# Immediate and Early Loading of Oxidized Tapered Implants in the Partially Edentulous Maxilla: A 1-Year Prospective Clinical, Radiographic, and Resonance Frequency Analysis Study

Kerstin Fischer, DDS;*† Mats Bäckström, DDS;* Lars Sennerby, DDS, PhD†

## ABSTRACT

*Background:* The use of immediate/early implant loading protocols offers obvious advantages for the patient. Although well documented in the totally edentulous mandible, information about clinical outcomes from such protocols in the partially edentate maxilla is lacking.

*Purpose:* The present study was conducted to clinically and radiographically evaluate a tapered implant design with an oxidized surface for immediate/early loading in the partially edentulous maxilla. The aim was also to correlate implant stability measurements using resonance frequency analysis (RFA) with implant diameter and length, bone quality and quantity, and marginal bone levels and marginal bone loss.

*Materials and Methods:* A total of 32 patients with a need of implant treatment in their partially edentulous maxilla were included in the study. A total of 53 Replace Select TiUnite™ implants (Nobel Biocare AB, Göteborg, Sweden) were used in the study; 16 for single tooth replacements in 16 patients and 37 implants for partial bridges in another 16 patients. The single tooth replacements were loaded the same day with a temporary crown, while permanent partial bridges were delivered within 16 days. Intraoral radiographs were taken at surgery and after 1 year for marginal bone measurements. RFA measurements were performed at baseline and after 3, 6, and 12 months.

*Results:* One implant used for a single tooth replacement failed, giving an overall survival rate of 98.1% after 1 year. On average, 1.1 mm (SD 1.0) bone was lost during 1 year; 1.5 mm (SD 1.0) in single tooth and 0.9 mm (SD 1.0) in partial cases. The implant stability increased with time from 63.3 implant stability quotient (ISQ) (SD 6.1) at baseline to 64.3 (SD 5.3), 65.0 (SD 4.6), and 66.8 (SD 5.6) after 3, 6, and 12 months, respectively. The average change from baseline to 1 year was 3.3 ISQ (SD 5.0) and was statistically significant ($p < .05$). There was no difference between single and partial cases. Implant stability correlated with bone quantity and quality at implant sites, but not with marginal bone level measurements.

*Conclusions:* It is concluded that immediate/early loading can be used in the partially edentulous maxilla with good clinical and radiographic short-term outcomes. Implant stability at placement correlated with bone quantity and quality, and increased with time as measured with RFA, indicating a favorable bone tissue response to the loaded implants. Any correlations between RFA and marginal bone level measurements were not observed in the present study.

KEY WORDS: clinical study, dental implants, partially edentulous maxilla, radiography, resonance frequency analysis

An increasing number of published studies and reports on scientific meetings indicate that one-stage surgery and early/immediate loading of dental implants is a feasible concept for prosthetic rehabilitation of the edentulous patient.[1–3] However, in a review of the literature, Attard and Zarb[4] concluded that such procedures are well documented in the totally edentulous mandible, but that studies are still lacking on other

*Private practice, Falun, Sweden; †Department of Biomaterials, Institute for Surgical Sciences, Göteborg University, Göteborg, Sweden

Reprint requests: Dr. Kerstin Fischer, Strandvägen 54, S-791 42 Falun, Sweden; e-mail: kerstin.fischer@swipnet.se



DOI 10.1111/j.1708-8208.2008.00096.x

indications, although promising outcomes have been reported.

In the past, most investigators used implants with a machined, minimally rough surface which, in good bone qualities, seems to result in similar high survival rates as previously reported for two-stage procedures. However, with this implant surface, the clinical documentation also points to an increased risk of failure in certain situations: (1) soft bone,[5,6] (2) occlusal loading,[5] (3) single tooth replacements,[6–8] and (4) implants placed in extraction sockets.[6,9] The data indicate that impaired biomechanics, that is, low degree of stability and high relative loading, may lead to failure, at least with the machined surface.

The use of resonance frequency analysis (RFA) has been suggested for identification of implants/patients suitable for immediate loading.[3,10–13] Östman and colleagues[3,13] used a primary stability value of 60 implant stability quotient (ISQ) as a threshold value for immediate loading. Glauser and colleagues[11] demonstrated a continuous decrease of stability until clinical failure for immediately loaded implants that were lost during 1 year in function, in spite of high primary stability. In a dog model, Sennerby and colleagues[14] demonstrated a correlation between marginal bone loss and implant stability. Together, these findings indicate that repeated measurements of implant stability during clinical function may be used to identify implants at risk for failure.

It is well known from experimental research that modification of the implant surface by, for instance, blasting, etching, spraying, anodic oxidation, or combinations of techniques, results in more bone–implant contacts and a higher resistance to removal torque than machined control implants.[15–17] It seems like the rough surface results in a firm contact with the blood clot, which in turn allows for migration and differentiation of precursor osteogenic cells which form bone directly at the implant surface.[18,19] The surface irregularities also create a strong interlock between the implant and bone, which explains the high resistance to removal torque forces. Anodic oxidation of titanium results in an increased thickness of the native oxide layer and the formation of a porous surface structure.[20–22] Animal research and histology of clinically retrieved microimplants have demonstrated a more rapid and stronger bone response to oxidized implants than to machined control implants.[23–27] However, the impact of implant surface modification on the clinical outcome of immediate/early loading is not fully known because comparative studies are few. Fröberg and colleagues[28] compared machined and oxidized implants when used for immediate loading with a fixed provisional bridge in the mandible and found no differences. Rocci and colleagues[21] reported a 10% higher failure rate for machined than for oxidized implants when used for immediate loading in the posterior mandible, which corroborates with the findings of Schincaglia and colleagues.[29] Similarly, Glauser and colleagues[5,30] reported markedly higher failure rates for machined (17.2%) than for oxidized (3%) after 1 year when used for immediate loading in all regions of the jaws. The data indicate that surface-modified implants may perform better in challenging situations such as soft bone and in partially edentulous patients. Noncomparative studies using surface-modified implants confirm high survival rates also in partially edentulous jaws including single tooth replacements.[31–33]

We have earlier shown the possibility of early loading in the totally edentulous maxilla using SLA implants.[34] The results support the idea that surface-modified implants may be used for early loading protocols also in softer bone densities. The results encourage to expand the indication of immediate or early loading also to the partially edentulous maxilla.

