Short (8-mm) Dental Implants in the Rehabilitation of Partial and Complete Edentulism: A 3- to 14-Year Longitudinal Study

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Purpose: This study aimed to evaluate the clinical effectiveness of different implant sizes (8- and 10-mm lengths with 3.75-, 4.1-, and 4.8-mm diameters) in diverse host bone sites in a selected sample of partially and completely edentulous patients. ***Materials and Methods:*** Over a 14-year period, 129 patients (68 women and 61 men) were consecutively treated with a fixed prosthesis (single or multiunit, screw or cement retained) supported by 265 different-sized implants (154 standard 10-mm; 111 shorter 8-mm). Two types of implants were used (141 titanium plasma-sprayed and 124 Sand-blasted, large-grit, acid-etched). ***Results:*** Dropouts were recorded for 23 patients with 23 prostheses supported by 42 implants. In the remaining 106 patients (223 implants), 8 implants failed (4 standard and 4 shorter), in type 3 or 4 bone. Mean marginal bone loss and gingival crevice probing depth associated with either implant length were statistically comparable ($P > .05$). The 14-year cumulative survival rates for all short and standard implants were 97.9% and 97.1%, respectively. Survival rates were 92.3% and 95.9% for titanium plasma-sprayed short and standard implants, respectively, and 100% and 98.5% for the Sand-blasted, large-grit, acid-etched short and standard implants, respectively. Six of the 8 lost implants required implant replacement after the host sites' healing period. The remaining 2 lost implants were managed by converting the distal unit of the fixed partial prosthesis to a cantilever. ***Conclusion:*** Within the limits of the study design and observation period, a mix of implant sizes did not appear to compromise the effectiveness of implant therapy in this particular population group. *Int J Prosthodont 2006;19:586–592.*

Well-documented studies concerning implant-supported prostheses have shown highly predictable clinical results in the treatment of partially or totally edentulous patients.[1–4]

Nevertheless, anatomic conditions may limit the use of oral implants, and so different sizes have been designed to circumvent anatomic morphologic restrictions. Consequently, shorter implants with larger diameters are used in host bone sites with vertically compromised height; however, this can result in overloading, which leads to implant failure. In fact, van Steenberghe et al[5] observed that the use of short implants led to unfavorable results compared to longer implants within the same implant system. Bone quality at the implant site also plays an important role in the distribution of biomechanical forces. Loose spongy bone, as frequently found in the maxilla, particularly in the posterior region, does not appear to withstand the same forces as the dense bone usually found in the interforaminal region of the mandible.[6] Other parameters, such as implant site specificity and prosthesis design, are additional considerations when choosing short implants for prosthetic rehabilitation. Furthermore, both microscopic and macroscopic implant surface characteristics may be determinants of success, although their specific role is far from clear.[7]

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Table 1 Implant Distribution by Length and Diameter

Length/diameter	No.
8 mm	
3.75 mm	21
4.1 mm	68
4.8 mm	22
Total	111
10 mm	
3.75 mm	25
4.1 mm	92
4.8 mm	37
Total	154

Table 2 Distribution of Patients and Implants*

Patients (n = 128)	Implants (n = 265)
30	60 short TPS
27	51 short SLA
38	81 standard TPS
33	73 standard SLA

*All patients received only 1 prosthesis.

The purpose of this study was to evaluate the clinical effectiveness of different implant sizes (8- and 10-mm lengths with 3.75-, 4.1-, and 4.8-mm diameters) in different host bone sites in partially and completely edentulous patients.

Materials and Methods

Patients

Between April 1990 and May 2004, 129 patients (61 men with a mean age of 52 years, and 68 women with a mean age of 54 years) were consecutively treated at the Dental Clinic, Department of Medicine, Surgery, and Dentistry, University of Milan, Italy. Each patient received 1 implant-supported prosthesis. The follow-up, after prosthesis placement, ranged from 3 to 14 years (mean: 6.4 years).

