Influence of Prosthetic Parameters on the Survival and Complication Rates of Short Implants

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Purpose: *Implants shorter than 10 mm can be a long-term solution for sites with limited bone height. The purpose of this study was to determine the influence of some prosthetic factors on the survival and complication rates.* ***Materials and Methods:*** *Two hundred sixty-two short machined-surface Brånemark System implants were consecutively placed in 109 patients and followed for a mean of 53 months. The prosthetic parameters were recorded, and the data were examined for relation to peri-implant bone loss and biologic or biomechanical complications.* ***Results:*** *Relatively few crown-to-implant (C/I) ratios were < 1 or > 2 (16.2%). Occlusal table (OT) width ranged from 5.4 to 8.3 mm. Opposing dentition was most often natural teeth, a fixed prosthesis supported by natural teeth, or an implant-supported fixed restoration. Occlusion with a normal buccolingual maxillomandibular relationship was found in 72.7% of the cases. No significant difference in peri-implant bone loss was correlated with C/I ratio or OT. Neither cantilever length nor bruxism had a significant effect on peri-implant bone loss. Mean bone loss was 0.74 ± .65 mm. The difference in the complication rate (15% overall) between the bruxer and the nonbruxer group was not statistically significant ($P = .51$). One implant was lost in a heavy bruxer after 7 years of function.* ***Discussion:*** *Increased C/I and OT values do not seem to be a major risk factor in cases of favorable loading. In 67% of the cases, the mesiodistal length of the prosthesis was less than the corresponding natural tooth length, which may have contributed to better load distribution and more favorable results.* ***Conclusions:*** *Short implants appear to be a long-term viable solution in sites with reduced bone height, even when the prosthetic parameters exceed the normal values, provided that force orientation and load distribution are favorable and parafunction is controlled.* (Case Series) INT J ORAL MAXILLOFAC IMPLANTS 2006;21:275–282

Key words: *crown-implant ratios, implant complication rates, prosthetic parameters, short implants*

Successful treatment outcomes using implants of different geometric configurations and surface coatings have been widely reported in individual and multicenter studies.[1–5] Recent clinical studies have demonstrated that short implants may be a viable long-term solution for sites with limited bone height,[6–8] although the risk increases if the bone is not of good quality.[9] However, limited information on the prosthetic characteristics of the implant-supported fixed restorations was provided in these reports. In clinical situations where severe bone resorption has occurred, the therapeutic options may be either bone reconstruction or the use of short (less than 10 mm) implants.[10–12] The benefits and risks of each option need to be carefully appraised in view of the long-term esthetic and functional stability of the prosthetic restoration. The determining factors contributing to implant failures have been defined as either endogenous (either systemic or local) or exogenous (operator- or biomaterial-related).[13] Bone quality and quantity are among the most influential factors affecting the outcome of therapy.

Bone resorption is often accompanied by an unfavorable jaw relationship and increased maxillomandibular space, with the inevitable prosthetic consequences of excessive crown height and occlusal table design with increased buccolingual cantilever.[14] Maximal occlusal forces applied and toler-

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ated vary greatly according to implant position in the arch, the functional and parafunctional habits of each individual, and the nature of the opposing dentition. High bending moments, unfavorable force distribution, and increased force magnitude, as seen in the posterior areas of the jaws, may produce biomechanical overload on the hardware and the supporting bone.[15] Biomechanical complications have been reported in a number of studies. Prosthetic screw loosening or fracture, veneer fracture, abutment screw or implant fracture, peri-implant bone loss, and loss of integration have been among the most commonly reported complications.[16]

The purpose of this study was to determine the influence of prosthetic factors, namely crown-to-implant (C/I) ratio, dimension of the occlusal table, nature of opposing dentition, mesial and distal cantilever, mesiodistal dimension of the prostheses in relation to the number and distribution of the implants, veneering material, and parafunctional habits on the survival and complication rate of short machined-surface Brånemark System implants.