The present study was conducted to clinically and radiographically evaluate a tapered implant design with an oxidized surface for immediate/early loading in the partially edentulous maxilla. The aim was also to correlate implant stability measurements using RFA with implant diameter and length, bone quality and quantity, and marginal bone levels and marginal bone loss.

## MATERIALS AND METHODS

### Study Groups

A total of 32 patients with a need of implant treatment in their partially edentulous maxilla were included in the study: 16 patients (nine women and seven men, mean age 54 years, range 30 to 80 years) with single tooth loss and 16 patients (nine women and seven men, mean age of 65 years, range 52 to 81 years) lacking two or more teeth. The protocol for the study was approved by the Ethics Committee at Medical Faculty, Uppsala University, Sweden, and informed consent was obtained. Patients were enrolled in the study from June 2003 to May 2005. The patients were included if general and local health permitted oral surgery and a sufficient

**TABLE 1 Implant Diameters and Lengths Used in the Study**

| | | Single Implants ($n = 16$) | | Partial Bridges ($n = 16$) | |
|---|---|---|---|---|---|
| Diameter (mm) | Length (mm) | Placed | Failed | Placed | Failed |
| 5.0 | 10 | 1 | 0 | 5 | 0 |
| 5.0 | 13 | 2 | 1 | 2 | 0 |
| 5.0 | 16 | 0 | 0 | 1 | 0 |
| 4.3 | 10 | 1 | 0 | 5 | 0 |
| 4.3 | 13 | 7 | 0 | 12 | 0 |
| 4.3 | 16 | 5 | 0 | 12 | 0 |
| Total | | 16 | 1 | 37 | 0 |

amount of bone was available for at least 10 mm implants as judged from clinical and radiographical examinations including panoramic and intraoral radiographs.

## Surgical Procedure

Surgery was performed by one surgeon (K.F.). Prophylactic antibiotics were provided by administration of 3 g of amoxicillin (Amimox®, Tika Läkemedel AB, Lund, Sweden) orally 1 hour prior to surgery. Local anesthesia was induced by infiltration of lidocaine (Xylocaine®–Adrenaline, AstraZeneca, Södertälje, Sweden). The site was exposed via a crestal incision and raising of mucoperiosteal flaps. A total of 53 Replace Select TiUnite™ implants (Nobel Biocare AB, Göteborg, Sweden) were used in the study: 16 for single tooth replacements and 37 for partial bridges. The implants were placed according to instructions and drill sequences recommended by the manufacturer. The implants were placed with machine, and final tightening was made with a manual wrench with an insertion torque of at least 32 Ncm. Implant lengths and diameters are presented in Table 1. Implant sites were recorded according to tooth position (Figure 1). Bone quality and quantity were determined according to Lekholm and Zarb's criteria[35] (Table 2). The implants were provided with sterile impression copings before suturing the mucoperiosteal flap.

## Prosthetic Procedures

One dentist (M.B.) performed all the prosthodontic treatments. Immediately after surgery, impressions (Impregum Penta®, 3M ESPE Dental AG, Seefeld, Germany) of the implant and opposing jaw and a bite registration were taken. Healing abutments were placed on the implant. Provisional crowns or bridges were fabricated by a dental laboratory. The single crowns were delivered within 6 hours and placed in light occlusion and with light interapproximal contacts and articulation to minimize lateral forces. After mean 3 months and 10 days (range 2 months and 27 days to 4 months and 15 days), a permanent crown made on a GoldAdapt® abutment (Nobel Biocare AB) was delivered from the laboratory. For partial bridges, the final construction was delivered after an average 16 days (range 14 to 24 days). All crowns and bridges were screw-retained and were tightened to 35 Ncm using a torque controller (Nobel

**TABLE 2 Bone Quality and Quantity at Implant Sites for (A) Single Implants and (B) Partial Bridges According to Lekholm and Zarb**

A

| Quality | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Implants | – | 9 | 6 | 1 (1) |

| Quantity | A | B | C | D | E |
|---|---|---|---|---|---|
| Implants | – | 5 | 10 (1) | 1 | – |

$n = 16$. Failure within brackets.

B

| Quality | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Implants | 1 | 20 | 14 | 2 |

| Quantity | A | B | C | D | E |
|---|---|---|---|---|---|
| Implants | – | 12 | 14 | 11 | – |

$n = 37$.

