Immediate loading of Brånemark System® TiUnite™ and turned-surface implants in the anterior mandible

Kjell Krister Fröberg
ABSTRACT
The purpose of the present study was to compare the treatment outcome of TiUnite- and machined-surfaced Brånemark System implants when applying immediate loading of cross-arch designed FPDs in the anterior mandible.

Fifteen patients with edentulous mandibles participated in the study. In one half of the jaw, between the exit of the nerve-vessel bundle and the midline, one type of implants was placed and in the remaining half the other type. The implants were loaded the day of surgery via a fixed, temporary supra-construction (Schnitman et al. 1997). Ten days later the permanent one was screw retained to the implant pillars.

The present 18-month clinical trial failed to demonstrate any differences regarding healing and cumulative success rate of an an-oxidized implant surface (TiUnite) and a machined (turned) one when implants in the anterior mandible were exposed to functional load within 24 hours after installation.

In conclusion, a high predictability regarding the treatment outcome for immediately loaded Brånemark implants in the anterior mandible was observed. Furthermore, no difference between the traditional turned and the an-oxidized implant surface (TiUnite) could be observed. However, it has to be stressed that all implants (irrespective of surface) were placed in the
anterior mandible and also that all the patients demonstrated a high level of oral hygiene.

Key words:

Clinical study, Brånemark dental implants, immediate loading, rebuild denture, implant stability, machined – and an-oxidized implant surface.

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INTRODUCTION

In 1969 the original protocol for implant installation was described by Brånemark and collaborators.\(^1\) (Brånemark et al. 1969) The protocol recommended a 2-stage surgical procedure, i.e., a two-piece implant is used and the fixture is submerged during a 3-6-month healing period. Thereafter the abutment connection has to be performed, the supra-construction fabricated, and screw-retained to the implant pillars.\(^2\) (Zarb & Jansson 1985) In 1977, the follow-up results of the treatment outcome of 235 edentulous jaws (128 maxillas and 107 mandibles) were presented.\(^3\) (Brånemark et al. 1977) The observation period varied from 9 months to 8 years. The data reported revealed that 85% of all the supra-constructions installed were stable.

A high predictability of implant treatment has been demonstrated in long-term follow-up studies for edentulous (15 years)\(^4\) (Adell et al. 1990) as well as for partially dentate jaws.\(^5\)\(^-\)\(^6\) (Lekholm et al. 1994, 1999) Over the years a re-evaluation of the traditional Brånemark 2-stage protocol has occurred. Schroeder et al.\(^7\)\(^-\)\(^9\) (1976, 1978, 1983) have shown that it is possible to achieve predictable osseointegration even when using a 1-stage technique, i.e. that immediately following installation the implant pillar is exposed in the oral cavity. This observation has further been confirmed in animal studies using one-piece implants\(^10\)\(^-\)\(^13\) (Gotfredsen et al. 1991, Abrahamsson...

About 20 years ago it was stated that “premature load on implants leads to the formation of fibrous tissue instead of the formation of bone tissue [ontogenesis]” (Albrektsson et al. 1986). When implants are placed according to the one-stage protocol the implants most likely will be exposed to a certain load immediately following placement. Ericsson and associates (1997) concluded that “an initial and direct loading of implants piercing the mucosa via the adjusted and relined denture obviously does not jeopardize a proper osseointegration of the fixtures”. This statement is supported by observations reported by Henry & Rosenberg (1994), who stated that “controlled immediate loading of adequately installed, non-submerged implants, by reinsertion of a modified denture, does not appear
to jeopardize the process of osseointegration in the anterior mandible”.

Furthermore, Becker et al.\(^{19}\) (1997) have alleged that “one-step Brånemark implants may be considered a viable alternative to two-step implants”.

An important pre-requisite for obtaining a predictable healing process of implants (osseointegration) is that the so-called micro motion, i.e., the movement at the interface between the bone and the implant surface, is limited.\(^{30-33}\) (Cameron et al 1973, Brunski 1992, 1999, Pilliar 1995)

Søballe et al.\(^{34}\) (1993) have reported that the tissues involved probably will accept a micro motion amounting to 50 µm – 150 µm. Furthermore, Brunski\(^{32}\) (1999) has reported that micro motions of approximately 100 µm may constitute a threshold value for turned implant surfaces to osseointegrate properly.