MATERIALS AND METHODS

The study group consisted of 109 patients, 44 men and 65 women with a mean age of 53.6 years (range, 22 to 80 years), consecutively treated and followed since June 1994. All had limited bone height, mostly in the posterior areas of the jaws, and all were rehabilitated with implant-supported fixed restorations. Two hundred sixty-two machined-surface implants (Nobel Biocare, Göteborg, Sweden), all 10 mm or shorter, supported 123 fixed prostheses. Fourteen patients had 2 restorations in different quadrants of each of their jaws. Thirty-three implants supported single-tooth restorations, 223 supported fixed prostheses in different partially edentulous situations, and 6 supported 2 fixed prostheses in a partially edentulous patient who became completely edentulous after losing his last severely periodontally diseased teeth. Two patients who were treated during that period with an implant-supported overdenture were excluded from the study and were not accounted for. The great majority of the implants were placed in the mandible (88.5% in the mandible versus 11.5% in the maxilla) and in premolar or molar sites (98.5%, versus 1.5% in incisal or canine sites). Porcelain-fused-to-metal crowns were fabricated for all patients. Seventy-eight restorations were screw-retained and 33 were cemented. The clinical survival rate of these implants has been reported in a separate article.[6] The patients were followed in the present study for 12 to 108 months (mean, 53 months). They were seen every 6 to 12 months for examination and maintenance. Twenty-nine patients accounting for 63 implants did not appear for the last recall visit. Therefore, some measurements could not be obtained.

The following prosthetic variables were assessed:

1. The buccolingual width of the occlusal table was measured from the palatal or lingual line angle to the buccal line angle of the premolars and molars with a vernier caliper to 0.1 mm.
2. The occlusal relationship between the maxillary and the mandibular teeth was defined as normal, edge-to-edge, crossbite, or buccolingual offset with an increased lever arm.
3. The nature of the opposing dentition was noted as being either natural dentition, partially fixed prostheses, a removable partial denture, or a complete denture.

Biomechanical complications (screw loosening, component fracture, veneer fracture, fixation or abutment screw loosening, implant loss, or loss of osseointegration) were recorded.

Periapical radiographs obtained with a long-cone technique and a noncustomized paralleling device (XCP positioner; Rinn, Elgin, IL) were used to evaluate the following prosthetic parameters. All measurements were made under a magnifying loupe (×8) using a Digimatic caliper (Mitutoyo, Tokyo, Japan) to 0.01mm (Fig 1).

- The crown height was measured from the abutment-implant interface to the most coronal radiographically determined occlusal limit of the ceramic crown.
- The implant length was measured from the plateau of the implant to its most apical part. This measure was compared with the actual implant length, and amount of error was determined. The C/I ratio (height/length) was then calculated.
- The mesiodistal length of the prosthetic restoration was measured at 2 levels: *(a)* At the crown level from the most mesial point (C′) to the most distal point (C) of the prosthesis and *(b)* at the implant level from the mesial abutment-implant interface of the anterior implant (A′) to the distal abutment-implant interface of the posterior implant (A) (Fig 1).
- The mesial cantilever (from line F to line G) and the distal cantilever (from line I to line J) were measured.

The number of implants in relation to the mesiodistal length of the prosthesis was also

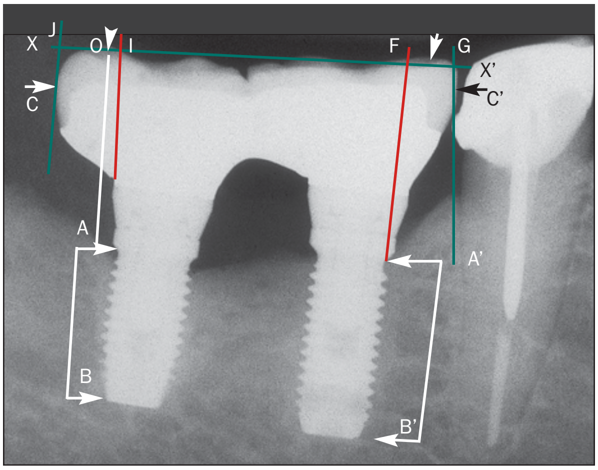

Fig 1 Diagram showing the reference points and planes used in the prosthetic measurements. A-A' = distance between the 2 implants at the implant level; C = distal contact point; C' = mesial contact point; C-C' = mesiodistal length of the prosthesis at the crown level; F-G = mesial cantilever; I-J = distal cantilever; XX' = the occlusal plane.