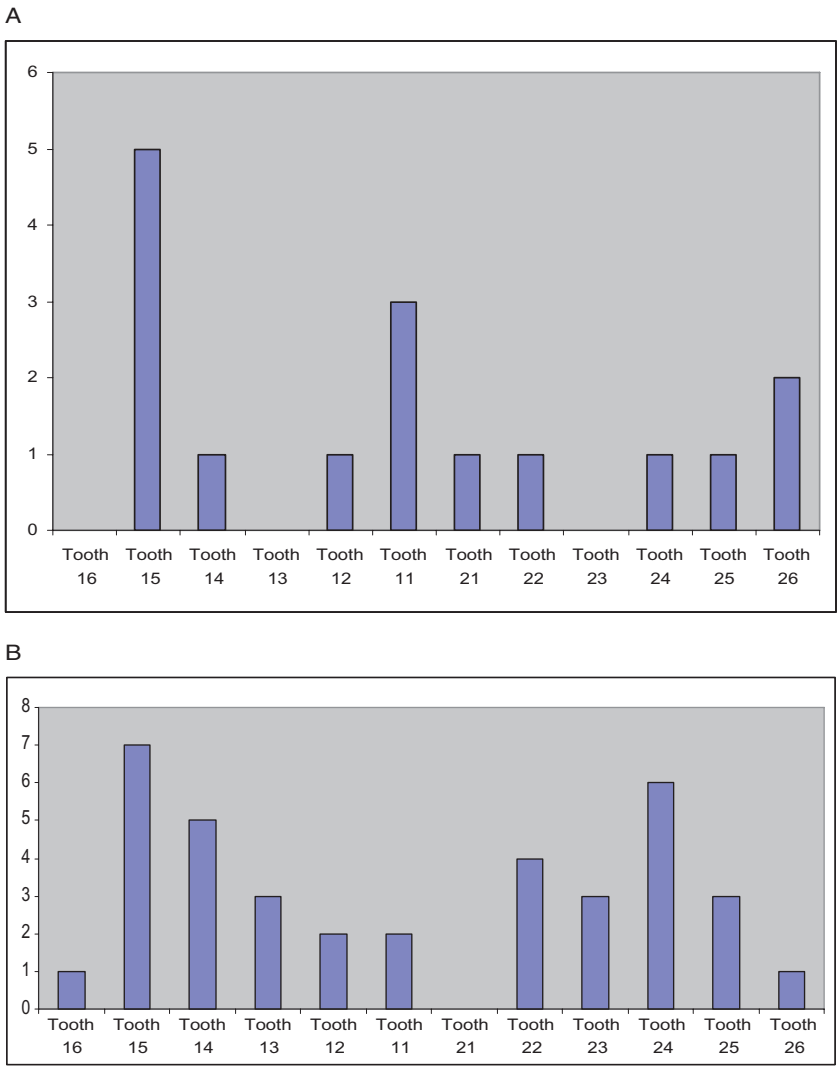


**Figure 1** *A*, Number and position of single-tooth implants in the maxilla. *B*, Number and position of implants used for partial bridges I in the maxilla.

Biocare AB). The screw holes were closed with a silicon plug and composite filling.

## Radiographic Examination

Radiographic examinations were executed at implant placement, at installation of the permanent crown (single tooth group), and at 12 months follow-up. Intraoral digital films (Digora, Soredex, Helsinki, Finland) were exposed with a paralleling technique so that the cervical implant threads were visible. Marginal bone level was measured by an independent specialist in oral radiology.

## Implant Stability

During surgery, the primary implant stability was subjectively graded as 1 = poor, 2 = good, or 3 = excellent by the surgeon. In addition, the stability of each implant was measured in ISQ units by RFA. Measurements were taken at implant placement; at installation of permanent crown (single tooth group); and after 3, 6, and 12 months of loading. At these occasions, the crown/bridge was removed and a transducer (type F13L5) was attached in a buccal-lingual direction, perpendicular to the bone. Only those measurements that exhibited graphs with a distinct resonance peak were included and analyzed.

## Statistics

The Wilcoxon signed rank test was used for paired evaluations of possible changes of implant stability and marginal bone level with time. The Spearman

correlation test was used to find possible correlations between implant stability and other parameters such as implant length and diameter, bone quality and quantity, marginal bone levels, and loss of marginal bone. Moreover, RFA data were divided into quartiles where the values of the first (25% lowest values) and fourth (25% highest values) quartiles were analyzed with the Wilcoxon rank sum test for unpaired observations. A statistically significant change, difference, or correlation was considered if $p < .05$.

## RESULTS

### Clinical Findings

One implant was lost during 1 year in function giving an overall survival rate of 98.1%. The failed implant belonged to the single tooth group which showed a survival rate of 93.8%, while the partial group showed a survival rate of 100%. The failed implant was placed in quality 4 bone in the right second premolar region with poor primary stability (ISQ 56). The implant was found mobile and was removed 7 weeks after installation. The patient was successfully reoperated and withdrawn from the study.

### Radiographic Findings

Radiographic measurements could be made at 48 implants at baseline and after 1 year. For all implants, the marginal bone level was located 0.7 mm (SD 1.1) above the reference point at baseline and 0.5 mm (SD 1.2) below after 1 year in function (Table 3). On average, 1.1 mm (SD 1.0) bone was lost during 1 year. For single tooth replacements, the marginal bone level was situated 0.5 mm (SD 0.7) above the reference point at baseline and 1.0 mm (SD 0.9) below after 1 year. The corresponding values for implants in partial cases were 0.7 mm (SD 1.1) and 0.2 (SD 1.2) at baseline and 1 year, respectively (see Table 3). Thus, the average marginal bone loss amounted to 1.5 mm (SD 1.0) and 0.9 mm (SD 1.0) for single tooth and partial cases, respectively, during the first year. The change was statistically significant ($p < .001$).

The proportions of implants showing more than 2 mm bone loss after 1 year were 18% (all implants), 25% (single), and 14.7% (partial). The corresponding proportions of implants showing more than 3 mm resorption were 6% (all implants), 6.3% (single), and 5.9% (partial).

**TABLE 3 Marginal Bone Levels and Bone Loss for Immediately or Early Loaded Replace Select Tapered Implants in the Maxilla when Used for Single Tooth Replacements or Partial Bridges**

| | Single | Partial | All |
|---|---|---|---|
| Bone level baseline | 0.5 (0.7) | 0.7 (1.1) | 0.7 (1.1) |
| Bone level 1 year | –1.0 (0.9) | –0.2 (1.2) | –0.5 (1.2) |
| Mean bone loss | –1.5 (1.0) | –0.9 (1.0) | –1.1 (1.0) |
| >2 mm | 25% | 14.7% | 18% |
| >3 mm | 6.3% | 5.9% | 6% |

### RFA Findings

The implant stability increased with time as measured with RFA with no differences between single and partial implants (Figure 2). For all implants, measurements showed a mean ISQ value of 63.3 (SD 6.1) at baseline, and 64.3 (SD 5.3), 65.0 (SD 4.6), and 66.8 (SD 5.6) after 3, 6, and 12 months, respectively. The average change from baseline to 1 year was 3.3 ISQ (SD 5.0) and was statistically significant ($p < .05$).

### Correlations

Statistically significant correlations were found between primary stability and bone quantity ($p < .05$) and quality ($p < .05$), but implant length and diameter did not correlate with stability. No correlations between marginal bone levels and ISQ values could be found for baseline and 1 year data. There was no correlation between change of ISQ and loss of marginal bone. Also, the quartile analyses failed to show any statistically significant differences in marginal level or bone loss (Table 4).