Favourable loading conditions can be achieved for teeth connected to each other via a rigid FPD.\(^{35-36}\) (Glantz et al. 1984a, b). However, individual implant pillars installed according to the 1-staged surgical procedure are most likely unpredictably exposed to load immediately after installation. Therefore, it is reasonable to assume that implants have to be joined together via a rigid construction as soon as possible following placement. The micro motion at the interface between bone and implant surfaces will be limited and hopefully within an acceptable level thus facilitating the healing process (osseointegration). During the last years good and
predictable results of implant treatment have been reported when implants are exposed to early, functional load in the anterior mandible.\cite{Randow1999,Ericsson2000,Chow2001}. This treatment concept has been launched in Scandinavia as the “Nordic Bridge concept”.\cite{Ericsson2001}

Schnitman and co-workers (1997) reported on 63 Brånemark System implants placed in 10 patients. Out of these 63 implants, 28 were placed and ”immediately loaded to support an interim fixed bridge”. Out of these 28 implants 4 failed. The remaining 35 implants installed according to the original 2-stage protocol all osseointegrated properly. In other words, the survival rate for the immediately loaded implants was about 85 %.

However, it has to be emphasized that Schnitman et al. (1997) reported on a 10-year outcome. The survival rate for the submerged implants was 100 %. Furthermore, Balshi & Wolfinger (1997) applied a treatment approach for the edentulous mandible similar to that of Schnitman et al. (1997). They reported that 80 % (32 out of 40) of the immediately loaded Brânemark System implants survived over the observation period and concluded that their "preliminary results have been favorable, with all patients functioning with a fixed implant prosthesis from the day of first-stage surgery". Another treatment modality has recently been presented, namely the “Brânemark Novum concept”\cite{Brånemark1999}. “The new protocol involves
prefabricated components and surgical guides, elimination of the prosthetic impression procedure and attachment of the permanent bridge on the day of implant placement”. Fifty patients were followed 6 months to 3 years following completion of the rehabilitation. Three implants failed to integrate and 3 implants were lost during the observation period resulting in an overall survival rate of 98% and a prosthetic survival rate also of 98%. The average bone loss is in agreement with figures reported for the original protocol and “did not exceed 0.2 mm per year when calculated from the 3-month examination”. Furthermore, van Steenberghe et al. (2004) reported on 50 patients treated according to “Brånemark Novum concept” and followed during a 12-month period. The cumulative success rate for implants and prostheses was found to be 93% and 95%, respectively, thus supporting the data presented by Brånemark et al. (1999). Hatano (2001) presented the “Maxis New” another one-day treatment concept of the edentulous mandible using standard Brånemark System components and an individualized fixed dental bridge. The author concluded: “the treatment was successful in 35 patients followed for 2 to 36 months of loading”.

During the introduction of the osseointegration concept¹ (Brånemark et al. 1969) a great interest of the texture and condition of the implant surfaces was established. Implant surface can vary significantly depending on its preparation and handling.⁴⁴ (Kasemo et al. 1988) It is generally accepted that the outermost atomic layer of the implant surfaces is a key factor for the
osseointegration process. The cell-oxide interaction takes place over a few atomic distances; compositional changes occurring at that level could influence biocompatibility and healing. (Kasemo et al. 1985) Today, it is generally accepted that implants with a somewhat rough surface will i) facilitate to obtain initial stability, ii) enlarge the surface area (Wennerberg 1996), and iii) speed up the osseointegration process. (Larsson 2000, Schüpbach et al. 2005). Focus has thus been set on surface characteristics. (Karlsson et al. 1998, Cordioli et al. 2000, Gotfredsen et al. 2000, Gotfredsen & Karlsson 2001). In order to create such a surface you can e.g., blast or titanium-plasma-spray it or perform an anodic oxidation of the surface (Hall & Lausmaa). It has been shown that the bone-to-implant contact is higher for a TiUnite (an-oxidized) surface compared with a machined one. This observation is supported by human histological findings recently reported. (Rocci et al. 2002, Ivanoff et al. 2003, Schüpbach et al. 2005) This is possibly due to osteoconductive properties of the TiUnite surface.

