of 1 to 3 years.

MATERIALS AND METHODS

Patients

The patients chosen for treatment with short threaded implants were referred between October 2006 and July 2007 for single or partial implant-supported rehabilitation in posterior areas at three different centers.

All patients had advanced alveolar bone resorption in the posterior areas of the maxilla or mandible that was planned to be treated with implant therapy. Patients had been advised that they were not candidates for long implants without extensive preparatory implant site development because of insufficient alveolar ridge height. However, all sites had a sufficient alveolar ridge width to receive implants at least 3.75 mm in diameter.

The decision to use short implants was made after discussion with the patients and after obtaining informed written consent. The following criteria were used to select the patients in whom this kind of implant could achieve successful results:

- *Inclusion criteria:* highly controlled oral hygiene, absence of acute infection in the oral cavity, residual bone volume at least 3.5 mm in width and 5 mm in height (for the maxilla) or 3.5 mm in width and 8 mm in height (for the mandible), and willingness to participate in an oral hygiene maintenance program
- *Exclusion criteria:* insufficient bone volume, bruxism, smoking more than 20 cigarettes per day, abuse of alcohol, radiotherapy in the maxillofacial region, chemotherapy, liver diseases, blood diseases, kidney diseases, inflammatory and autoimmune diseases, immunosuppressed status, corticosteroid therapy, pregnancy, or insufficient oral hygiene

Treatment was performed at three centers: the Department of Morphological and Biomedical Sciences, Section of Dentistry and Maxillofacial Surgery, University of Verona, and two private offices. All subjects provided written informed consent.

Implant System

All implants used were short threaded implants (Brånemark System Mk III Shorty , Nobel Biocare; NobelSpeedy Shorty, Nobel Biocare) with a length of 7 or 8.5 mm and with an oxidized surface (TiUnite, Nobel Biocare). They were provided by the manufacturer and purchased by the clinicians. These implants are short versions of long threaded implants with oxidized surfaces, which are available in diameters of 3.75 or 4.0 mm for regular-platform implants (platform diameter: 4.1 mm) and 5.0 mm for wide-platform implants (platform diameter: 5.1 mm). They were machined from titanium alloy (Ti-6Al-4V) as a parallel design, with a designed intrabony length of 6.3 or 7.8 mm, and a standard 0.7-mm-high external-hex connection. All implants featured the oxidized surface described by Hall and Lausmaa.[6]

Treatment Planning

An initial examination of patients was performed to assess their oral condition and to evaluate the possibility of placing short implants. Particular attention was paid to the psychologic aspect of the patients in an attempt to understand what prompted them to approach oral rehabilitation without complex bone grafting, ie, vertical and vestibular onlay grafting or direct sinus elevation with consideration of the risk/benefit ratio of short implants.

After informed consent was obtained for the prosthetic plan, patients were examined to evaluate the inclusion and exclusion criteria, as well as other parameters required for the treatment planning. All patients were examined by means of panoramic and periapical radiographs and, if necessary, computed tomography (CT), which enabled assessment of the level of bone atrophy and the locations of anatomic reference points (Figs 1 to 4).

Surgical Procedures

The patients were submitted to a preventive protocol. This included amoxicillin and clavulanic acid (2 g) 1 hour before surgery, ketorolac tromethamine (20 mg) and chlordimethyldiazepam (0.8 mg) 30 minutes before surgery, and betamethasone sodium phosphate (1.5 mg/2 mL intramuscularly) an hour before the operation and twice daily thereafter for the following 3 days.

Implants were placed in a two-stage approach after a full-thickness mucoperiosteal flap was raised, as described by the manufacturer. A flap technique is necessary to observe the underlying alveolar bone and adjacent anatomical structures and to place implants in the correct positions. In cases of alveolar ridges that were too small to receive 3.75- × 7.0-mm implants, special surgical procedures were performed to increase the available bone volume: split crest and indirect sinus elevation techniques were the first choices of techniques to augment the ridge horizontally and vertically, respectively. These two techniques were accomplished as described by Simion et al[23] and Summers,[24] respectively.

Implant sites were prepared using rotating burs and/or hand osteotomes. The rotary burs were made of surgical stainless steel and coated with an amorphous diamond layer and were used with external irrigation. The osteotomes were used in posterior maxillary sites with bone type III or IV or with bone height ≤ 8 mm. It is important to use an in-and-out motion and drill in bone for 1 to 2 seconds; to move the drill up without stopping the handpiece motor, which also allows the irrigation to flush away debris; and to proceed with this technique to the correct depth in accordance with bone quality and implant diameter.