recorded. Prosthetic parameters which could not be precisely determined in this study were the lever arm in the buccolingual direction (ie, the distance between the point of application of occlusal force and the emergence axis of the implant) and the cuspal inclination.

The presence of parafunction was evaluated based on the patient's awareness of any bruxing habit and signs of occlusal trauma (wear facets, temporomandibular joint disorders). Patients were classified as nonbruxers, occasional bruxers, or heavy bruxers.

Radiographic Evaluation

Periapical radiographs obtained at abutment connection were compared with those obtained at the last follow-up visit and analyzed for peri-implant bone loss. Radiographs were considered for analysis in cases where the threads on the mesial and distal sides of the implants were distinctly visible (Fig 2). The reference point for evaluation of bone loss was the border between the conical and the cylindric parts of the implant head. For the 5-mm regular platform (RP) implant, the abutment-implant connection was used as the reference point.

Statistical Analysis

Analysis of variance (ANOVA) revealed that mesial, distal, and mean mesiodistal bone loss were not affected by site location within each patient ($P = .48$), while the patient as a factor had a significant influence on variation in bone loss ($P < .05$). Consequently, for statistical analysis purposes and whenever appropriate, implants were treated as multiple observations within each patient.

All data analyses were performed using SPSS version 14.0 (SPSS, Chicago, IL). Single linear regression analysis was used to examine the effect of width of the occlusal table, crown-to-implant ratio, and mesial and distal cantilever on peri-implant bone loss. Multiple linear regression analysis with stepwise-forward selection was used to examine the combined effect of the occlusal table, C/I ratio, and mesial and distal cantilever on bone loss and to determine the combination of variables accounting for most of the variations observed. ANOVA was used to determine the effect of the occlusion type on bone loss and post hoc examination of group mean differences was done using the Tukey test. Crosstabular analysis using the Fisher exact test was performed to determine whether complications were dependent on bruxism. All significance tests were conducted at the 95% significance level.

RESULTS

Based on 262 measurements, the mean percentage of error between the actual length of the implant and the value obtained from the periapical radiographs using a magnifying loupe and a Digimatic caliper was 0.5% ± 2.8%. All measurements were done twice by the same calibrated operator, who was blinded with respect to subject. Because of the small margin of error, no corrections were made on the final values.

The crown-to-root ratio in human natural teeth, according to Wheeler, has a mean value of 0.6 for maxillary teeth and 0.55 for mandibular teeth.[17] The C/I ratios in the current investigation were sorted into 6 groups (Table 1) based on 234 measurements; 12.8% of the cases belonged to the < 1 group, 29.9% to the 1-to-1.2 group, 24.7% to the 1.21-to-1.4 group, 12.3% to the 1.41-to-1.6 group, 16.6% to the 1.61-to-2 group, and 3.4% to the > 2 group. When peri-implant bone loss was related to the crown-to-implant ratios (Table 2), no significant difference could be found among the different groups ($P = .290$). The mean bone loss was 0.74 ± 0.65 mm.

The width of the occlusal tables, based on 194 measurements, varied between 5.4 and 8.3 mm. The implants were sorted by occlusal table width into 4 groups (Table 3); 73.7% of the cases were in the 6- to 8-mm range. Peri-implant bone loss was measured in the different groups to determine any potential influence of this prosthetic parameter on the survival rate of the implants (Table 4). No significant difference could be found among the various groups with respect to peri-implant bone loss ($P = .150$).