The purpose of the present study was to compare the treatment outcome of TiUnite- and machined-surfaced Brånemark System implants when applying immediate loading of cross-arch designed FPDs in the anterior mandible.
MATERIAL AND METHODS

During 2001-2003, 15 patients with edentulous mandibles were consecutively collected to participate in the present study. Detailed information regarding gender and age is presented in Table 1.

Table 1. Gender and age distribution of patients.

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<td>Women (n=6)</td>
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The patients were pre-operatively examined clinically and radiographically. The examination protocol (including inclusion and exclusion criteria) used was in line with the recommendations presented by Lekholm, \(^\text{56}\) (2003) e.g. 1) systemic diseases resulting in increased risk of infections and impaired healing around the implants, 2) some serious cardiac diseases, 3) deficient homeostasis and blood dyscrasias, 4) anticoagulant medication, 5) psychological diseases, and 6) uncontrolled acute infections excluded patients from participating.

In the opposing jaw (the maxilla), 4 of the participating patients had their natural teeth remaining or a FPD supported by teeth, while 10 patients wore complete removable dentures (CD). The remaining one used a cross-arch designed implant supported bridge (IFPD) (Table 2).
Table 2. Condition of the maxillas.

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FPD = fixed partial denture, CD = complete denture, IFPD = implant supported fixed partial denture.

Six patients (2 women and 4 men) were smokers and were asked to terminate or decrease their smoking habits during a period of at least 2-3 weeks before as well as after the surgical implant session.

Before treatment clinical photos were taken. Furthermore, all patients were informed about the study design and accepted to participate. Finally, each patient has to sign a written consent.

**Surgical and Prosthetic Technique.**

The following antibiotic regimen was used: 3 gram Amoxicillin pre-operatively and thereafter 750 mg Amoxicillin twice a day during a 5-day period (Amoxicillin Scand Pharm, Stockholm, Sweden).

The surgical area was the anterior mandible between the exits of the nerve-vessel bundles. During surgery the exit of the nerve-vessel bundle (foramen mentale) was identified bilaterally, and the outline of the jaw, especially at the lingual aspect, was inspected. The implant sites were prepared in accordance with the classical step-by-step-protocol.⁵⁷ (Adell et al. 1985)
In one half of the mandible (between foramen mentale and the midline) 3 implants were installed supplied either with the turned-\(^{58}\) (Lausmaa et al. 1990) or the TiUnite\(^ {53}\) (Hall & Lausmaa 2000) surface with a diameter of 3.75 mm, (Brånemark System®, Mk III implants, Nobel Biocare AB, Göteborg, Sweden), (Figure 1). A total number of 89 (45 turned + 44 TiUnite) fixtures were placed.

Fig. 1 Left, Turned surface. Right, Ti-unite surface.

The “toss of a coin procedure” was used to select the half of the jaw where the 3 turned implants had to be placed. An identical surgical procedure was then performed in the corresponding contra lateral area of the mandible where the 3 TiUnite implants were placed. Because lack of space between foramen mentale and the midline one patient could only host 2 TiUnite fixtures. Following fixture placement, abutments (Multi Unit Abutments (MUA), Brånemark System®, Nobel Biocare AB, Göteborg, Sweden) were connected and tightened according to the manual. The length and type of implants are presented in Table 3.
<table>
<thead>
<tr>
<th>Length</th>
<th>Turned</th>
<th>TiUnite</th>
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<tr>
<td>13 mm</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>15 mm</td>
<td>38</td>
<td>40</td>
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<td>18 mm</td>
<td>2</td>
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<tr>
<td>Total=89</td>
<td>45</td>
<td>44</td>
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Resonance Frequency Assessments (RFA)\(^{60}\) (Meredith 1997) were recorded by means the Ostell® instrument (Integration Diagnostics, Göteborg, Sweden). The RFA, stiffness of the implant interfacial-bone complex, value was expressed with a numerical value between 0 – 100 (ISQ= Implant Stability Quotient).\(^{60}\) (Meredith 1997) RFA recordings were performed at abutment level on the day for implant installation.