Patient selection depended on the following inclusion criteria: good general health at the time of the surgical procedure; a favorable maxillomandibular relationship; and adequate bone volume at the implant site to accommodate implants at least 8 mm in length, as evaluated radiographically. The exclusion criteria were: history of alcohol or tobacco abuse, radiotherapy in the head and neck region, severe renal or liver disease, chemotherapy for malignant tumors at the time of surgery, uncontrolled diabetes, periodontal disease involving the residual dentition, mucosal disease (eg, lichen planus) in the area to be treated, poor oral hygiene, and a need for prostheses supported by combined short and standard implants. Furthermore, implant-supported prostheses exhibiting an unfavorable crown-to-implant ratio were also excluded from the study. A crown-to-implant ratio was considered unfavorable if the distance between the implant neck and the opposing dentition exceeded the implant's actual length. Calibrated plastic probes and periapical radiographs taken before treatment were used to approximate the crown-to-implant ratio.

The routine treatment evaluation protocol comprised the following: panoramic radiographs taken before treatment; periapical radiographs taken before treatment and at the time of implant placement, prosthetic rehabilitation, and every year thereafter; and computerized tomography (CT) scans whenever radiographs and clinical examination were determined insufficient (ie, limited alveolar ridge height or thickness) to plan the implant treatment. Twenty-seven patients showed severe atrophic ridges. Since neither periapical nor panoramic images provide evidence of proposed host bone site volume, and since tomography was not routinely used, different diameter implants were chosen following exposure of the alveolar crest of the implant site, before implant placement.

Examinations

Two hundred sixty-five straight, 2-part, grade IV, pure titanium, solid screw, Straumann dental implants were placed. One hundred eleven of these were short (8 mm) and 154 were standard (10 mm). Furthermore, 2 types of implant surfaces were used: 124 implants were Sand-blasted, large-grit, acid-etched (SLA), and 151 were titanium plasma-sprayed (TPS).

The suprabony, smooth portion of each implant had a machined surface, whereas the infrabony portion had either a TPS surface with typical roughness and porosity or an SLA (hydrochloric/sulfuric acid) surface with 2 levels of roughness. No roughness on the infrabony portion of the machined implants was present. Implant distribution by diameter and length is reported in Table 1.

Four groups of patients were treated (Table 2): *(1)* 30 patients with 60 short TPS implants; *(2)* 27 patients with 51 short SLA implants; *(3)* 38 patients with 81 standard TPS implants; and *(4)* 33 patients with 73 standard SLA implants. All patients received only 1 prosthesis.

Table 3 Implant Lengths and Locations

Implant length/region	No. (%)
8 mm	
Maxillary anterior	19 (17.1)
Maxillary posterior	26 (23.4)
Mandibular anterior	10 (9.0)
Mandibular posterior	56 (50.5)
10 mm	
Maxillary anterior	17 (11.0)
Maxillary posterior	48 (31.2)
Mandibular anterior	19 (12.3)
Mandibular posterior	70 (45.5)

Table 4 Implant Distribution by Prosthesis Type

Implant type	Prosthesis type (n = 128)			
(n = 265)*	FPD	FCD	ST	Total
TPS				
8 mm	30 (13)	15 (2)	15 (15)	60 (30)
10 mm	43 (19)	22 (3)	16 (16)	81 (38)
SLA				
8 mm	26 (11)	11 (2)	14 (14)	51 (27)
10 mm	38 (16)	22 (4)	13 (13)	73 (33)

*The numbers in parentheses show the number of prostheses supported by the implants.

Forty-five and 66 short implants were placed in the maxilla and mandible, respectively, while 65 and 89 standard implants were placed in the maxilla and mandible, respectively. Both arches had implants placed in the anterior and posterior regions, with the anterior region including incisors and canines and the posterior region including premolars and molars (Table 3).

Overall, 49 and 79 prostheses were placed in the maxilla and mandible, respectively. The following prostheses were used (Table 4): 58 fixed single-tooth prostheses (ST), 60 fixed partial dentures (FPD), and 11 fixed complete dentures (FCD).

If a patient could not be followed up at consecutive annual examinations, the corresponding implants were classified as dropout implants. Reasons for dropouts were lack of interest in attending the examinations (n = 9) and moving out of the area (n = 4); 10 patients could not be reached. Thus, a total of 23 patients with 23 prostheses supported by 42 implants (corresponding to 15.8% of the placed implants) were excluded from the follow-up protocol. The prostheses included 10 FPDs and 13 STs.