The occlusal relationships between the implant-supported prostheses and the opposing dentition

Table 1 C/I Ratio (n = 234)

C/I ratio	Mean	SD	n
< 1.00	0.88	0.15	30
1.00 to 1.20	1.09	0.06	70
1.21 to 1.40	1.30	0.06	58
1.41 to 1.60	1.49	0.04	29
1.61 to 2.00	1.80	0.11	39
> 2.00	2.36	0.18	8

Table 2 Peri-implant Bone Loss Related to C/I Ratio (n = 234)

C/I ratio	Mean M-D bone loss (mm)	SD	n
< 1.00	0.88	0.74	30
1.00 to 1.20	0.75	0.71	70
1.21 to 1.40	0.73	0.58	58
1.41 to 1.60	0.77	0.71	29
1.61 to 2.00	0.66	0.54	39
> 2.00	0.62	0.76	8
Total	0.74	0.65	234

No significant differences were found between the groups *(P* = .290). M = mesial; D = distal.

Table 3 Occlusal Table Width (n = 194)

Width of OT	Mean	SD	n
< 6.0 mm	5.62	0.39	39
6.1 to 7.0 mm	6.67	0.28	86
7.1 to 8.0 mm	7.49	0.27	57
> 8.0 mm	8.42	0.27	12
Total	6.81	0.82	194

Table 4 Mean Mesiodistal Peri-implant Bone Loss Related to the Width of the Restoration (n = 194)

Width of OT	Mean M-D bone loss (mm)	SD	n
< 6.0 mm	0.49	0.43	39
6.1 to 7.0 mm	0.69	0.67	86
7.1 to 8.0 mm	0.79	0.65	57
> 8.0 mm	0.92	0.75	12
Total	0.67	0.64	194

No differences were found between the groups with respect to peri-implant bone loss (*P* = .150; linear regression test).

Table 5 Mean Mesiodistal Bone Loss in Relation to the Type of Occlusion on the Rehabilitated Side

Type of occlusion	Mean M-D bone loss (mm)	SD
A (n = 73)	0.72	0.62
B (n = 12)	0.60	0.48
C (n = 14)	0.42	0.38
Total	0.66	0.58

ANOVA showed no difference with respect to bone loss among types A, B, or C (*P* = .174; linear regression test).

were categorized into 4 types based on 99 observations: type A (normal maxillomandibular occlusal relationship), type B (end-to-end occlusion), type C (lateral cross-bite; mandibular teeth buccal to the maxillary teeth), and type D (buccal cusps of the mandibular teeth occlude with the buccally overextended cusps of the maxillary teeth). Ten patients fell into more than 1 group because they had prostheses in contralateral quadrants of the mouth. Type A occlusion was most frequently encountered (73 observations; 73.7% of cases). Type B occlusion was observed in 12 cases (12.1%), type C in 14 cases (14.1%), and type D (the worst case, the occlusal relationship that produces the most severe bending moments on the components) in 1 case (1%). Information on opposing dentition was missing in 29 cases. ANOVA showed no difference with respect to bone loss among types A, B, or C (*P* = .174; linear regression test) (Table 5). Natural dentition, fixed prostheses supported by natural teeth, and implant-supported restorations represented 98.2% of the opposing dentition (based on 113 observations). A complete denture was present in 1 case, and a removable partial denture in another.

Bruxing habits were included in 3 groups based on the criteria defined; 22.6% of the patients belonged to the bruxer group, 5.9% to the occasional bruxer group, and 71.4% to the nonbruxer group. No statistical differences were found among the 3 groups using the Fisher exact test (*P* = .51)

The mesiodistal length of the implant-supported restorations compared to the mesiodistal dimension of the natural teeth in the respective treated sites was evaluated (Table 6). They were separated into 6 groups ranging from single-tooth restorations to restorations consisting of 4 crowns supported by 4 implants. In 33% of the cases, the mesiodistal dimension of the implant-supported restorations exceeded the mesiodistal length of the natural teeth, and in 67% of the cases, that dimension was less than the related natural dentition length.

