Radiologic Follow-up of Peri-implant Bone Loss Around Machine-Surfaced and Rough-Surfaced Interforaminal Implants in the Mandible Functionally Loaded for 3 to 7 Years

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Purpose: *In this retrospective study, marginal peri-implant bone height around machined and sandblasted/acid-etched interforaminal implants in the mandible was evaluated radiologically at least 3 years after functional loading.* ***Materials and Methods:*** *Fifty-one patients, each with 4 interforaminal screw-type implants placed between 1994 and 1998, were included in this study. Of these, 36 patients (70.6%) with a total of 144 implants (76 machined Mk II implants and 68 sandblasted/acid-etched Frios implants) were available for follow-up studies. Interforaminal marginal bone loss was evaluated by extraoral rotational panoramic radiographs. In addition, predictive factors such as patient age and sex, nicotine use, implant position, implant life, and site of measurement were recorded, as well as bone loss at surgery (ie, baseline bone loss). Analysis of covariance for repeated measurements was used for statistical analysis. Between-group differences were expressed as least square means ± standard error.* ***Results:*** *Sandblasted/acid-etched implants showed significantly less marginal bone loss than machine-surfaced implants (2.4 ± 0.23 mm vs 1.64 ± 0.27 mm). Implants placed in the anterior of the arch showed significantly more peri-implant bone loss than implants placed in the posterior (*P *= .0001).* ***Discussion and Conclusions:*** *Significantly less long-term peri-implant bone loss was observed for rough implant surfaces compared to machine-surfaced implants. However, it was also demonstrated that both types of implants, in combination with bar-supported overdentures, can produce excellent long-term results in the atrophic edentulous mandible. Mesially placed implants showed more bone resorption than distally positioned implants, independent of surface roughness.*
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Based on the observation of direct bone apposition to screw-type machine-surfaced (MS) implants, Brånemark defined the contact interface between organized living bone tissue and the surface of the loaded implant as a functional and structural unit (osseointegration).[1] For many years MS implants were thought to be ideally suited for long-term osseointegration.[2–4] Several authors reported that the gross and microscopic surface texture of MS implants was critical for the osseointegration of dental implants.[2,5] Increased bone apposition observed on rough implant surfaces prompted the development of various kinds of rough-surfaced implants, such as implants coated with hydroxyapatite, titanium plasma-sprayed implants, sandblasted/acid-etched

(SE) implants, and anodized implants.[6–9] Rough implant surfaces have been found to show more bone-to-implant contact within the initial healing period.[10] However, with coated implants, the unstable physical bonding between the coating and the implant material could interfere with osseointegration.[11] In addition, coated implants have been associated with inflammatory bone resorption and implant loss more often than uncoated implants.[12,13]

Surface roughening of uncoated implants was intended to combine the advantages of coated implants in terms of bony healing with the high success rates of MS implants.[3,4,14] The effects of surface roughening by sandblasting and acid etching on the apposition of bone during healing have been investigated in several experimental studies.[15–17] In an experimental surface analysis, SE implants showed more cell apposition than MS implants after only 5 days of incubation.[18] Long-term success, however, depends on minimizing the amount of marginal bone loss after several years of functional loading.[3,4,14,19,20] Only 2 studies have compared marginal bone loss for MS implants and SE implants. Lazzara and coworkers[21] published a histologic study on healing in humans 6 months after placement of unloaded implants. Khang and associates[22] reported survival rates of MS and sandblasted screw-type implants in bone of varying quality after a follow-up period of 3 years; however, the status of the marginal peri-implant bone was not specified.

Radiologic studies to evaluate changes in marginal peri-implant bone height during implant recall programs are widely accepted. Conventional imaging techniques using (intraoral) periapical radiographs and (extraoral) panoramic radiographs have been recommended.[23–25] However, these will provide reliable and reproducible information only if imaging errors related to beam geometry and the resultant asymmetric distortions are precluded. Consequently, right-angle imaging techniques with symmetric distortion have been advocated for evaluating peri-implant bone loss.[26,27] Based on an experimental study, Hermann and coworkers measured peri-implant bone loss from right-angle radiographs and found their results to be within 0.2 mm of the histometric measurements in 97.3% of cases.[28]

In the present retrospective study MS implants and SE implants were compared radiologically to evaluate marginal peri-implant bone loss after at least 3 years of functional loading. To ensure comparability, only patients with 4 interforaminal implants supporting bar overdentures were enrolled. The effects of some other factors (patient age and sex, nicotine use, implant position, implant life, and site of measurement) on the marginal bone were also evaluated.

