Immediate Loading of Brånemark System Implants®: A Comparison Between TiUnite™ and Turned Implants Placed in the Anterior Mandible

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ABSTRACT

Purpose: The aim of the present study was to compare the treatment outcome of TiUnite™- and turned-surfaced Brånemark System® (Nobel Biocare AB, Göteborg, Sweden) implants when applying immediate loading of cross-arch designed fixed partial dentures in the anterior mandible.

Materials and Methods: 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 implant was placed and in the remaining half the other type. The implants were loaded the day of surgery via a fixed, temporary supra-construction. Ten days later, the permanent one was screw retained to the implant pillars.

Results: 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 turned (turned) one when implants in the anterior mandible were exposed to functional load within 24 hours after installation.

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: an-oxidized implant surface, Brånemark dental implants, clinical study, immediate loading, implant stability, rebuild denture, turned

In 1969, the original protocol for implant installation was described by Brånemark and colleagues.[1] The protocol recommended a two-stage surgical procedure, that is, a two-piece implant is used and the fixture is submerged during a 3- to 6-month healing period. Thereafter, the abutment connection has to be performed, the supra-construction fabricated, and screw retained to the implant pillars.[2] In 1977, the follow-up results of the treatment outcome of 235 edentulous jaws (128 maxillae and 107 mandibles) were presented.[3] 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] as well as for partially dentate jaws.[5–6] Over the years, a reevaluation of the traditional Brånemark two-stage protocol has occurred. Schroeder and colleagues[7–9] have shown that it is possible to achieve predictable osseointegration even when using a one-stage technique, that is, 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] or two-piece implants,[11,14] as well as in a number of well-controlled clinical studies using the Brånemark System® (Nobel Biocare AB, Göteborg, Sweden).[15–24] Similar clinical observations have been reported by using ITI® implants (Straumann AG, Waldenburg, Switzerland)

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(one-piece) in different situations,[25] in edentulous mandibles,[26–27] and in edentulous maxillae.[28]

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."[29] 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 colleagues[16] 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 and Rosenberg,[17] 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 and colleagues[19] have alleged that "one-step Brånemark implants may be considered a viable alternative to two-step implants."

An important prerequisite for obtaining a predictable healing process of implants (osseointegration) is that the so-called micromotion, that is, the movement at the interface between the bone and the implant surface, is limited.[30–33] Søballe and colleagues[34] have reported that the tissues involved probably will accept a micromotion amounting to 50 to 150 μm. Furthermore, Brunski[32] has reported that micromotions of approximately 100 μm may constitute a threshold value for turned implant surfaces to osseointegrate properly.

Favorable loading conditions can be achieved for teeth connected to each other via a rigid fixed partial denture (FPD).[35–36] However, individual implant pillars installed according to the one-stage 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 micromotion 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.[37–39] This treatment concept has been launched in Scandinavia as the "Nordic Bridge concept."[40]

Schnitman and colleagues[41] 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, four failed. The remaining 35 implants installed according to the original two-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 and colleagues[41] reported on a 10-year outcome. The survival rate for the submerged implants was 100%. Furthermore, Balshi and Wolfinger[42] applied a treatment approach for the edentulous mandible similar to that of Schnitman and colleagues.[41] The authors[42] reported that 80% (32 out of 40) of the immediately loaded Brånemark 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 "Brånemark Novum concept."[43] "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 three 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 and colleagues[44] 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 and colleagues.[43] Hatano[45] presented the "Maxis New," another 1-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 concept,[1] 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.[46] 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.[47] Today, it is generally accepted that implants with a somewhat rough surface will: (1) facilitate to obtain initial stability, (2) enlarge the surface area,[48] and (3) speed up the osseointegration process.[49,50] Focus has thus been set on surface characteristics.[51–54] To create such a surface, you can, for example, blast or titanium plasma spray it or perform an anodic oxidation of the surface.[55] It has been shown that the bone-implant contact is higher for a TiUnite™ (Nobel Biocare AB) (an-oxidized) surface compared with a turned one. This observation is supported by human histological findings recently reported.[50,56–57] 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 turned-surfaced Brånemark System implants when applying immediate loading of cross-arch designed FPDs in the anterior mandible.

MATERIALS AND METHODS

During 2001 to 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.

The patients were preoperatively examined clinically and radiographically. The examination protocol (including inclusion and exclusion criteria) used was in line with the recommendations presented by Lekholm,[58] for example, (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), four of the participating patients had their natural teeth remaining or an FPD supported by teeth, while 10 patients wore complete removable dentures (CD). The remaining one used a cross-arch designed implant-supported FPD (IFPD) (Table 2).