The mesiodistal length of the restorations was evaluated in the different restorative situations (Table 7). The mesial and distal cantilevers were measured on the implant-supported restorations. The average mesial cantilevers measured 2.75 ± 1.65 mm,

Table 6 Mesiodistal Length of the Implant-Supported Restorations vs the Mesiodistal Dimension of the Natural Teeth (n = 115)

Type of prosthetic restoration	Mean ± SD (mm)		n	
	+	–	+	–
Single restorations	1.13 ± 0.99	0.98 ± 0.86	12	17
Single restorations on 2 implants	1.60 ± 1.09	1.52	2	1
2 crowns on 2 implants	1.34 ± 0.96	2.55 ± 1.94	16	36
3 crowns on 3 implants	1.74 ± 2.40	4.41 ± 3.01	3	22
4 crowns on 3 implants	5.80 ± 2.54	—	4	—
4 crowns on 4 implants	0.62	0.47	1	1

+ = mesiodistal length of the restorations exceeding the mesiodistal length of the natural teeth.
– = mesiodistal length of the restorations less than the mesiodistal dimension of the natural teeth.
n = number of cases treated in each clinical study.

Table 7 Mesiodistal Length of the Restorations at the Crown and Implant Levels

	M-D length (Mean ± SD) of the restorations (mm)	
	Crown level	Implant level
Single crown (n = 31)	9.76 ± 1.92	4.86 ± 0.60
Prosthesis supported by 2 implants (n = 124)	19.38 ± 3.36	13.95 ± 2.28
Prosthesis supported by 3 implants (n = 87)	25.36 ± 3.55	21.17 ± 2.26
Prosthesis supported by 4 implants (n = 8)	34.95 ± 0.10	31.90 ± 2.47

and the average distal cantilevers measured 2.24 ± 1.6 mm. Linear regression analysis revealed no effect of these parameters on mean mesiodistal bone loss ($P < .05$).

Multiple regression analysis was used to analyze the effect of all four variables (occlusal table, C/I ratio, mesial and distal cantilever, and type of occlusal pattern) on peri-implant bone loss. No statistically significant effect on the mean mesiodistal bone loss could be found for any of the 4 variables ($P = .242$).

Complications were observed in 15% of the patients: 7.8% experienced screw loosening, and 5.2% had porcelain fracture. In 1 case, an implant fracture was observed, and in another, a 7-mm implant was lost after 7 years of loading (Figs 3a to 3c). The patient reported with concern for the loosening of her prosthesis. The implant had been placed in type 2 bone and functioned well over the observation period. No marginal bone loss was observed, but peri-implant radiolucency was evident.

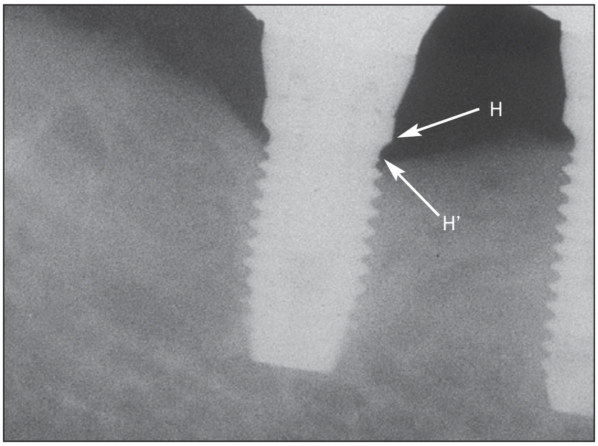

Fig 2 The reference points for measurement of bone loss. H = the reference point; H' = the most coronal radio-graphically visible bone level.