Prosthetic Treatment

Following a healing period of 3 to 4 months in the mandible and 4 to 6 months in the maxilla, patients were recalled for a preprosthetic evaluation. After removal of the healing screws (3 to 6 months after implant placement), the abutments were placed as recommended by the manufacturer.

Single-piece cast prosthesis frameworks and esthetic veneers were fabricated in gold alloy and porcelain, respectively. Cemented prostheses were luted with zinc-oxyphosphate cement (32 FPDs, 3 FCDs, 49 STs) or zinc oxide–eugenol cement (14 FPDs), while the 30 screw-retained prostheses (13 FPDs, 8 FCDs, 9 STs) were secured to the abutments by means of abutment-framework screws using a manual torque driver. Twenty-one temporary prostheses were used to restore anterior teeth. Each definitive prosthesis was opposed by an intact or restored dentition for 193 and 72 implants, respectively. Short and standard implants opposing mobile partial or total prostheses were excluded from the study.

Assessments

Annual clinical and periapical radiographic examinations were carried out. The following parameters were evaluated:

1. Radiographic assessments of mesial and distal peri-implant marginal bone levels were determined by comparing radiographs taken at the time of prosthetic insertion with those obtained every year thereafter. Use of cemented prostheses precluded their removal for radiographic evaluation using a specific film holder. Consequently, the radiographic monitoring evaluation were made with all prostheses in situ. The distance between the apex of the implant and the most coronal level of direct bone-to-implant contact was measured mesially and distally by means of computerized analysis (Canoscan radiograph scanner, Canon; ImageJ software, National Institutes of Health).[8] Periapical radiographs (Kodak Ekta-speed EP-22, Eastman Kodak) were taken using a parallel technique to control projection geometry (exposure parameters: 65 to 90 kV, 7.5 to 10 mA, 0.22 to 0.25 seconds). Dimensional distortion related to the periapical radiographs was corrected by comparing actual dimensions of the loaded implants to the image on film.
2. Peri-implant soft tissue parameter probing depth was measured with a calibrated plastic probe (TPS probe, Vivadent) at the time of prosthetic insertion and every year thereafter. Scores were recorded at 4 sites for each implant (mesial, distal, buccal, and lingual). It is conceded that these measurements are neither diagnostic nor prognostic of implant success outcomes.

3. The Lekholm-Zarb jawbone quality classification[6] was used with an additional subjective evaluation made during exploratory drilling while preparing the implant site.

Prognostic Criteria

Success outcome determinants and any treatment-related complications were evaluated according to Zarb and Albrektsson[4] and Roos et al.[9]

Clinical mobility was confirmed following prosthesis removal, and mobile implants were recorded as failures.

Statistical Analysis

Data and statistical life analysis were performed as described by Kalbfleish and Prentice[10] and Colton[11] at the end of March 2005, and life tables were calculated for short implants supporting different types of prostheses.

All patients completed at least 3 years of clinical examinations. Cumulative survival and success rates were calculated for the entire group of 265 implants according to internationally accepted outcome criteria.[4]

Life tables included the following parameters: observation time, number of implants at interval start, number of early failed implants (nonloaded implants), number of loaded implants, number of implants lost to follow-up as a result of patient dropout, number of implants at risk (representing the "harmonic mean" of the implants at the beginning of an interval and those remaining at the end of the same interval), number of failed implants during the interval, annual survival and success rates, and cumulative survival and success rates.[11]

The chi-square test was performed to compare the survival and success rates of short and standard implants. A 95% significance level was selected, and the influence of implant height on parameters such as marginal bone length and probing depth was tested by means of multiple linear regression analyses.

Results

No early failures were observed, and all implants were functionally loaded. No implant fractures occurred, but 4 short (3.6%) and 4 standard (2.6%) implants became mobile and were removed following varying years of service. The failed short implants were TPS 4.1 × 8 mm (n = 3) and TPS 3.75 × 8 mm (n = 1). The failed standard implants were SLA 4.8 × 10 mm (n = 1), SLA 4.1 × 10 mm (n = 1), TPS 4.1 × 10 mm (n = 1), and TPS 3.75 × 10 mm (n = 1). Five of the failed implants were in the maxilla and 3 were in the mandible.