If rotating burs were used, these included:

- A twist drill with a 2-mm-diameter tip to drill to the appropriate depth
- A 2.4- to 2.8-mm-diameter twist step drill to continue site preparation
- A 3.0- to 3.2-mm-diameter twist drill for medium-density bone (or 3.2- to 3.4-mm-diameter twist drill for dense bone) prior to placement of 3.75-mm implants and 4.0-mm implants, respectively, to drill to the appropriate depth (ie, the length of the implant being placed)
- A 3.8-mm-diameter twist drill for medium-density bone (or a 4.2-mm-diameter twist drill for dense bone), in case of 5-mm-diameter implants
- A screw tap, matching the diameter of the final twist drill, to pre-tap the implant site in medium/dense bone

During site preparation, a 2.0/2.4- to 2.8-mm-diameter directional indicator was used, as recommended, to check for correct orientation. A depth probe was also used to confirm the appropriate depth of the osteotomy. Great care was taken to ensure that the implant burs did not experience chatter (particularly in sites with a dense upper cortex) to guarantee that the osteotomy maintained the perfectly concentric shape needed to achieve the required initial tight press-fit of the implant.

After the implant packaging was opened and the sterile inner vial was removed, the appropriate implant driver was connected to the handpiece, and the implant was picked up by applying light pressure on the implant driver. The implant was placed in the osteotomy site using low speed (25 rpm) and 30 to 45 Ncm of torque, and the implant was turned until it was fully inserted. At this point, the driver was removed with an easy upward motion. A cover screw was positioned

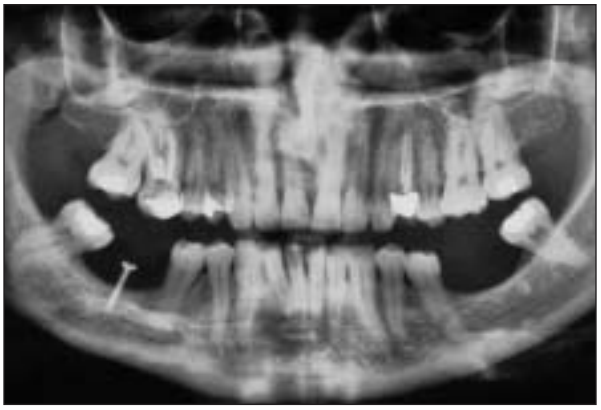


Fig 1 Preoperative panoramic radiograph obtained at 1 year before surgery.

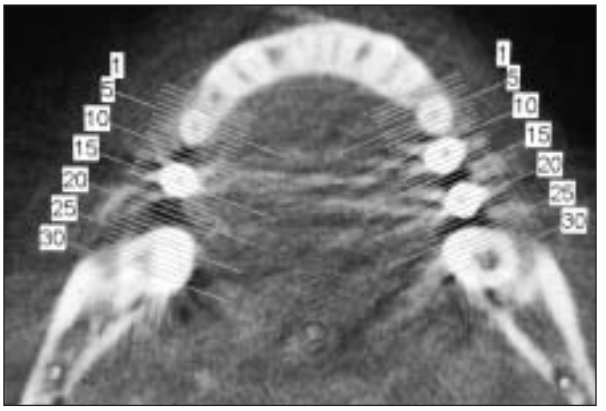


Fig 2 Preoperative CT obtained 1 month before surgery.

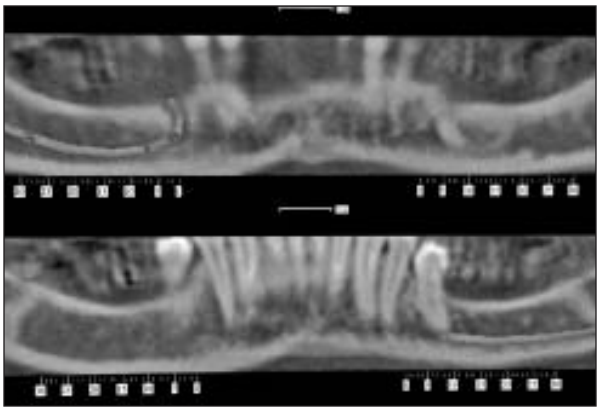


Fig 3 Preoperative CT showing coronal sections of the mandible.