DISCUSSION

The C/I ratio has been considered 1 of the geometric load factors that may increase the risk of biomechanical complications.[14] In the current investigation, it did not prove to be a major complicating factor, although it was found to be increased by 2 to 3 times in nearly 87% of cases. Peri-implant bone resorption was nearly equivalent in all C/I ratio groups. It may be possible to explain this finding by the favorable maxillomandibular occlusion found in 72.7% of cases. In cases where lateral discrepancy of the jaws was encountered because of an unfavorable bone resorp-

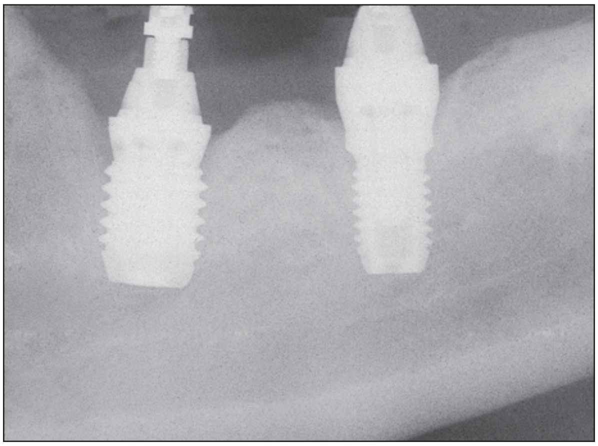

Fig 3a A 5 × 6-mm implant and a 3.75 × 7-mm implant were placed in the posterior mandible to replace 2 missing molars.

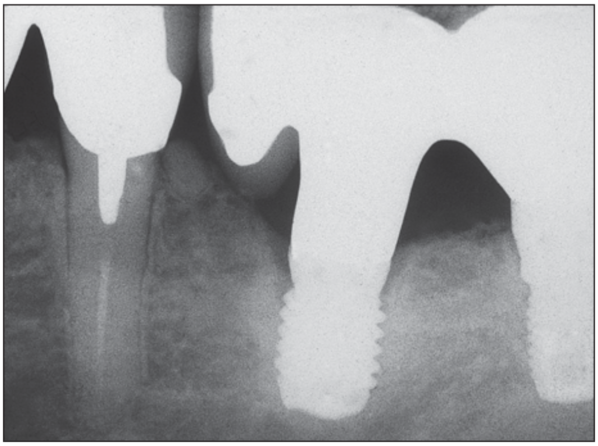

Fig 3b Six years postloading. Note the absence of marginal bone resorption.

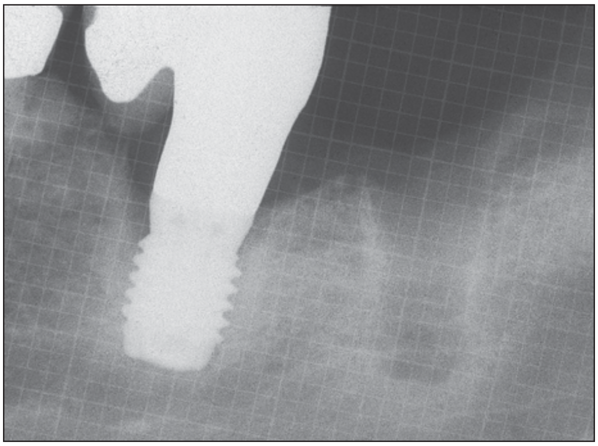

Fig 3c Seven years postloading. Loss of the 3.75 × 7-mm implant without signs of marginal bone resorption.

tive pattern consequent to tooth loss, end-to-end occlusion or lateral crossbite occlusion resulted. In these 2 situations, all working and nonworking interferences were carefully screened and eliminated.

It has been demonstrated that axial forces distribute stress more evenly throughout the implant as compared to bending moments.[15] Stress is generally lowest under axial load and highest under lateral load and is concentrated around the neck of screw-type implants, as determined by mathematical models and finite element analysis.[18–20] Force direction, rate, frequency, and magnitude may all interfere with the mechanical loading of implants and interfere with the healing of supporting bone.[21,22] It is important to note that the axial load is not, in an in vivo model, the only direction of force application, but if the occlusion is properly adjusted and occlusal contacts placed as closely as possible to the emerging axis of the implant, increased C/I ratio will not represent a major biomechanical risk factor. This is in accordance with the results of Nedir and associates.[23] In their study, C/I ratios ranged from 1.05 to 1.80, with no mentioned detrimental consequences on the final success rate.