Following proper adaptation and suturing of the mucoperiosteal flaps towards the mucosally piercing implant pillars an impression was taken by means of impression copings and a stiff impression material (e.g. Impregum®, 3M, Sollentuna, Sweden). In addition, a bite registration as well as an impression of the opposing jaw was taken.

A modification of the “Nordic Bridge” concept\(^{42}\) (Ericsson & Nilner 2002) was applied. Briefly, the original complete denture was rebuilt in such a way that it was possible to connect it to the implant pillars the day of
surgery.\textsuperscript{37-38} (Schnitman et al. 1990, 1997) Furthermore, at the same appointment a tooth set-up in wax for the permanent supra-construction was tried in. The permanent IFPD with a milled titanium framework (Procera Implant Bridge= PIB, Nobel Biocare AB, Göteborg, Sweden) was fabricated,\textsuperscript{2} (Zarb & Janson 1985) and connected to the implants 10 days following implant installation. At the same time, the sutures were removed, and the patients carefully instructed how to perform proper oral hygiene.

FOLLOW-UP EXAMINATIONS

\textit{Implant Stability}

The ISQ-value\textsuperscript{60} (Meredith 1997) was recorded at abutment level at the day of delivery of the permanent IFPD, and at every follow-up examination, i.e., 3, 6, 12, and 18 months later.

\textit{Peri-implant Mucosa}

The condition of the peri-implant mucosa surrounding the implant pillars was evaluated by means of the “Angulated Bleeding Index”\textsuperscript{61} (Van der Weijden 1994) at the time for delivery of the permanent IFPD and at every follow-up examination. Briefly, a probe was inserted into the crevice to a depth of approximately 2mm and then angulated about 45 degrees in relation to the long axis of the implant (Fig. 2). Thereafter the probe was moved gently along the marginal mucosa over a length of about 2 mm. This procedure was performed once at 4 different areas around the implant.
Presence or absence of bleeding within 30 seconds following probing was recorded. The evaluations were repeated 3, 6, 12, and 18 months later.

![Clinical photo illustrating the run of the probe when recording the “Angulated Bleeding Index”](image.png)

**Fig. 2.** Clinical photo illustrating the run of the probe when recording the “Angulated Bleeding Index”.

**Marginal Bone Level**

The marginal bone level was assessed in radiographs obtained at the delivery of the provisional IFPD, i.e., the day of surgery. This examination was repeated 18 months later.

The intra-oral radiographs were taken with a X-ray apparatus (Planmeca OY, 00810 Helsinki, Finland, Suomi, Type: Prostyle Intra 8 mA, 70 kV maximum 1800 AS/h.) supplied with a long cone and an “Eggen film holder”.\(^\text{62}\) (Eggen 1969) Kodak Ultraspeed film (Eastman, Kodak Co., Rochester, NY, USA) was used, and the radiographs were processed in a Durr Dental XR 24 Nova developing processor. A specialist in oral
radiology (CL) has evaluated the radiographs. The marginal bone level has been measured mesially and distally using the abutment-fixture junction (AFJ) as reference point. At each observation interval the distance between AFJ and the most apical level of the bone judged to be in contact with the fixture surface was measured.\textsuperscript{14-16} (Ericsson et al 1994, 1996, 1997) The distance was assessed using a lens with a magnification factor of 7 and increments of 0.1 mm.

\textit{Occlusal design}

The anatomy of the occlusal surfaces was documented by means of clinical photos. The overall design was flat intending the implants to be loaded as axially as possible and thus avoiding deflective forces to act during function.\textsuperscript{63} (Rangert & Renourd 2001)

\textit{Statistic analysis}

Differences between the implant types, change over time as well as at different time points, were analyzed with Wilcoxon Signed Rank test for paired analysis. The statistical tests were based on patient as the unit, i.e. means of all loaded implants in the right and left side of the jaw, respectively, were calculated per patient. Significance tests were two-tailed and conducted at the 5% significance level.
RESULTS

At the 18-month follow-up examination all 89 implants placed were in service and found to be clinically stable.