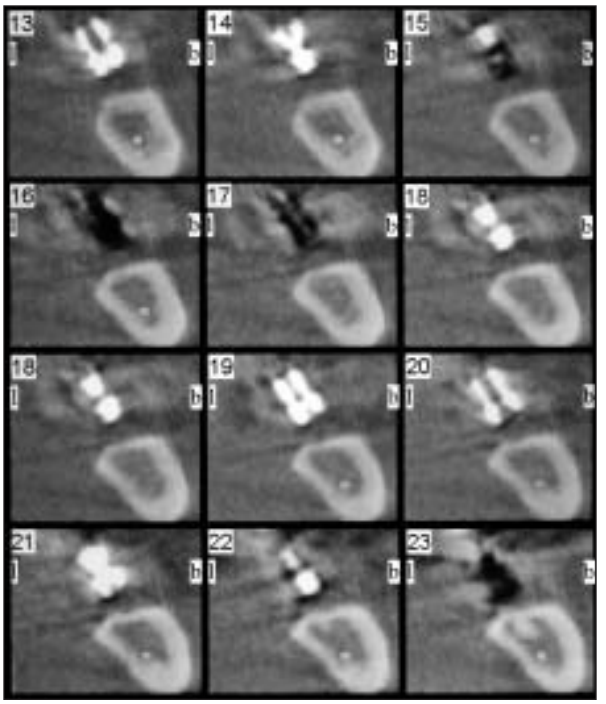


Fig 4 Preoperative CT showing parasagittal sections of the edentulous area.

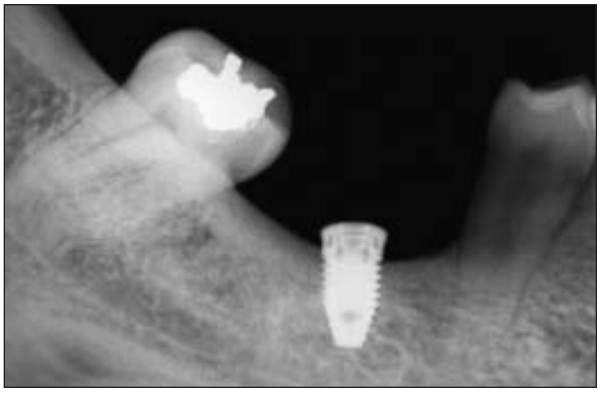
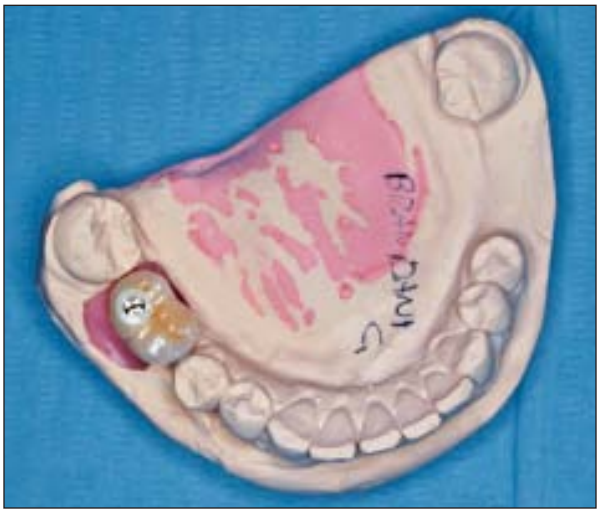


Fig 5 Intraoral radiograph obtained after surgery.

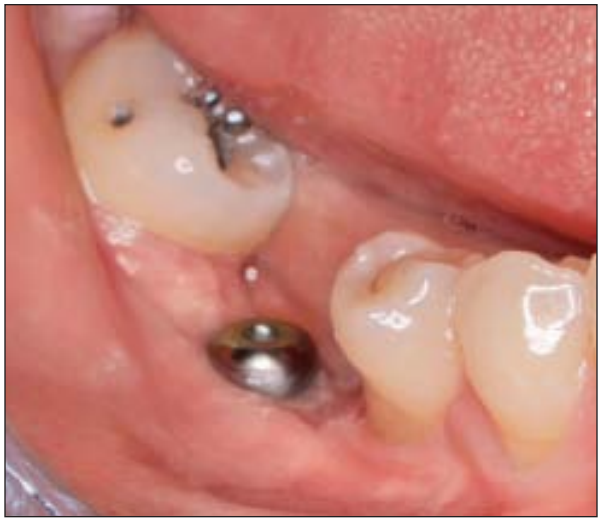
on the implant using a Unigrip screwdriver (Nobel Biocare), and a tissue flap suture was performed to ensure submerged first-intention healing (Fig 5).