## DISCUSSION

The present study showed that oxidized tapered implants placed in the maxilla to support single crowns or partial bridges can be loaded immediately after surgery or within 16 days with good results after 1 year of loading. Only one of 53 implants failed during 1 year of loading, giving a survival rate of 93.8% for the single implant group and 100% for the partial bridge group. In a previous study, 33 implants of the present tapered design were placed together with 90 parallel-walled implants in totally edentulous maxillae for immediate loading.[3] After 1 year of loading, one (3%) of the tapered and none of the parallel-walled implants were lost.

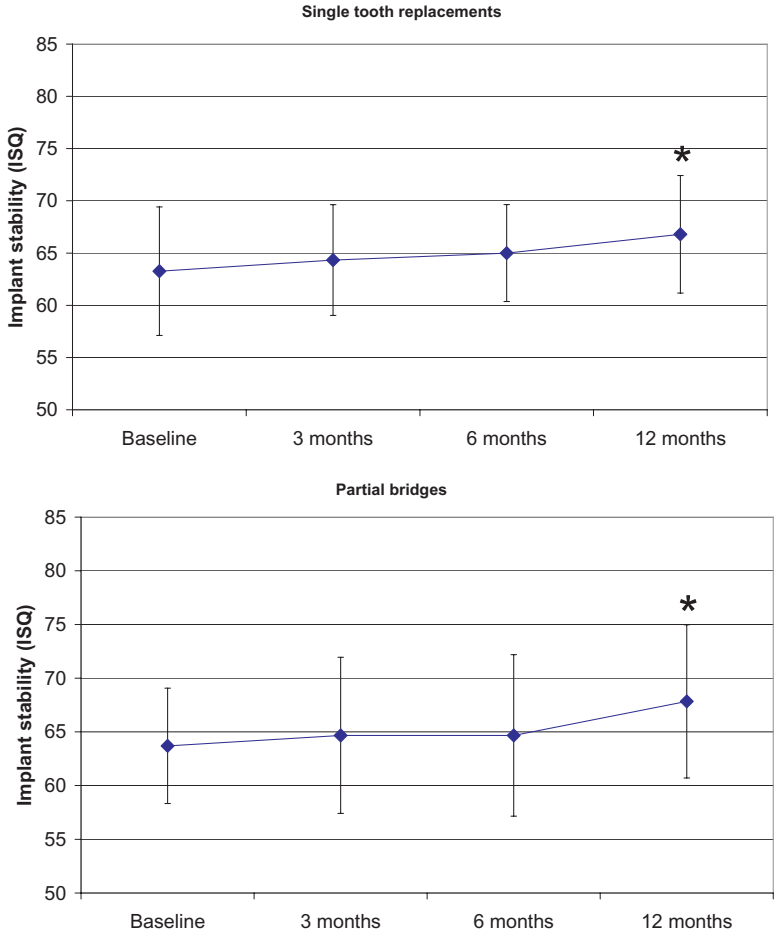


**Figure 2** Results from resonance frequency analysis measurements, mean (SD). *$p < .05$ compared with baseline.

However, the results from marginal bone height measurements were not reported separately for the implant designs. Achilli and colleagues[36] evaluated 120 oxidized tapered implants where 32 were placed in the maxilla. The implants were loaded with fixed partial bridges within 24 hours or 6 weeks. No implant failures were reported. Rao and Benzi[37] followed 51 tapered implants used for single molar replacements in the mandible and lost no implants during 1 year of loading. Other authors have used similar implant designs but with hydroxyapatite-coated surface, and reported survival rates from 89.3 to 100% when used for single tooth replacements.[38–42] In the present study, no implant was lost when used for partial bridges, which agrees with the results of Kan and Rungcharassaeng[43] who followed 14 implants in six patients with a similar design as in the present study. Recently, Ostman and colleagues[44] and Albrektsson and colleagues[45] reported failure rates of 5.2 and 11.8% with immediately loaded one-piece implants with the same surface and geometry as of the bone-integrated part in the present study. The reason for the poor results may be attributed to this particular concept with the use of a one-piece implant, flap-less surgery, in situ high-speed grinding, and a rough oxidized surface in contact with the mucosa. Parallel-walled implants with the same oxidized surface as in the present study have been previously used for immediate loading with similar good outcome as in the present study.[3,6,30,46–49]

The average marginal bone resorption was 1.1 mm for implants during 1 year in the present study, which is in line with previous reports on the same[36,37] and other implant designs.[50] Three implants (6%) showed more than 3 mm of bone loss after 1 year, which is slightly more than previously reported for oxidized parallel-walled implants.[13,51] The bone level was on average situated some 0.5 mm below the reference point after 1 year which is above the first thread (Figures 3 and 4). Because this implant has a 1.5 mm high smooth collar, it is not surprising that this part did not become bone integrated, which is in accordance with the experiences from

**TABLE 4 Quartile Analyses of Resonance Frequency Analysis and Marginal Bone Measurements**

| | ISQ at Placement | | |
|---|---|---|---|
| | Q1 | Q4 | Statistics |
| Mean bone loss mm (SD) | –1.2 (0.8) | –1.2 (1.2) | ns |
| Bone level, 1 year mm (SD) | –0.6 (1.2) | –0.3 (1.4) | ns |
| | **ISQ at 12 Months** | | |
| | Q1 | Q4 | Statistics |
| Mean bone loss mm (SD) | –1.0 (0.5) | –1.0 (0.8) | ns |
| Bone level, 1 year mm (SD) | –0.8 (1.1) | –0.7(1.4) | ns |
| | **Change of ISQ** | | |
| | Q1 | Q4 | Statistics |
| Mean bone loss mm (SD) | –1.6 (1.5) | –1.0 (0.7) | ns |
| Bone level, 1 year mm (SD) | –0.5 (1.8) | –0.5(1.2) | ns |

Q1 represents the 25% of implants with the lowest ISQ values, and Q4 the 25% of implants with the highest ISQ values at placement after 12 months, and the change from placement to 12 months.
ISQ = implant stability quotient; ns = not significant.