Fig 1 Screw-type Brånemark System Mk II implants (MS implants, *left*) and Frios implants (SE implants, *right*).

MATERIALS AND METHODS

Patients with edentulous mandibles who received 4 submerged interforaminal implants between December 1994 and May 1998 and were rehabilitated with bar-supported overdentures after a healing period of 3 months were recruited for the study. They were fully informed about the purpose and method of the study and gave their consent for treatment. Of the 51 patients, 36 (25 women and 11 men) were available for follow-up (recall rate, 70.6%). Fifteen patients were unavailable: 3 patients were deceased at the time of recall, another 7 had moved away without leaving a forwarding address, and 5 declined to appear for follow-up studies for personal reasons (eg, poor health, long travel time). The MS implant group comprised 19 patients ranging in age from 51.7 to 86.3 years (mean 64.8 years), and the SE implant group comprised 17 patients ranging in age from 48.7 to 78.9 years (mean 70.7 years). Eight of the 36 patients were nicotine users, smoking 13 to 60 cigarettes (mean 25.4 cigarettes) a day.

Screw-type implants were used (Fig 1)—Brånemark System Mk II implants (length 13 or 15 mm; diameter 3.75 mm; surface roughness = 0.063 µm according to Ogawa and coworkers[29]; Nobel Biocare, Göteborg, Sweden) for the MS implant group and Frios implants (length 12 or 14 mm; diameter 3.75 mm; self-tapping with an SE surface; surface roughness = 0.159 µm according to Ogawa and coworkers[29]) for the SE implant group.

Surgery was performed as recommended by the manufacturers by experienced oral and maxillofacial

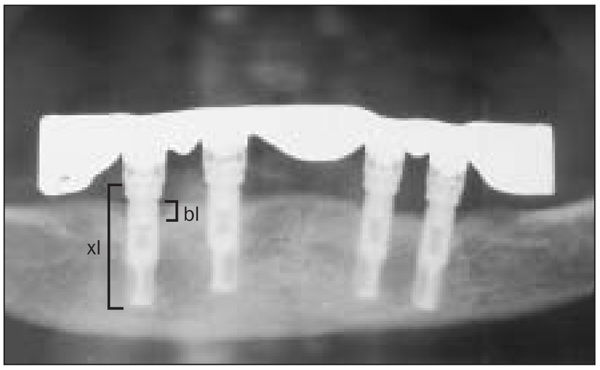

Fig 2 The radiologic implant length (xl) was measured on orthopantomograms to correct for magnification. Measured implant lengths were divided by the actual lengths of the implants to determine the magnification factor for each implant and compute the actual bone loss from the radiologic bone loss (bl) mesial and distal to the implants.

Table 1a Peri-implant Bone Loss as Related to Prognostic Factors

	LSM	SEM	*P*
Implant type			
Frios (SE)	–1.64	0.27	
Mk II (MS)	–2.36	0.23	.0422
Implant site			
Mesial side of implant	–2.01	0.18	
Distal side of implant	–1.99	0.19	.7591
Implant position			
Mesial—23 (32) and 26 (42)	–2.14	0.19	
Distal—21 (34) and 28 (44)	–1.85	0.19	< .0001
Nicotine use			
No	–1.84	0.18	
Yes	–2.15	0.35	.4487
Gender			
Male	–1.78	0.28	
Female	–2.21	0.20	.1740

LSM = least square mean; SEM = standard error of measurement.
$P < .05$ was considered statistically significant.