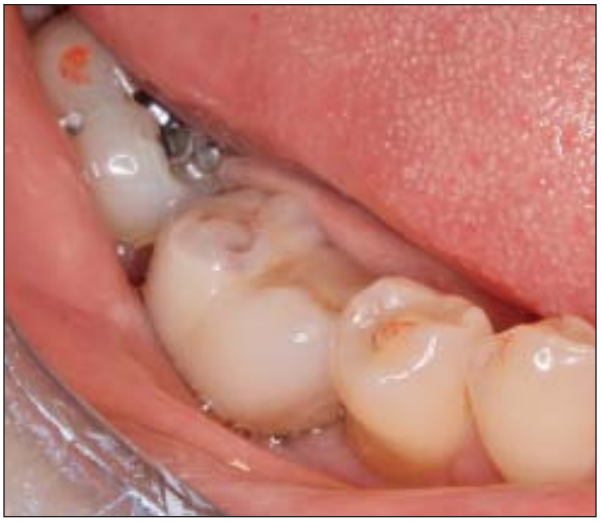
Prosthetic Procedures

The initial healing period ranged from 3 to 6 months, depending on the clinical circumstances and the treating clinician's preference. After the healing period, a provisional healing abutment was then positioned on the implant to achieve adequate peri-implant soft tissue healing. After soft and hard tissue healing was completed, implant-supported prostheses were created and fixed with screws or cement, depending on the treating clinician's preference. Implants were restored with single crowns, crowns with a cantilever, or fixed prostheses, according to the patients' needs and desires. However, cement-retained prostheses were usually used for single crowns, while screw retention was usually used in cases of fixed prostheses.



Figs 6a and 6b Lateral and occlusal views of the master model and zirconia-ceramic crown.





Figs 7a and 7b Clinical appearance before and after definitive rehabilitation with zirconia-ceramic crown.

All definitive restorations were placed into occlusion, where the occlusal surface was thoroughly modeled (Fig 6), so that it was in contact with reduced areas during lateral and protrusive excursions to reduce the dislocating vectorial components. More contacts were maintained in maximum intercuspation (Fig 7).

Postoperative Follow-up

Patients were included in a maintenance program to achieve optimal hard and soft tissue healing, which comprised professional oral hygiene every 6 months and twice-daily rinsing with chlorhexidine digluconate 0.2% during the first 2 weeks after implant placement. Clinical evaluations were performed weekly during the first month, after provisional restoration, and then monthly during the first 6 months after definitive restoration. Further examinations were performed every 6 to 9 months and consisted of analysis of soft tissue health (Plaque Index, Gingival Index), evaluation of probing pocket depths, and radiographic examinations (panoramic or intraoral radiographs) (Figs 8 and 9).

Determinants of Success

An implant was considered successful if it met all the success criteria proposed by Albrektsson and Zarb[25,26]: *(1)* absence of any complaints such as pain, dysesthesia, or paresthesia in the implanted area, *(2)* absence of recurring peri-implant infection and/or suppuration, *(3)* absence of perceptible mobility of the implant, *(4)* absence of radiolucency at the implant-bone junction, and *(5)* absence of persistent peri-implant bone resorption greater than 1.5 mm during the first year of loading and 0.2 mm per year during the following years. The implants were considered successful in the absence of all of the aforementioned complaints at the most recent recall appointments.

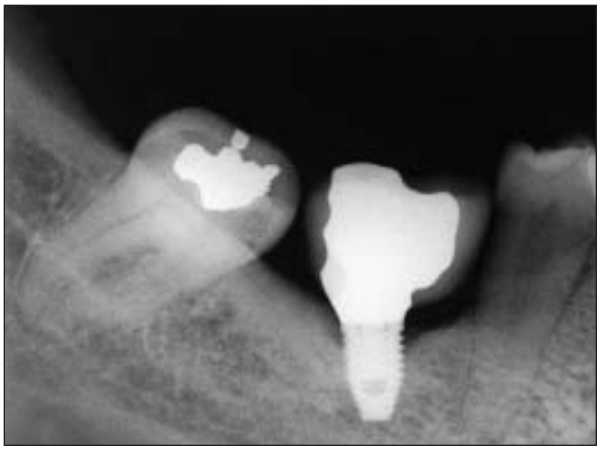


Fig 8 Intraoral radiograph after functional loading (baseline).