a previous Brånemark® implant design with a 3.5 mm tapered collar.[52] It has been suggested that some surface roughness is needed to better maintain the marginal bone. However, Ostman and colleagues[44] reported on extensive marginal bone resorption at one-piece implants with the same thread geometry and surface as in the present study, but with an oxidized surface all the way up, facing both bone and soft tissue. According to the manufacturer, this implant was designed to minimize marginal bone resorption because of the absence of an abutment/implant junction microgap and presence of the rough surface for bone and soft tissue integration. However, Ostman and colleagues[44] reported a mean bone loss of 2.1 mm after 1 year with 20% of the implants showing more than 3 mm of loss. Considering that the studied implant was designed to minimize bone resorption, these data are alarmingly poor. Finne and colleagues[46] performed marginal bone level measurements and concluded that the implants performed well. However, bone loss was not reported. Astrand and colleagues[53] compared the marginal bone response to surface-modified Astra Tech® and machined Brånemark implants during 5 years, and no differences between the two types of implants were observed. Also, the Astra Tech implants showed an initial bone loss around the implant collar, in spite of the rough surface topography. Also, Wennstrom and colleagues[54] found no differences between implants with smooth or rough implant collars. Novel designs of implants have macroscopical modifications of the collar with, for instance, micro-threads which may facilitate to maintain the marginal bone level as demonstrated by Shin and colleagues.[55]

Previous studies using two-stage techniques have shown high failure rates in soft bone.[56,57] The assessment of primary stability is therefore of importance for the prognosis of implant treatment and especially in immediate loading. Primary implant stability is determined by

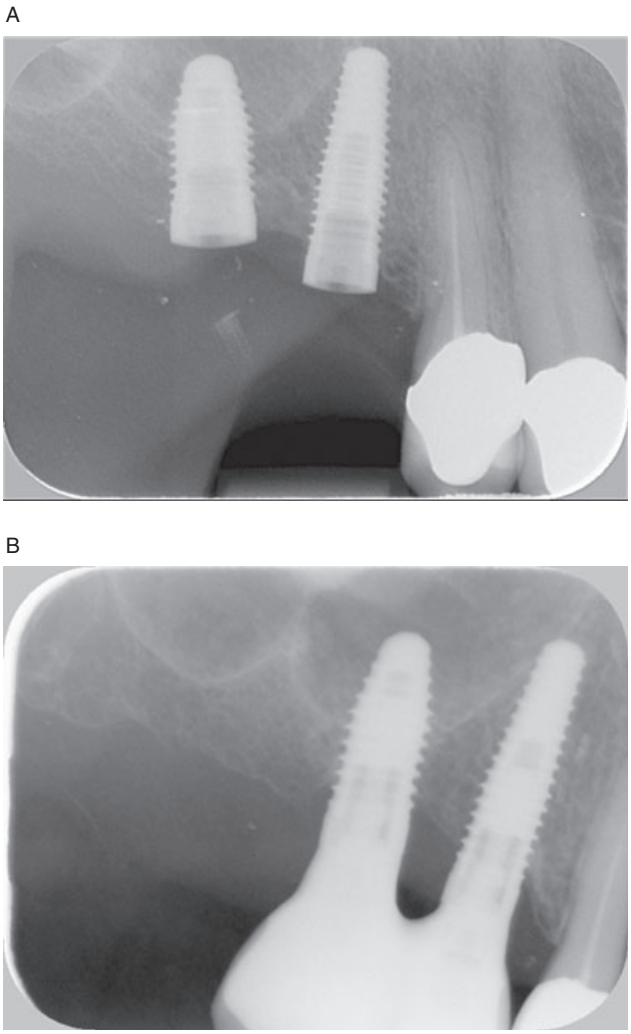


**Figure 3** Radiographs from a patient treated with two implants in the posterior maxilla (A) at surgery and (B) at the 1-year follow-up showing bone remodelling to the first thread.

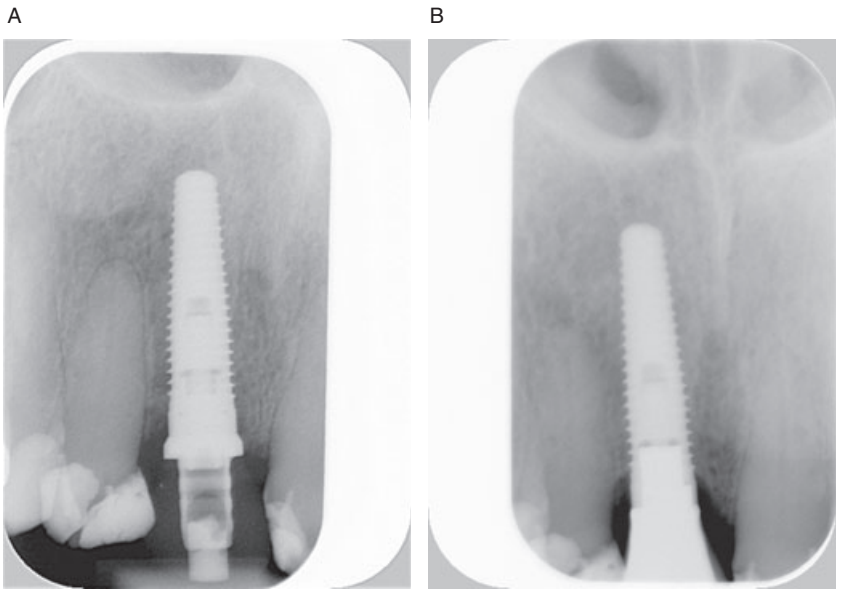


**Figure 4** Radiographs from a patient treated with one implant in the anterior maxilla (A) at surgery and (B) at the 1-year follow-up showing bone remodelling to the first thread.

the bone density, implant design, and surgical technique.[10] The bone density has commonly been assessed in a subjective manner by the surgeon during implant placement according to the Lekholm and Zarb index.[35] Several objective measurement techniques are available today such as resonance frequency measurement (RFA), Periotest, and insertion torque measurements. Alsaadi and colleagues[58] found that the subjective assessment of bone quality correlated well with the results from RFA, Periotest value, and placement torque measurement at implant insertion. In a clinical study, Östman and colleagues[12] found a correlation between RFA values and bone density, which indicates that the subjective assessment of bone density according to the Lekholm and Zarb index is useful. Also in the present study, a significant correlation between RFA at placement and bone quantity/quality could be established.