Table 5 Short and Standard Implant Distribution According to Bone Quality*

	Bone quality (no. failed)			
	1	2	3	4
Maxilla	0 (0)	38 (0)	69 (1)	34 (4)
Mandible	16 (0)	54 (0)	49 (3)	5 (0)
Total	16 (0)	92 (0)	118 (4)	39 (4)

*Lekholm-Zarb classification.[6]

Short implant distribution according to the Lekholm-Zarb classification for bone quality[6] is reported in Table 5. Type 1 bone was found in 6.6% of the implant sites, type 2 in 34.3%, type 3 in 43.8%, and type 4 in 15.3%. All failed implants were placed in type 3 (50%) or type 4 (50%) bone.

Life table analyses recorded 7 short and 9 standard implants as complications. Peri-implant probing depths at 7 these implants were greater than 3 mm on each peri-implant site (measurements were performed with a calibrated plastic probe). Ten implants, 4 short and 6 standard, demonstrated bone loss accompanying active peri-implant gingivitis. Exposure of the rough implant surfaces was observed and successfully managed with debridement and optimal hygiene measures.

Mean marginal bone loss and probing depth values were recorded for short and standard implants at the beginning of prosthesis insertion and at time of the last recall appointment (Table 6). Six implants (3 short and 3 standard) showed more than 1.0 mm of marginal bone length during the first year of loading, followed by more than 0.2 mm of bone resorption per year. At the time of the last evaluation, mean values for marginal bone loss were 1.6 and 1.7 mm for short and standard implants, respectively.

No statistically significant differences in marginal bone loss and probing depth values were observed between short and standard implants ($P > .05$); thus, no relationship between implant length and these parameters was seen, as tested by multiple linear regression analysis.

TPS short and standard implants showed 14-year cumulative survival rates of 92.3% and 95.9%, respectively, while short and standard implants showed 80.6% and 83.5%, respectively.

SLA short and standard implants showed 5-year implant cumulative survival rates of 100% and 98.5%, respectively, while the short and standard implants showed 97.9% and 97.1%, respectively.

The prosthodontic implications of the 8 failed implants were recorded. In 2 patients, the 2 failed implants (3.75 × 8 mm and 4.1 × 10 mm) supporting 2

Table 6 Radiographic and Clinical Assessments at the Time of Prosthetic Loading and at Last Clinical Evaluation

	Marginal bone loss (mm) (mean ± SD)		Probing depth (mm) (mean ± SD)	
	Loading	Last evaluation	Loading	Last evaluation
Short (n = 111)				
Mesial	0.5 ± 0.4	1.4 ± 1.4	1.8 ± 1.4	2.4 ± 1.1
Distal	0.4 ± 0.6	1.8 ± 1.5	1.7 ± 1.2	2.4 ± 1.6
Buccal			2.1 ± 1.3	2.1 ± 1.5
Lingual			1.6 ± 1.3	2.0 ± 1.5
Mean	0.5 ± 0.5	1.6 ± 1.5	1.8 ± 1.4	2.3 ± 1.4
Standard (n = 154)				
Mesial	0.2 ± 0.4	1.6 ± 1.4	1.5 ± 1.1	1.8 ± 1.7
Distal	0.3 ± 0.5	1.8 ± 1.3	1.5 ± 1.2	2.4 ± 1.5
Buccal			1.9 ± 1.2	1.6 ± 1.5
Lingual			1.3 ± 1.4	2.3 ± 1.4
Mean	0.3 ± 0.5	1.7 ± 1.4	1.5 ± 1.3	2.1 ± 1.5

multiimplant FCDs were not replaced, as the original prostheses were modified and retained in function. Two other failed short implants (both 4.1 × 8 mm) supporting two 3-unit FPDs were replaced with 2 wider implants (4.8 × 8 mm) following a 3-month healing period. The FPDs were modified to adapt to the slight and inevitable changes in implant location. Another short implant (4.1 × 8 mm) supporting a 2-unit FPD was also replaced by an equally short but wider implant (4.8 × 8 mm) following suitable healing of the site, and a new FPD was made. Two standard implants (3.75 × 10 mm, 4.1 × 10 mm) supporting two 2-unit FPDs failed and were replaced with two 4.1 × 10 mm implants, thus necessitating 2 new FPDs. Finally, one ST (4.8 × 10 mm) was replaced by a longer implant (4.8 × 12 mm) in a better position with a readapted crown placement.