*ISQ Analysis/ Implant stability*

At any observation interval all implants showed absence of clinically detectable mobility by tapping the implant pillar. The ISQ-values are reported in Fig 3.

![Resonance Frequency](image)

Fig. 3 Dots and lines show mean values and standard error of means in implants with a TiUnite surface (n = 44) and a turned surface (n = 45), respectively. II, implant insertion; fFPD, final Fixed Partial Denture

No statistically significant difference could be detected between the 2 implant surfaces at any time (P>0.30).

*Radiographic analysis*

The analyses of the radiographs demonstrated absence of continuous radiolucency at assessed implant surfaces at any of the observations. The
marginal bone level was possible to assess at 100 implant surfaces. The amount of marginal bone remodelling is reported in Table 5. No significant differences were found regarding changes in marginal bone level between the 2 groups of implants during the entire follow-up period (P>0.30) (Table 5).

Table 5 Change in marginal bone level during 18 months after implant insertion.

**Turned Surface**

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<th></th>
<th>Change 0-12m</th>
<th>Change 0-18m</th>
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<tr>
<td></td>
<td>Mesial</td>
<td>Distal</td>
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<tr>
<td>Mean (mm)</td>
<td>0.81</td>
<td>0.41</td>
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<tr>
<td>SD (mm)</td>
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**TiUnite Surface**

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<th>Change 0-12m</th>
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<td></td>
<td>Mesial</td>
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<tr>
<td>Mean (mm)</td>
<td>0.89</td>
<td>0.77</td>
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<tr>
<td>SD (mm)</td>
<td>1.62</td>
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<td>n</td>
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**Peri-implant Mucosa**

In all patients, healing proceeded without complications and with minimal postoperative problems noticed for the patients. Absence of clinical peri-implant infection was observed at all sites. Irrespective of implant surface similar figures were recorded regarding “Bleeding on probing”, i.e. 15-25 % of the sites at every follow-up examination except when the permanent
IFPD was connected. At that moment more frequent bleeding was observed (60-75 %).

The clinical examinations as well as the interviewing of the patients revealed that all IFPDs had a proper function as well as an acceptable aesthetics (Fig. 4).
Fig. 4. Clinical appearance at delivery of permanent IFPD (10 days post op) compared to 18-month follow-up examination (a, b). The corresponding images without the prosthesis (c, d). The radiographic control at delivery of permanent IFPD compared to 18-month follow-up (e, f).
DISCUSSION

The present 18-month clinical trial failed to demonstrate any differences regarding healing and cumulative success rate of an an-oxidized implant surface (TiUnite) and a machined (turned) one when implants in the anterior mandible were exposed to functional load within 24 hours after installation. This observation is, without considering the differences regarding the implant surfaces, in agreement with findings reported by several teams. (e.g. Schnitman et al. 1990, 1997, Henry & Rosenberg.1994, Randow et al. 1999, Ericsson et al. 2000, Chow et al. 2001)

Implant surface quality is known to be one out several important factors to obtain osseointegration predictably (Albrektsson et al. 1981). Surface quality includes chemical, physical, mechanical, and topographical properties. The importance of the implant surface condition to facilitate proper osseointegration of the implant has to some extent been investigated over the years. (Steinemann et al. 1986, Lausmaa et al.1988, Binon et al 1992, Wennerberg 1996, Larsson 2000, Davis 1998. Rocci et al. 2003b, Schüpbach et al. 2005) Furthermore, experimental studies have demonstrated that implants with a roughened surface will result in a stronger bone anchorage compared to implants with a smoother surface. (Gotfredsen et al. 2000) It has also been observed that anodic oxidation of implants will result in an increased bone response (= bone-to-implant
contact, removal torque) compared to turned implants.\textsuperscript{70-71} (Albrektsson et al. 2000, Henry et al. 2001) However, it has to be realized that the present clinical trial did not allow us to perform any qualitative or quantitative evaluation regarding bone response towards the 2 surfaces used.