More recent follow-up studies have shown good results as also in soft bone.[59,60] This may be the result of modified surgical techniques, that is, the use of self-tapping implants, tapered implants, and reduced final drill diameters. Astrand and colleagues[61] showed no differences in survival rate and marginal bone level changes when comparing tapered Brånemark system Mark IV implants and standard Brånemark Mark II implants, both with a machined surface. However, Astrand and colleagues stated that compared to earlier results of Brånemark implants placed in soft bone, the Mark IV implant demonstrated an improved survival rate. It may also be attributed to the development of new implant surfaces as implants with a moderately rough surface integrate more rapidly than machined controls.[23–27] In the present study, one of 16 implants was placed in low bone quality, class IV, and this implant was lost. At surgery, the subjective primary stability of this implant was graded as poor and a low ISQ value was obtained, although not representing the lowest value of all implants. In a study on immediately loaded implants, Glauser and colleagues[11] showed that failing implants showed a continuous decrease of stability until failure. Low RFA levels after 1 and 2 months seemed to indicate an increased risk for future failure. In the present study, the implant was mobile 7 weeks after surgery when no RFA value was possible to obtain. The remaining implants in the present study were clinically successful and showed small stability changes over time. Huwiler and colleagues[62] observed that a decrease of RFA occurred after the implant stability was lost and concluded that no predictive value for loosing implant stability can be attributed to RFA.

Veltri and colleagues[63] have shown that the transducer orientation influences the measurements. In this study, the RFA measurements have been standardized with the transducer orientated in a buccal-palatal direction. Östman and colleagues[12] found higher ISQ values in men compared with women, in mandibles compared

with maxillae, in posterior compared with anterior sites, and for wide-platform implants in comparison with regular/narrow-platform implants. Sennerby and colleagues[14] found, when comparing smooth (turned) and roughened (SLA) surfaces, a linear relationship between radiographic and RFA findings because of loss of marginal bone and decrease in implant stability. There was a tendency of more bone loss for implants showing the greatest loss of stability with time, but this could not be verified with statistical tests. In fact, no correlations between marginal bone levels and ISQ values could be found in the present study.

The type and magnitude of loading are probably of importance for the outcome of immediate loading. It is important to assess in which way the implants in various studies have been subjected to loading and whether centric and excursive contacts have been relieved or not. In a recent study of Hall and colleagues,[64] single-tapered implants in the anterior maxilla were restored either within 4 hours or after 26 weeks with a provisional screw-retained crown out of occlusion. After 1 year, no difference in clinical outcome for the two groups was found. Norton[65] investigated 25 patients treated with immediately restored maxillary single-tooth implants with nonfunctional esthetic provisional restorations. The survival rate was 96.4%. Glauser and colleagues[5] reported that parafunction was one major risk factor for implant losses when using an immediate loading protocol. They also found that implants placed in the posterior maxilla were less successful than implants placed in other regions. Thus, the combination low bone density and presumably low implant stability and extensive loading should be avoided. In a retrospective study, Hultin and colleagues[66] suggested the use of wide-diameter and implants longer than 8.5 mm implants to better counteract high masticatory load and lateral forces. In the present study, all implants were 4.3 or 5.0 mm in diameter and with lengths of 10 to 16 mm.

It is concluded that immediate/early loading can be used in the partially edentulous maxilla with good clinical and radiographic short-term outcomes. Implant stability at placement correlated with bone quantity and quality, and increased with time as measured with RFA, indicates a favorable bone tissue response to the loaded implants. Any correlations between RFA and marginal bone level measurements were not observed in the present study.

## REFERENCES


1. Chee W, Jivraj S. Efficiency of immediately loaded mandibular full-arch implant restorations. Clin Implant Dent Relat Res 2003; 5:52–56.
2. Bergkvist G, Sahlholm S, Karlsson U, Nilner K, Lindh C. Immediately loaded implants supporting fixed prostheses in the edentulous maxilla: a preliminary clinical and radiologic report. Int J Oral Maxillofac Implants 2005; 20:399–405.
3. Östman PO, Hellman M, Sennerby L. Direct implant loading in the edentulous maxilla using a bone density-adapted surgical protocol and primary implant stability criteria for inclusion. Clin Implant Dent Relat Res 2005; 7:s60–69.
4. Attard NJ, Zarb GA. Immediate and early implant loading protocols: a literature review of clinical studies. J Prosthet Dent 2005; 94:242–258.
5. Glauser R, Ree A, Lundgren A, Gottlow J, Hammerle CH, Scharer P. Immediate occlusal loading of Branemark implants applied in various jawbone regions: a prospective, 1-year clinical study. Clin Implant Dent Relat Res 2001; 3:204–213.
6. Rocci A, Martignoni M, Gottlow J. Immediate loading of Branemark system TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003; 5(Suppl 1):57–63.
7. Ericsson I, Nilson H, Lindh T, Nilner K, Randow K. Immediate functional loading of Branemark single tooth implants. An 18 months' clinical pilot follow-up study. Clin Oral Implants Res 2000; 11:26–33.
8. Maló P, Rangert B, Dvärsäter L. Immediate function of Brånemark implants in the esthetic zone: a retrospective clinical study with 6 months to 4 years of follow-up. Clin Implant Dent Relat Res 2000; 2:138–146.
9. De Bruyn H, Collaert B. Early loading of machined-surface Branemark implants in completely edentulous mandibles: healed bone versus fresh extraction sites. Clin Implant Dent Relat Res 2002; 4:136–142.
10. Sennerby L, Meredith N. Resonance frequency analysis: measuring implant stability and osseointegration. Compend Contin Educ Dent 1998; 19:493–498.
11. Glauser R, Sennerby L, Meredith N, et al. Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading. Successful vs. failing implants. Clin Oral Implants Res 2004; 15:428–434.
12. Östman P-O, Hellman M, Wendelhag I, Sennerby L. Resonance frequency analysis measurements of implants at placement surgery. Int J Prosthodont 2006; 19:77–83.
13. Östman PO, Hellman M, Sennerby L. Immediate occlusal loading of implants in the partially edentate mandible. A prospective 1-year radiographic and 4-year clinical study. Int J Oral Maxillofac Implants 2008. (In press)
14. Sennerby L, Persson LG, Berglundh T, Wennerberg A, Lindhe J. Implant stability during initiation and resolution