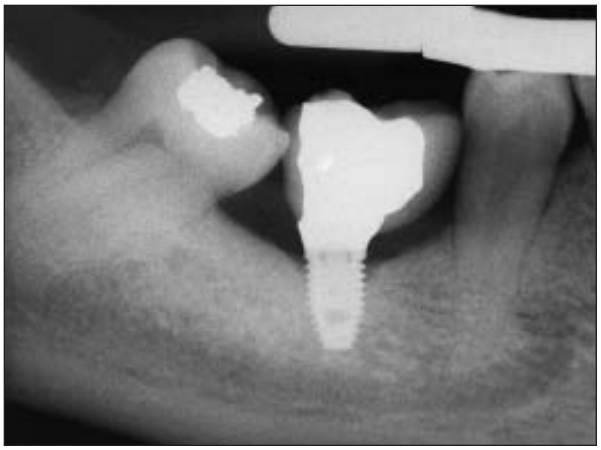


Fig 9 Intraoral radiograph 1 year after functional loading (follow-up).

All radiographs of implants from each subject's last recall visit were reviewed independently by an oral radiologist at a magnification of ×6 for the measurements of marginal bone levels. Bone levels were assessed mesially and distally by identifying the lowest observed point of crestal bone in intimate contact with the implant; to quantify marginal bone loss, this was compared to the bone level observed at baseline.

Clinical complications such as pain, dysesthesia, or paresthesia were assessed by interviewing the patients. Peri-implant infection with or without suppuration and implant mobility were assessed by clinical observation and pressure. Implant immobility was assessed by evaluating the mobility of the prosthesis, in cases of single-crown restoration; in cases of fixed prostheses, the immobility of each implant was assessed following removal of the prosthesis.

Statistical Analysis

All data were analyzed according to the Fisher exact test. A P value < .05 was considered statistically significant. Thus, it was possible to compare the success rates and the mean bone loss around short implants in grafted sites with those in nongrafted sites and determine the presence or absence of statistically significant differences between the two groups. The effects of implant length (7 mm versus 8.5 mm) and implant diameter (regular-platform versus wide-platform) on implant success were also evaluated. Finally, the implant success rate was investigated according to the kind of prosthesis placed: ie, single crown versus fixed cantilevered prosthesis versus fixed prosthesis.

RESULTS

Summaries of implant locations, types of prostheses placed, and time in function at the time of data collection for this report are presented in Tables 1 to 3.

In total, records were analyzed for 107 implants in 46 subjects (aged from 36 to 78 years; 25 women and 21 men) who needed to restore single or multiple teeth. The university center contributed 56 implants in 23 subjects and had the longest follow-up times (12 to 38 months in function; mean follow-up 24.3 ± 8.7 months). Private office 1 (Verona, Italy) contributed 27 implants in 13 subjects (12 to 48 months in function; mean follow-up 28.4 ± 11.9 months), who were treated by an oral maxillofacial surgeon; and private office 2 (Mantua, Italy) contributed 24 implants in 10 subjects (12 to 32 months in function; mean follow-up 21.5 ± 6.8 months), who were treated by a general dentist.

With regard to implant length, 7-mm-long implants and 8.5-mm-long implants were used in 69.2% (n = 74) and in 30.8% (n = 33) of cases, respectively. With respect to implant diameter, 3.75-mm, 4-mm, and 5-mm implants were used in 26.2% (n = 28), 51.4% (n = 55), and 22.4% (n = 24) of sites, respectively. Seventy-nine implants were used to replace molar teeth, and 28 replaced premolar teeth. Eighty-six implants (80.4%) were placed in the posterior mandible and 21 implants (19.6%) were placed in the posterior maxilla (Table 1).

In 40.2% of cases, the implant site was grafted with heterologous bone at the time of implant placement using the split-crest or indirect sinus lift techniques. In the other 59.8% of sites, bone grafting was not required for implant placement.

Table 1 Distribution of Implants According to Locations

Site	Mandible	Maxilla	Total
First premolar	11	3	14 (13.1%)
Second premolar	24	5	29 (27.1%)
First molar	35	8	43 (40.2%)
Second molar	16	5	21 (19.6%)
Total	86	21	107 (100.0%)

Table 2 Distribution of Implants According to the Type of Prosthesis Placed

Prosthesis type	No. of patients	No. of implants
Single crown	12	29 (27.1%)
Cantilevered	9	18 (16.8%)
Fixed prosthesis	25	60 (56.1%)
Total	46	107 (100%)

Table 3 Distribution of Implants According to Time in Function

Follow-up (mo)	No. of patients	No. of implants
12–17.9	16	34 (31.8%)
18–23.9	7	15 (14.0%)
24–29.9	10	25 (23.4%)
30–35.9	5	12 (11.2%)
36+	8	21 (19.6%)
Total	46	107 (100.0%)