Table 1b Peri-implant Bone Loss as Related to Prognostic Factors—Continuous Variables

	LSM	SEM	*P*
Patient age*	0.0047	0.0182	.7974
Implant life*	–0.0121	0.0126	.3378
Bone loss at surgery	0.2349	0.0552	< .0001

LSM = least square mean; SEM = standard error of measurement.
$P < .05$ was considered statistically significant.
*At follow-up.

surgeons. For all patients the splinting suprastructure consisted of a milled gold alloy bar cantilevered posteriorly with no more than 1.6 times the anteroposterior distance between the mesial and distal implants and an implant-supported overdenture with 12 resin teeth.[30] Orthopantomograms (Scanora; Soredex, Orion, France) were recorded postoperatively on the day of surgery.

Follow-up radiology was done between June 2001 and April 2002 by the Department of Oral Surgery of the University of Vienna Dental School. As usual for recalls, orthopantomograms were recorded and the patients were asked to detail any nicotine use (smoking material and amount).

Peri-implant marginal bone loss was assessed and compared on baseline and follow-up radiographs by measuring the vertical distance between the reference point (the implant-abutment interface) and the bone level at the crest. For each implant, the radiographic implant length was measured (Fig 2) and divided by the actual implant length to determine the magnification factor for the correction of system-inherent magnification. The bone loss in millimeters detected radiologically was divided by the magnification factor to obtain the actual bone loss. Measurements were made mesial and distal to the implants with a precision slide jaw caliper with a maximum resolution of 0.01 mm (Zürcher Modell; Planer, Vienna, Austria).

Statistical Analysis

Associations between bone loss and the prognostic factors—patient sex and age, nicotine use, implant life (at follow-up), implant type (SE vs MS), site of measurement (mesial vs distal to the implants), and implant position (mesial vs distal to the foramen)—were evaluated by analysis of covariance with repeated measurements (Table 1a). Additionally, the baseline measurement (bone loss at time of surgery) was included in the model. Bone loss was measured mesial and distal to each implant (every patient had 1 implant in the right first premolar region, 1 in the right lateral incisor region, 1 in the left lateral incisor region, and 1 in the left first premolar region); thus the variance-covariance structure for the repeated measurements within a patient was assumed to be compound symmetry. Potential interactions between implant type and the other prognostic factors were evaluated and, where there was no significant effect, removed from the model. Effects are described with least square means and corresponding standard error of the mean for categorical prognostic factors and with parameter estimates for the continuous variables—patient age, implant life, and bone loss at time of surgery (Tables 1a and 1b). Statistical analyses were carried out with the statistical software package SAS (SAS Institute, Cary, NC).[31] All tests were 2-tailed, and $P < .05$ was considered significant.

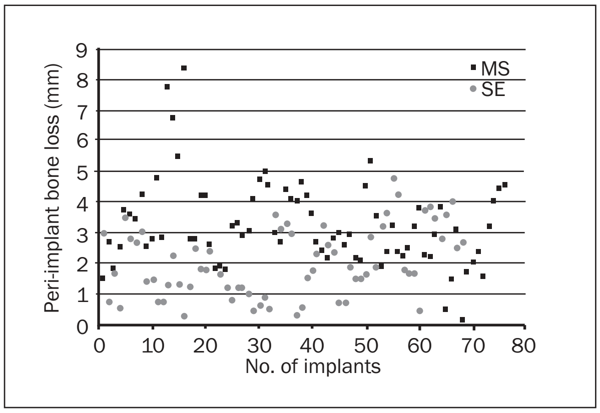

Fig 3 Plot graph of values for peri-implant bone loss around all implants followed up in numeric order (MS = machined implants; SE = sandblasted/acid-etched implants).

Table 2 Life of MS Implants vs SE Implants in Months

	Minimum	Maximum	Mean
MS implants	37.8	77.6	54.36
SE implants	39.5	86.4	66.89

RESULTS

The bone loss around SE implants (–1.64 ± 0.27 mm) was significantly less than that around MS implants (–2.36 ± 0.23 mm; $P = .0422$; Fig 3). Mean bone loss around distal implants was 0.29 mm less than around mesial implants (–2.14 ± 0.19 mm mesially vs –1.85 ± 0.19 mm distally; $P < .0001$). The mean rate of bone resorption was 0.0233 mm/mo for MS implants and 0.0015 mm/mo for SE implants. This difference was not significant ($P = .413$) and therefore was removed from the final model. No statistically significant relationship was detected between measurements on the mesial and distal sides of the same implant and the bone loss measured at follow-up ($P = .7591$). Similarly, there was no significant relationship between bone loss and patient age ($P = .7974$), nicotine use ($P = .4487$), implant life ($P = .3378$), or patient sex ($P = .1740$). No significant interactions between implant type and the prognostic factors were detected.