of experimental peri-implantitis: an experimental study in the dog. Clin Implant Dent Relat Res 2005; 7:136–140.
15. Wennerberg A, Albrektsson T, Andersson B. Bone tissue response to commercially pure titanium implants blasted with fine and coarse particles of aluminum oxide. Int J Oral Maxillofac Implants 1996; 11:38–45.
16. Buser D, Nydegger T, Oaxland T, et al. Interface shear strength of titanium implants with a sandblasted and acid-etched surface: a biomechanical study in the maxilla of miniature pigs. J Biomed Mater Res 1999; 45:75–83.
17. Ellingsen JE, Johansson C, Wennerberg A, Holmén A. Improved retention and bone-to-implant contact with fluoride-modified titanium implants. Int J Oral Maxillofac Implants 2004; 19:659–666.
18. Davies JE, Hosseini MM. Histodynamics of endosseous wound healing. In: Davies JE, ed. Bone engineering. Toronto, Canada: Em Squared Incorporated, 2001:1–15.
19. Buser D, Broggini N, Wieland M, et al. Enhanced bone apposition to a chemically modified SLA titanium surface. J Dent Res 2004; 83:529–533.
20. Hall J, Lausmaa J. Properties of a new porous oxide surface on titanium implants. Appl Osseointegration Res 2000; 1:5–8.
21. Rocci A, Martignoni M, Burgos PM, Gottlow J, Sennerby L. Histology of retrieved immediately and early loaded oxidized implants: light microscopic observations after 5 to 9 months of loading in the posterior mandible. Clin Implant Dent Relat Res 2003; 5(Suppl 1):88–98.
22. Schüpbach P, Glauser R, Rocci A, et al. The human bone-oxidized titanium implant interface: a light microscopic, scanning electron microscopic, back-scatter scanning electron microscopic, and energy-dispersive X-ray study of clinically retrieved dental implants. Clin Implant Dent Relat Res 2005; 7:S36–43.
23. Yuong-Taeg S, Johansson C, Jeong Y, Wennerberg A, Albrektsson T. Resonance frequency and removal torque analysis of implants with turned and anodized surface oxides. Clin Oral Implants Res 2002; 13:252–259.
24. Zechner W, Tangl S, Furst G, et al. Osseous healing characteristics of three different implant types. Clin Oral Implants Res 2003; 14:150–157.
25. Ivanoff CJ, Widmark G, Johansson C, Wennerberg A. Histologic evaluation of bone response to oxidized and turned titanium micro-implants in human jawbone. Int J Oral Maxillofac Implants 2003; 18:341–348.
26. Salata LA, Burgos PM, Rasmusson L, et al. Osseointegration of oxidized and turned implants in circumferential bone defects with and without adjunctive therapies: an experimental study on BMP-2 and autogenous bone graft in the dog mandible. Int J Oral Maxillofac Surg 2007; 36:62–71.
27. Palma VC, Magro-Filho O, de Oliveria JA, Lundgren S, Salata LA, Sennerby L. Bone reformation and implant integration following maxillary sinus membrane elevation: an experimental study in primates. Clin Implant Dent Relat Res 2006; 8:11–24.
28. Fröberg KK, Lindh C, Ericsson I. Immediate loading of Brånemark system implants: a comparison between TiUnite and turned implants placed in the anterior mandible. Clin Implant Dent Relat Res 2006; 4:187–197.
29. Schincaglia GP, Marzola P, Scapoli C, Scotti R. Immediate loading of dental impants supporting fixed partial dentures in the posterior mandible: a randomized controlled split-mouth study, machined versus titanium oxide implant surface. Int J Oral Maxillofac Implants 2007; 22(1):35–46.
30. Glauser R, Lundgren AK, Gottlow J, et al. Immediate occlusal loading of Branemark TiUnite implants placed predominantly in soft bone: 1-year results of a prospective clinical study. Clin Implant Dent Relat Res 2003; 5(Suppl 1):47–56.
31. Calandriello R, Tomatis M, Rangert B. Immediate functional loading of Brånemark System® implants with enhanced initial stability. A prospective 1- to 2-year clinical and radiographic study. Clin Implant Dent Relat Res 2003a; 5(Suppl 1):10–20.
32. Cornelini R, Cangini F, Covani U, Barone A, Buser D. Immediate loading of implants with 3-unit fixed partial dentures: a 12-month clinical study. Int J Oral Maxillofac Implants 2006; 21:914–918.
33. Bornstein M, Schmid B, Belser U, Lussi A, Buser D. Early loading of non-submerged titanium implants with sandblasted and acid-etched surface: 5-year results of a prospective study in partially edentulous patients. Clin Oral Implants Res 2005; 16:631–638.
34. Fischer K, Stenberg T. Three-year data from a randomized, controlled study of early loading of single stage dental implants supporting maxillary full-arch prostheses. Int J Oral Maxillofac Implants 2006; 21:245–252.
35. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark PI, Zarb GA, Albrektsson T, eds. Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago, IL: Quintessence, 1985:199–209.
36. Achilli A, Tura F, Euwe E. Immediate/early function with tapered implants supporting maxillary and mandibular posterior fixed partial dentures. Preliminary results of a prospective multicenter study. J Prosthet Dent 2007; 97:S52–S58.
37. Rao W, Benzi R. Single mandibular first molar implants with flapless guided surgery and immediate function: preliminary clinical and radiographic results of a prospective study. J Prosthet Dent 2007; 97:S3–S14.
38. Chaushu G, Chaushu S, Tzohar A, Dayan D. Immediate loading of single-tooth implants: immediate versus non-immediate implantation. A clinical report. Int J Oral Maxillofac Implants 2001; 16:267–272.