Table 4 Cumulative Success Rate of the Short Implants Placed

Time in function (mo)	Implants in situ	Implants lost or failed	Interval failure rate (%)	Cumulative success rate (%)
0–5.9	107	0	0	100.0
6–11.9	107	0	0	100.0
12–17.9	107	0	0	100.0
18–23.9	73	2	2.7	97.3
24–29.9	58	1	1.7	95.6
30–35.9	33	1	3.0	92.6
≥ 36	21	0	0	92.6

Single crowns were used to restore 29 implants (27.1%), whereas another 60 implants (56.1%) were restored with a fixed prosthesis. The remaining 18 implants (16.8%) were restored with fixed cantilevered prostheses (Table 2).

No surgical or prosthetic complications associated with implant placement were observed. All 107 implants became osseointegrated and functioned as planned. At the time of this report, these implants had been functioning for a mean follow-up of 24.6 ± 9.4 months (range, 12 to 48 months). All 107 implants were followed for at least 1 year, 58 were followed for at least 2 years, and 21 implants had a follow-up period of more than 3 years (Table 3).

Only two implants were lost in two patients treated by the university center. The first patient had received a 4.1- × 7-mm implant in a maxillary first molar site; this patient had poor oral hygiene and a smoking habit (> 10 cigarettes/day), which likely resulted in the peri-implantitis and consequent implant loss at the 18-month follow-up. The second patient had received two 4.1- × 7-mm implants in the mandibular first and second molar sites after the split crest technique, which were restored with two single crowns; the mesial implant was lost because of overloading and related excessive crestal bone loss in the 32-month follow-up. After 24.6 ± 9.4 months of mean follow-up, the overall survival rate was therefore 98.1%.

Two additional implants were considered to have failed since they did not meet all the success criteria adopted in this study. One of these implants failed after 18 months because of excessive bone resorption caused by peri-implantitis, and the other failed at 24 months because of excessive bone resorption caused by occlusal overloading. While the first implant was successfully treated by means of a surgical approach, which consisted of peri-implant curettage and bone tissue regeneration with heterologous bone and a collagen membrane, the second was successfully treated with a strict maintenance program, including professional oral hygiene every 6 months.

In all, the four failed implants, out of 107 placed, resulted in an overall success rate of 96.3% and a cumulative success rate of 92.6% (Table 4). The characteristics of the failed implants are provided in Table 5.

With regard to implant length, 7-mm-long implants showed a success rate comparable to that of 8.5-mm-long implants (95.9% and 97.0%, respectively); with regard to implant diameter, implant success rates were 96.4% and 95.8% for regular-platform (4.1-mm) and wide-platform (5-mm) implants, respectively. Differences between 7-mm and 8.5-mm implants were not statistically significant ($P = .0598$); no significant differences were observed between implants with different platforms ($P = .1344$).

Table 5 Characteristics of the Failed Implants

Implant	Site	Bone graft?	Implant size (mm)*	Prosthesis	Time of failure	Time of loss	Reason	Notes
1	Max R first molar	No	4.1 × 7	Cantilever	_	18 mo	Peri-implantitis	Poor oral hygiene and smoking > 10 cigarettes/day; Summer osteotome technique
2	Mand L second premolar	Yes	5 × 8.5	Fixed prosthesis	18 mo	_	Excessive bone resorption owing to peri-implantitis	Smoking < 10 cigarettes/day
3	Mand L first molar	Yes	4.1 × 7	Single crown	_	32 mo	Occlusal overloading	Split crest graft
4	Mand R second molar	No	4.1 × 7	Single crown	24 mo	_	Excessive bone resorption	_

Table 6 Distribution of Implants According to Crestal Bone Loss During Follow-up Period

Mean bone loss (mm)	Implants
< 0.1	5 (4.7%)
0.1–0.5	71 (66.4%)
0.6–1.0	21 (19.6%)
1.1–1.5	5 (4.7%)
1.6–2.0	2 (1.9%)
2.1–2.5	1 (0.9%)
> 2.5	2 (1.9%)
Total	107 (100.0%)

In contrast, the implant success rates were quite different with regard to the type of prosthesis placed: 93.1% for single crowns, 94.4% for cantilevered prostheses, and 98.3% for fixed prostheses. The success rate of implants restored with fixed prostheses was significantly higher than those of implants restored with single crowns or cantilevered restorations ($P = .0322$ and $P = .0437$, respectively).