Both TPS and SLA short implants exhibited a 5-year cumulative survival rate of 100%. Similarly, comparison of the 5-year cumulative success rate of short TPS (94.7%) and SLA (97.9%) implants showed no statistical differences ($P > .05$). Likewise, when the 5-year cumulative survival rates of standard TPS (97.5%) and SLA (98.5%) implants were compared, no statistical differences were found ($P > .05$). In addition, the 5-year cumulative success rates of standard TPS (94.9%) and SLA (97.1%) implants were not statistically different ($P > .05$).

During the follow-up period, a number of prosthetic complications were recorded. Two abutment-framework screws were lost, and 2 cemented prostheses luted with zinc-oxyphosphate cement (1 ST and 1 FPD) required recementation. Furthermore, 1 pontic (FPD) and 5 porcelain esthetic veneers (4 ST and 1 FPD) fractured.

Discussion

This study reports favorable results for 8-mm-long dental implants compared to 10-mm-long implants. Bone quality appeared to play a decisive role as a treatment outcome determinant, since all 8 failed implants were placed in low-density trabecular bone (types 3 and 4). This parallels the experiences reported by other studies.[2,5] Nevertheless, more rigorous research is needed to confirm this observation, given the relatively low number of short implants studied and the possibility that bone quality is not the only factor determining implant prognosis.

Jaffin and Berman[8] and Quirynen et al[12] reported that implant length was directly related to failure rates. While other studies[13–16] come to different conclusions, a possible explanation is that implant design characteristics, including diameter and the nature of the implant-bone interface, are additional success outcome determinants. Furthermore, the earlier reports[8] did not include the benefits of a surgical protocol that employed self-tapping implants, another design improvement.

This study also compared the implant treatment outcome by type of implant surface (TPS/SLA). While a reduced follow-up (1- to 3-year survival and success rates) of SLA implants has been published, similar results have been reported with both types of implants.[17,18] The claimed favorable properties of the TPS short (8-mm) implants, with healing periods of 3 to 4 months, have been successfully used in partially edentulous patients over the last 14 years. The introduction of the SLA surface promises an even further reduction of the healing period to 6 weeks in all sites with nor-

mal bone density (types 1 to 3) and with subsequent implant success rates greater than 99% at 2 years after prosthetic restoration.[19] It must be emphasized, however, that rigorous and long-term success outcomes for different surface implants are far from compellingly documented.

The apparent effectiveness of both SLA and TPS implants appears to be confirmed by the present study when the respective implant survival and success rates are compared. However, a split-mouth design for a prospective study concerning SLA and TPS implants may be indicated, since support for such a research design appears to be lacking.

Overall, the cumulative survival rates of short implants as observed in this study are consistent with those concerning the prognosis of standard implants supporting FPDs.[20–23] The long-term treatment outcome of patients with severely resorbed edentulous mandibles treated with 247 short Brånemark implants showed a 5-year cumulative survival rate of 95.5%, leading to the conclusion that placement of short implants in the prosthodontic management of severely edentulous mandibles can be a highly predictable treatment procedure.

ten Bruggenkate and Van den Bergh[24] published the results of a 7-year follow-up trial with a recorded success rate of 93.8% for 253 6-mm-long implants. They concluded that short implants can be successfully used in minimal height residual bone, especially if they are used adjunctively with longer implants.

In the present report, the authors excluded implant-supported prosthetic restorations exhibiting an unfavorable crown-to-implant ratio to preclude higher levels of tensile stress in the bone-implant interface that may lead to the loss of the osseointegration.[25]

Instead, the results endorse the suggestion[26] that employing short implants supporting fixed prostheses in selected patients permits *(1)* avoidance of sophisticated, expensive, and complex invasive procedures (ie, sinus lift and bone grafting procedures); and *(2)* use of surgery without attempting to place the longest implant possible.