39. Groisman M, Frossard WM, Ferreira HMB, de Menezes Filho LM, Touati B. Single-tooth implants in the maxillary incisor region with immediate provisionalization: 2-year prospective study. Pract Proced Aesthet Dent 2003; 15:115–122.
40. Kan J, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. Int J Oral Maxillofac Implants 2003; 18:31–39.
41. Kirketerp P, Andersen JB, Urde G. Replacement of extracted anterior teeth by immediately loaded Replace Select HA-coated implants. A one-year follow-up of 35 patients. Appl Osseointegration Res 2002; 3:40–43.
42. Proussaefs P, Lozada J. Effects of immediate loading with threaded hydroxyapatite-coated root-form implants on single premolar replacements: a preliminary report. Int J Oral Maxillofac Implants 2002; 17:567–572.
43. Kan J, Rungcharassaeng K. Inter-implant papilla preservation in the esthetic zone; a report of 6 consecutive cases. Int J Periodontics Restorative Dent 2003; 23:249–259.
44. Ostman PO, Hellman M, Albrektsson T, Sennerby L. Direct loading of Nobel Direct and Nobel Perfect one-piece implants: a 1-year prospective clinical and radiographic study. Clin Oral Implants Res 2007; 18:409–418.
45. Albrektsson T, Gottlow J, Meirelles L, Ostman PO, Rocci A, Sennerby L. Survival of NobelDirect implants: an analysis of 550 consecutively placed implants at 18 different clinical centers. Clin Implant Dent Relat Res 2007; 9:65–70.
46. Finne K, Rompen E, Toljanic J. Clinical evaluation of a prospective multicenter study on 1-piece implants. part 1: marginal bone level evaluation after 1 year of follow-up. Int J Oral Maxillofac Implants 2007; 22:226–234.
47. Degidi M, Piattelli A, Gehrke P, Carinci F. Clinical outcome of 802 immediately loaded 2-stage submerged implants with a new grit-blasted and acid-etched surface: 12-month follow-up. Int J Oral Maxillofac Implants 2006; 21:763–768.
48. Vanden Bogaerde L, Rangert B, Wendelhag I. Immediate/early function of Branemark system TiUnite implants in fresh extraction sockets in maxillae and posterior mandibles: an 18-month prospective clinical study. Clin Implant Dent Relat Res 2005; 7(Suppl 1):S121–130.
49. Calandriello R, Tomatis M, Vallone R, Rangert B, Gottlow J. Immediate occlusal loading of single lower molars using Branemark system wide platform TiUnite implants: an interim report of a prospective open-ended clinical multicenter study. Clin Implant Dent Relat Res 2003; 5(Suppl 1):74–80.
50. Oh TJ, Yoon J, Misch CE, Wang HL. The causes of early implant bone loss: myth or science? J Periodontol 2002; 73:322–333.
51. Glauser R, Ruhstaller P, Windisch S, et al. Immediate occlusal loading of Branemark system TiUnite implants placed predominantly in soft bone: 4-year results of a prospective clinical study. Clin Implant Dent Relat Res 2005; 7(Suppl 1):S52–59.
52. Malevez C, Hermans M, Daelemans P. Marginal bone levels at Branemark system implants used for single tooth restoration. The influence of implant design and anatomical region. Clin Oral Implants Res 1996; 7:162–169.
53. Astrand P, Engquist B, Dahlgren S, Grondahl K, Engquist E, Feldmann H. Astra Tech and Branemark system implants: a 5-year prospective study of marginal bone reactions. Clin Oral Implants Res 2004; 15:413–420.
54. Wennstrom JL, Ekestubbe A, Grondahl K, Karlsson S, Lindhe J. Oral rehabilitation with implant-supported fixed partial dentures in periodontitis-susceptible subjects. A 5-year prospective study. J Clin Periodontol 2004; 31:713–724.
55. Shin YK, Han CH, Heo SJ, Kim S, Chun HJ. Radiographic evaluation of marginal bone level around implants with different neck designs after 1 year. Int J Oral Maxillofac Implants 2006; 21:789–794.
56. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Branemark dental implants: a study from stage 1 surgery to the connection of completed prostheses. Int J Oral Maxillofac Implants 1991; 6:142–146.
57. Jaffin RA, Berman CL. The excessive loss of Branemark fixtures in type IV bone. A five-year analysis. J Periodontol 1991; 62:2–4.
58. Alsaadi G, Quirynen M, Michiels K, Jacobs R, van Steenberghe D. A biomechanical assessment of the relation between the oral implant stability at insertion and subjective bone quality assessment. J Clin Periodontol 2007; 34:359–366.
59. Friberg B, Sennerby L, Meredith N, Lekholm U. A comparison between cutting torque and resonance frequency measurements of maxillary implants. A 20-month clinical study. Int J Oral Maxillofac Surg 1999; 28:297–303.
60. Bahat O. Branemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years. Int J Oral Maxillofac Implants 2000; 15:646–653.
61. Astrand P, Billstrom C, Feldmann H, et al. Tapered implants in jaws with soft bone quality: a clinical and radiographic 1-year study of the Branemark system Mark IV fixture. Clin Implant Dent Relat Res 2003; 5:213–218.
62. Huwiler MA, Pjetursson BE, Bosshardt DD, Salvi GE, Lang NP. Resonance frequency analysis in relation to jawbone characteristics and during early healing of implant installation. Clin Oral Implants Res 2007; 18:275–280.
63. Veltri M, Balleri P, Ferrari M. Influence of transducer orientation on Osstell stability measurements of osseointegrated implants. Clin Implant Dent Relat Res 2007; 9:60–64.
64. Hall JAG, Payne AGT, Purton DG, Dip Tech BTNH, Duncan WJ, De Silva RK. Immediately restored, single-tapered implants in the anterior maxilla: prosthodontic and aesthetic

outcomes after 1 year. Clin Implant Dent Relat Res 2007; 9:34–45.

65. Norton MR. A short-term clinical evaluation of immediately restored maxillary TiOblast single-tooth implants. Int J Oral Maxillofac Implants 2004; 19:274–281.
66. Hultin Mordenfeld M, Johansson A, Hedin M, Billström C, Arvidson Fyrberg C. A retrospective clinical study of wide-diameter implants used in posterior edentulous areas. Int J Oral Maxillofac Implants 2004; 19:387–392.