The radiographs obtained at baseline and every year of follow-up (Figs 8 and 9) revealed a mean marginal bone loss during functional loading of 0.6 ± 0.2 mm (range, 0.0 to 1.9 mm). Five implants (4.7%) showed no bone resorption. Most implants (n = 71; 66.4%) showed bone resorption ranging from 0.1 to 0.5 mm, and only three implants (2.8%) showed bone loss between 1.6 and 2.5 mm at the final follow-up examination. None of the osseointegrated implants showed a marginal bone loss greater than 2.5 mm, except for the two lost implants (Table 6).

With regard to crestal bone loss in grafted and ungrafted sites, no statistically significant differences were observed ($P = .0678$). In grafted sites, bone resorption was 0.8 ± 0.3 mm (range: 0.2 to 1.9 mm), while in ungrafted sites, it was 0.6 ± 0.3 mm (range: 0.0 to 1.6 mm). The implant success rate also did not vary significantly with respect to grafting at the implant site; only two of the four failed implants were placed in grafted sites ($P = .1167$).

DISCUSSION

A recent redefinition of a short implant is one that has a designed intrabony length (ie, length of implant required to achieve and maintain osseointegration) of ≤ 8 mm.[13] This definition was used in the present report.

The threaded implants used here had a designed intrabony length of 6 or 7 mm, because they have a standard 1-mm-high external-hex connection, and therefore were considered short implants by the authors. They are characterized by an oxidized surface, which has repeatedly been found to induce an enhanced bone response compared to machined surfaces. The enhanced bone response appears to result in faster bone formation and a greater amount of bone in contact with the implant surface during healing, which results in greater osseointegration and in better maintenance of implant stability, despite the reduced implant length.[7–9]

Renouard and Nisand,[27] in a retrospective study, reported that short threaded implants can be considered for prosthetic rehabilitation of severely resorbed arches. The oxidized surface yielded a higher success rate (97.6%, with one failed implant) than the machined surface (92.6%, with four failed implants), but this difference was not statistically significant.

Frieberg et al,[17] in a retrospective study with a long-term follow-up, reported that short implants with an oxidized surface yielded survival rates of 95.5% and 92.3% at 5 and 10 years, respectively. The authors showed that short implants without bone grafting can be a predictable means of treating the severely resorbed mandible. However, the study provided data only on patients whose implants were restored with fixed implant-supported prostheses.

Malò et al[18] demonstrated in a retrospective study that short implants with an oxidized surface represent a viable concept for both arches. They achieved survival rates of 96.2% and 97.1% at 5 years for implants that were 7 mm and 8.5 mm long, respectively. In their study, implants were placed using a one-stage delayed-function approach; definitive abutments were delivered at the time of surgery, and definitive prostheses were delivered 4 to 6 months later. Data were reported for 237 patients treated with fixed prostheses supported by 408 implants. The number of cases seems sufficient to confirm the effectiveness of short implants with an oxidized surface.

Despite the limited number of cases treated and the short-term follow-up, the present report included data from different clinical situations: mandible and maxilla; implant restorations with single crowns, crowns supporting a cantilever, and fixed prostheses; patients enrolled at three different treatment centers; and the use of 7- and 8-mm-long implants. The acquired data support the possibility of using this kind of implant in the treatment of partially edentulous patients.

Many authors have confirmed that not only 8.5-mm-long but also 7-mm-long implants constitute a reliable solution in severely resorbed arches[17,18,28,29]; others have even proposed the use of implants with lengths < 7 mm.[30–33] Obviously, different authors have investigated different implant designs and surfaces, but many of them have validated the use of short implants as a predictable procedure.

Ten Bruggenkate et al[31] reported on the performance of 6-mm-long titanium plasma spray-coated implants using the nonsubmerged technique. Titanium plasma spray coating of bone-interfacing implants is known to increase the strength of osseointegration, at least as compared to machined-surface implants.[34] After an initial healing interval of 4 months, implants were used to support a variety of prostheses. Seven implants failed during the study and 28 of 253 implants were lost during the follow-up period. The overall failure rate was 6% after 1 to 7 years in function, but the failure rate in the maxilla was 13%.[31]