While the results of this study appear to endorse the reliability of short implants, the study design suffers from a number of shortcomings. The patient sample and the overall observation period are relatively limited, and only 70 of 128 prostheses can be claimed to have been actively, functionally loaded (possibly parafunctionally as well). The 58 single crowns cannot really be considered in the same loading context as multiunit fixed prostheses, and half of these were of the shorter implant variety. Consequently, the size of the partially edentulous spans may not be regarded as significantly challenging in the context of a broad range of occlusal loading, particularly since any adverse crown-to-root ratio was scrupulously avoided. Therefore, the reported results should be interpreted with caution, since they only apply to the shorter 8-mm implants within the specific and narrow context of the study's treatment planning and patient selection caveats. A specific comparison of prosthodontic treatment outcomes with other studies is also not reported, thereby limiting the scope of the study to implant survival outcomes.

Conclusions

Within the limitations of this study, the following preliminary conclusions can be drawn:

1. The variable long-term prognosis for 8-mm implants with different diameters appears to be consistent with the literature regarding other short implants.
2. In this study, cumulative success and survival rates for short and standard implants were not statistically different.
3. Five-year cumulative success and survival rates of SLA and TPS short and standard implants were not statistically different.
4. Bone quality seems to play a decisive role in determining implant prognosis, and the use of short implants does not seem to be recommended in poor quality bone.

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Literature Abstract

Retention of zirconium oxide ceramic crowns with 3 types of cement

This in vitro study aimed to determine the ability of selected luting agents to retain a zirconium oxide ceramic crown under simulated clinical conditions. Thirty-six human molars were prepared with a flat occlusal surface, 20-degree taper, and 4-mm gingivo-incisal height. The axial and occlusal surface areas were determined, and the specimens were distributed by total surface area into 3 groups of equal number. Zirconium oxide ceramic copings (Procera AllZirkon, Nobel Biocare) with an occlusal bar to facilitate removal were fabricated using a CAD/CAM technique. All copings were air abraded with 50 µm aluminum oxide and then cleaned with alcohol. Provisional cement was removed from the prepared teeth, followed by a pumice polish to simulate clinical steps. After trial insertion, the copings were cleaned with phosphoric acid, rinsed, and dried with alcohol. The samples were then cemented with a 10 kg force, using either a resin composite cement with an adhesive agent (Panavia F 2.0 and ED Primer A & B [PAN]), a resin-modified glass-ionomer cement (Rely X Luting [RXL]), or a self-adhesive modified resin composite (Rely X Unicem [RXU]). The cemented copings were thermal cycled at 5°C and 55°C for 5,000 cycles, and then removed along the path of insertion using a universal testing machine at 0.5 mm/min. The removal force was recorded, and the stress of dislodgement was calculated using the surface area of each preparation. A 1-way analysis of variance was used to analyze the data ($\alpha = .05$). The failure mode was also recorded. Mean dislodgement stresses were 5.1, 6.1, and 5.0 MPa for PAN, RXL, and RXU, respectively. No significant differences were noted in mean removal stress among the 3 groups. Regarding the mode of failure: *(1)* the most common failure was in the cement layer, *(2)* failure in the zirconium oxide copings was 46%, and *(3)* cement was found on the tooth in 25.7% of the specimens. Within the limitations of this study, the removal stresses of the 3 luting agents ranged from 5.0 to 6.1 MPa (not significant). Resin composite cement with a bonding agent did not yield better retention. However, stress calculation in this study included the axial wall surface area, which is questionable.

Palacios RP, Johnson GH, Phillips KM, Raigrodski AJ. *J Prosthet Dent* 2006;96:104–114. **References:** 23. **Reprints:** Dr Rosario Palacios, Department of Restorative Dentistry, University of Washington, D 780 Health Sciences Center, 1959 NE Pacific St, Box 357456, Seattle, WA 98195-7456. Fax: +206 543 7783—*Ansgar C. Cheng, Singapore*