Periodontal prosthesis concepts established several decades ago[24] provided for the reduction of the occlusal table of prosthetic restorations by as much as 40%. In addition, the flattening of cuspal inclines in clinical situations where the crown-to-root ratio was severely increased following periodontal disease-induced bone resorption was suggested to reduce the stress and strain on the supporting structures. For the same magnitude of occlusal load, bending moments are a function of the point of application of the forces, the size of the occlusal table, and the cuspal inclination. In the current series, all restorations were completed by referring dentists. Thus, the dimension of the occlusal table varied for the prosthetic restorations, though most were fabricated using a rather flat occlusal scheme. No difference in peri-implant bone loss was found when the different groups were compared, nor was increasing bone loss seen over the several years of observation.

One case of implant fracture in a very severe bruxer was encountered. After several years of function, metal fatigue can be the cause of component failure.[25,26] In the present case of implant fracture the C/I ratio was 1.37, and the implant was 10 mm long. The bruxer group contained 22.6% of the patients; 50% of the veneering fractures and 22% of the screw-loosening incidents occurred in that group.

Cantilevers have been considered a potential biomechanical risk factor for implant-supported protheses,[14] although Romeo and coworkers[27] did not find any detrimental effect of cantilevers, provided cantilever length was appropriate and occlusal function was under control. Longer cantilevers may increase the risk of failure.[28] In the current series, the mean mesial and distal cantilevers were limited to 2.75 ± 1.65 mm and 2.24 ± 1.60 mm, respectively. Mean bone loss was 0.74 ± 0.65 mm.

The mesiodistal length of the prostheses was compared to the mesiodistal length of the natural teeth in the respective treated areas. In 33% of the cases, the mesiodistal length of the prostheses exceeded the mesiodistal length of the natural teeth because the distance between 2 adjacent implants was adjusted to allow for the placement of the prosthetic restoration in the available edentulous space. In 26 cases, 14 mesial and 12 distal extensions greater than 4 mm were added to the prostheses; 4 of 9 cases of screw loosening were found in this group. In 67% of the cases, the mesiodistal length of the prostheses was less than the mesiodistal length of the natural teeth. In 96.6% of the patients, each missing tooth was individually replaced by an implant. In only 4 patients was a 4-unit prosthesis supported by 3 implants.

All prosthetic restorations involved ceramic fused-to-metal fabrication. It may be speculated that loads applied to a nonresilient material transmit a high amount of stress that may exceed the limits of tolerance for short implants and bone, thereby inducing resorption and ultimate mechanical failure of the system. With the exception of 1 case of loss of osseointegration after 7 years of function, there have been no biologic or biomechanical complications observed that have not been reported with other veneering materials. The effect of veneering material on stress distribution in implant-supported fixed restorations has been analyzed in several finite element studies. According to Ciftci and colleagues,[29] stresses developed with acrylic resin and reinforced composite resins were 25% and 15% less, respectively, than with porcelain. In other studies,[30–32] no significant effect of porcelain on the stress level could be found, and resin could not be demonstrated to have a protective effect on the implant-bone interface. In a study by Hobkirk and Psarros,[33] no difference in the load rates was found with the use of porcelain or acrylic resin.

CONCLUSIONS

1. Short implants appear to be a long-term viable solution in sites with reduced bone height even when the prosthetic parameters may not be favorable.
2. C/I ratio, even when increased by 2 to 3 times, did not seem to represent a biomechanical risk factor in cases of favorable force orientation and load distribution ($P = .290$).
3. No relation could be found between the width of the occlusal table and peri-implant bone loss ($P = .150$)
4. Mesial and distal cantilevers as reported did not have any detrimental effect on peri-implant bone stability ($P < .05$).
5. Bone loss was not affected by the 3 types of occlusal patterns ($P = .174$). Occlusion can be adapted to the specific needs of each situation, provided vertical force orientation and nonworking interferences are controlled.
6. Although more serious complications occurred in the bruxer group, there was no statistical difference in the rate of complications in the different bruxism groups examined ($P = .51$).

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