Patient age ranged from 48.7 to 86.3 years at follow-up. The implants had been in place for 37.8 to 86.4 months (mean implant life 60.63 months for all implants; 66.89 months for SE implants and 54.36 months for MS implants; Table 2). The mean functional loading time was 55.13 months. None of the implants failed during the follow-up period.

DISCUSSION

Particularly in the highly atrophic interforaminal mandible, rotational panoramic radiographs are a useful alternative to intraoral periapical radiographs for evaluating peri-implant bone loss in cases where poor imaging conditions make intraoral periapical radiography difficult or rule it out completely.[25] In a clinical study, rotational panoramic radiographs were comparable to intraoral periapical radiographs for evaluating peri-implant bone loss in the atrophic mandible.[32]

The beneficial effects of rough implant surfaces on peri-implant bony healing have been documented in numerous experimental and clinical studies.[8,9,17,22,32–34] A number of clinical and radiologic studies with several years of follow-up shed light on the pattern and course of marginal bone loss around roughened coated implants versus MS implants.[3,4,14,35–39] Only Khang and coworkers[22] compared MS and sandblasted screw-type implants in relation to bone quality during a follow-up period of 3 years. However, the main emphasis of their study was implant survival rather than marginal bone height assessment. The results of the present study agree with those reported for sandblasted implants by Khang and coworkers.

The present study radiologically compared SE implants with MS implants after 3 years of functional loading by means of rotational panoramic radiographs. It showed that both MS and SE screw-type implants with bar-supported overdentures can produce excellent long-term results in the edentulous atrophic mandible. Significantly less peri-implant bone loss was found around SE implants than around MS implants ($P = .0422$). The present study also showed roughened implant surfaces to be beneficial for long-term peri-implant bony healing.[17,22,32–34,40]

Statistical analysis of the effects of implant position (mesial vs distal) on peri-implant bone loss showed more bone resorption around implants in mesial positions than around those in distal positions. This difference was highly significant ($P = .0001$), confirming earlier clinical reports.[39,41–44] Mailath and associates[45] and Carlsson and associates[43] stressed that, in view of the loading conditions known from biomechanical investigations, the most distal implants were more likely candidates for overloading and peri-implant bone loss. However, the clinical data available suggest that distal extension resulting in an anterior-posterior spread ratio of no more than

1:1.6, is well defined within the biologically tolerated loading range.[30] Eliasson and associates thought that the thinner wall of the alveolar process was a likely cause of more pronounced peri-implant bone resorption.[45] Further clinical studies of larger patient samples are needed to clarify this point.

Patient age and patient sex did not interact statistically with the mean marginal bone loss. This agrees with the results reported by Carlsson and associates[43] and Eliasson and associates.[44] As in the studies by Haas and coworkers[46] and Lindquist and coworkers,[47] nicotine use was also not significantly correlated with marginal peri-implant bone loss in the mandible. Based on a retrospective radiologic follow-up study of 421 patients with 1,366 implants, Haas and coworkers found significantly greater bone loss around maxillary implants in smokers but not around mandibular implants. The authors attributed these results to the small number of patients seen in follow-up. In the present study, the number of smokers was also small (8 of the 36 patients seen in follow-up).[46] The effects of nicotine use on peri-implant bone loss can only be interpreted in light of reported data.

CONCLUSION

This radiologic retrospective study of interforaminal implants showed the mean peri-implant bone loss around MS and SE implants to be within the range defined for implant success.[2,40] The marginal peri-implant bone loss around SE implants was significantly lower at 3 to 7 years of functional loading than that around MS implants. Mesial implants showed more peri-implant bone loss than distal implants. This difference was highly significant statistically ($P = .0001$). Nicotine use did not have a significantly negative effect on peri-implant bone loss around interforaminal mandibular implants.

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