Deporter et al[30] reported on the efficacy of 5-mm-long sintered porous-surfaced implants placed in a submerged technique. Implants were restored with single crowns or as part of a fixed prosthesis with other implants. Only two implants failed after functional periods of up to 8 years. Both of the failed implants were maxillary ones, resulting in a maxillary failure rate of 14.3%. It is worth noting that these implants have a "designed intrabony length" (ie, the sintered porous surface responsible for implant integration) of only 4 mm, which is much shorter than that of other implants. The same authors had already established in previous prospective or retrospective studies that short sintered porous-surfaced implants with a length of 7 mm would permit success rates of 98.1% to 100% with predictable results.[21,35,36]

In addition, it is important to remember that the purpose of short implants is to rehabilitate the severely resorbed posterior area, both in the maxilla and in the mandible, where proximity to the inferior alveolar nerve and to the sinus cavity may preclude the possibility of using osseointegrated implants without augmentation of bone volume, as with autogenous block grafting, guided bone regeneration, or nerve repositioning.[37–39] Shorter implants offer several surgical advantages compared to longer implants: less need for vertical bone grafting, less time for treatment, lower cost of treatment, less discomfort, easier surgery, and fewer surgical risks (eg, sinus perforation, mandibular paresthesia, adjacent tooth injury). All of these factors make short implants a highly attractive restorative option.[38]

When short implants are used, ridge height is no longer a technical limitation for implant-supported prostheses. The most important limitation is ridge width, because a wide alveolar ridge is essential to retain implants with diameters of 4 or 5 mm; > 1 mm of cortical bone is necessary buccally and lingually, ie, a ridge width of more than 8 mm is required.[30,39] In these cases, surgical techniques of ridge augmentation can be useful to improve success rates for short implants.[30,33,36]

The main consequence of reduced ridge height is an unfavorable crown/implant (C/I) ratio. The C/I ratio has been considered one of the prosthetic factors that may increase the risk of biomechanical complications, because unfavorable occlusal forces, such as overloading or nonaxial loading, have been reported to be a possible cause of these complications.[40–42] A type of nonaxial loading is displayed by implant-supported reconstructions with high C/I ratios: the crown acts as a lever arm, creating a bending moment and transferring stress to the peri-implant crestal bone.[43,44] This bone stress may, eventually, result in either crestal bone loss and/or technical complications.[45,46] However, Tawil et al[47] demonstrated that an increased C/I ratio did not prove to be a major complicating factor, although it was found to be increased by two to three times in nearly 87% of cases:

peri-implant bone resorption was similar in all C/I ratio groups. Rokni et al[48] reported a mean C/I ratio of 1.5, with 78.9% of implants having a C/I ratio between 1.1 and 2.0 and 10.0% of implants having a C/I ratio increased by two to three times; these authors demonstrated that neither C/I ratio nor estimated implant surface area affected steady-state crestal bone levels. Recently, Blanes[44] systematically reviewed the occurrence of biologic and technical complications with respect to the C/I ratio of implant-supported restorations. A qualitative data analysis revealed that the survival rate of implant-supported reconstructions with a C/I ratio of more than 2 was 94.1%. In addition, peri-implant crestal bone loss seemed not to be influenced by the C/I ratio of the implant rehabilitation, except in one study. Technical complications related to implant-prosthetic components according to different C/I ratios were not found in any of the studies.

The data presented here suggest that short implants with an oxidized surface may provide an alternative solution to these surgical procedures, reducing most of the risk related to aggressive and invasive surgery, and achieving an overall success rate of 96.3%. However, the number of sites treated was limited to 86 posterior mandibular implants in 37 patients and 21 posterior maxillary implants in 9 patients. This study has described the authors' 1- to 3-year clinical experience with 7- and 8-mm-long implants. The overall survival rate of 98.1% was obtained in partially edentulous patients with severely resorbed alveolar ridges. Obviously, a larger prospective study with long-term follow-up is needed to provide more convincing evidence of the predictability and reproducibility of these implants.

CONCLUSIONS

The short implants used in this retrospective study would appear to be successful because of their threaded design and oxidized surface and the accurate surgical procedures employed. Despite the limited number of cases, these preliminary results demonstrate the predictability and safety of such implants when used with careful treatment planning and an appropriate clinical protocol. The possibility of using short implants in clinical practice should be considered as an alternative to avoid surgical procedures such as bone grafts or the like and their related disadvantages. The information obtained from this study might help clinicians improve their decision-making with the aim of enhancing implant success, or it might provide them with suggestions regarding operative possibilities.

ACKNOWLEDGMENTS

The authors wish to thank Professor Anthony Steele, Senior Lecturer in Medical English, University of Verona, for his invaluable assistance with the linguistic editing of this paper. The authors have no financial interest in any company or in any of the products mentioned in this article.

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