As no differences between the 2 groups of implants were observed it may indicate that the healing capacity of the bone in the anterior mandible is more important than the implant surface condition \textit{per se} to obtain proper osseointegration even when the implants are exposed to immediate loading. Such a hypothesis is supported by data reported by Rocci et al.\textsuperscript{23} (2003a) and Jungner et al.\textsuperscript{72} (2005) Both teams reported a higher success rate for implants with TiUnite surface than for the turned ones. Rocci and collaborators\textsuperscript{23} (2003) placed 66 Brånemark TiUnite implants in the posterior mandible and were immediately loaded via 24 partial FPDs. Corresponding figures for Brånemark machined implants were 55 and 22, respectively. The authors concluded that “the present study demonstrated a 10% higher success rate (95.5% vs 85.5%) following immediate loading of partial FPDs in the posterior mandible supported by TiUnite surface implants compared with success with machined implants”. Jungner et al.\textsuperscript{72} (2005) reported on 63 patients who had a 1-stage surgical session, out of who 24 were exposed to early functional loading. Remaining patients (73) participating in the study were treated according to the original 2-stage
protocol. A total number of 394 (199 TiUnite and 195 Machined) implants were installed. Both types of implants were placed in all 4 quadrants. The authors observed a 100 % success rate for the TiUnite implants during the observation interval, irrespective of position as well as surgical and loading protocol applied, while corresponding figures for the machined ones were 96.4 %.

In the present study, all 89 implants were found to be properly anchored and did not show any clinical mobility neither when placed nor at the delivery of the permanent IFPD or at the 3-, 6-, 12-, and 18-month follow-up examinations. In one of the patients the ISQ value was recorded to 48 at the delivery of the permanent IFPD (Table 4). However, during the observation interval the ISQ value for this particular implant increased to 59. Such an observation is in accordance with data reported by Meredith\textsuperscript{60} (1997) and Friberg et al.\textsuperscript{59,73} (1999) who concluded that an increase of ISQ value over time is generally more pronounced for implants with low ISQ value at placement. All remaining implants showed a high ISQ value (50-78) throughout the entire study.

Data from experimental studies reported by Rompen et al.\textsuperscript{74} (2000) and Zechner et al.\textsuperscript{75} (2003) revealed that the modification from a turned to a TiUnite surface enhances early bone response. Furthermore, an initial less decrease in ISQ value has been recorded for the TiUnite surface compared
with the turned one thus making the TiUnite surface more suitable to be exposed to immediate/early functional load.\(^{76-77}\) (Glauser et al. 2003, 2005)

Rompen and collaborators\(^{74}\) also stated that turned surfaces by time will end up with similar “permanent” ISQ values as for an-oxidized implants. However, in this respect our data could not find any difference between the 2 surfaces tested, most likely due to the design of the study.

The bone level measured at base line and 18 months after loading showed a slight reduction of bone, mean 0.60 - 0.89 mm, although there was a wide variation between implant surfaces, which also has been observed in other studies (Bergkvist et al., 2004). One explanation might be that the alveolar crest vary in thickness between regions as well as between patients, resulting in more or less extensive bone loss the first year after loading. However, no differences were found between the 2 groups of implants in this study.

The accuracy of measurements of the marginal bone level is influenced by the precision of the radiographic technique and the measurement technique used. It is very important that a parallel technique is used when obtaining the radiographs and the reason for excluding sites from measurements in this study was mostly because the projection was not parallel. Since marginal bone resorption of the alveolar crest in the anterior mandible may be so severe that film placement parallel to the implant is not only
extremely difficult but also very painful for the patient, it is sometimes very
difficult to use the paralleling technique.

Another reason making it impossible to perform measurements of the
marginal bone level is difficulties in identifying the reference points, both in
the alveolar bone and at the AFJ.

In conclusion, the present clinical study demonstrated a high predictability
regarding the treatment outcome for immediately loaded Brånemark
implants in the anterior mandible. Furthermore, no difference between the
traditional turned and the an-oxidized implant surface (TiUnite) could be
observed. However, it has to be stressed that all implants (irrespective of
surface) were placed in the anterior mandible and also that all the patients
demonstrated a high level of oral hygiene (Fig. 4).
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