Six patients (two females and four males) were smokers and were asked to terminate or decrease their smoking habits during a period of at least 2 to 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 g Amoxicillin™ preoperatively 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.[59]

In one half of the mandible (between the foramen mentale and the midline), three implants were installed supplied either with the turned-[60] or the TiUnite[55] surface with a diameter of 3.75 mm (Brånemark System Mk III implants®; Nobel Biocare AB), (Figure 1). A total number of 89 (45 turned + 44 TiUnite) fixtures were placed.

The "toss of a coin procedure" was used to select the half of the jaw where the three turned implants had to

TABLE 1 Gender and Age Distribution of Patients

Patient		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean Age
Men	($n = 9$)			67		63	76	69		63		75		60	62	76	67.9
Women	($n = 6$)	76	77		70				58		79		78				73
Total	($n = 15$)																69.9

TABLE 2 Condition of the Maxillae

Patient		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FPD	($n = 4$)	×			×					×			×			
CD	($n = 10$)		×	×		×	×	×	×		×	×			×	×
IFPD	($n = 1$)													×		
Total	($n = 15$)															

CD = complete denture; FPD = fixed partial denture; IFPD = implant-supported fixed partial denture.

be placed. An identical surgical procedure was then performed in the corresponding contralateral area of the mandible where the three TiUnite implants were placed. Following fixture placement, abutments (Multi Unit Abutments, Brånemark System, Nobel Biocare AB) were connected and tightened according to the manual. The length and type of implants are presented in Table 3.

Resonance Frequency Assessments (RFA)[61] were recorded by means of 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 and 100 (ISQ = implant stability quotient).[61] RFA recordings were performed at abutment level on the day for implant installation.

Following proper adaptation and suturing of the mucoperiosteal flaps toward the mucosally piercing implant pillars, an impression was taken by means of impression copings and a stiff impression material (eg, 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[40] was applied. Briefly, the original CD was rebuilt in such a way that it was possible to connect it to the implant pillars the day of surgery.[41] Furthermore, at the same appointment a tooth setup in wax for the permanent supra-construction was tried in. The permanent IFPD with a milled titanium framework (Procera Implant Bridge, Nobel Biocare AB) was fabricated,[2] and connected to the implants 10 days following implant installation. At the same time, the sutures were removed, and the patients were carefully instructed on how to perform proper oral hygiene.

Follow-Up Examinations

Implant Stability. The ISQ value[61] was recorded at abutment level at the day of delivery of the permanent IFPD, and at every follow-up examination, that is, 3, 6, 12, and 18 months later.

Peri-implant Mucosa. The condition of the peri-implant mucosa surrounding the implant pillars was evaluated by means of the "angulated bleeding index"[62] 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 2 mm and then angulated about 45 degrees in relation to the long axis of the implant (Figure 2). Thereafter, the probe was moved gently along the marginal mucosa over a length of about 2 mm. This procedure was performed once at four different areas around the implant. The

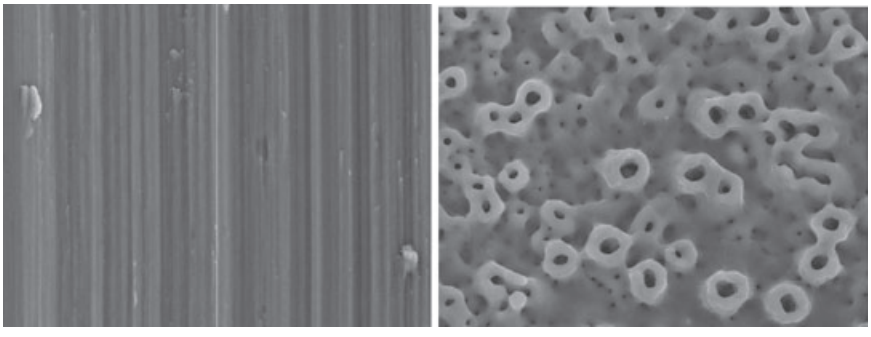

Figure 1 (A) Turned surface. (B) TiUnite™ surface.

TABLE 3 Number and Length of Implants Placed

Length (mm)	Turned	TiUnite™
13	5	4
15	38	40
18	2	
Total = 89	45	44

presence or absence of bleeding within 30 s following probing was recorded. The evaluations were repeated 3, 6, 12, and 18 months later.

Marginal Bone Level. The marginal bone level was assessed in radiographs obtained at the delivery of the provisional IFPD, that is, the day of surgery. This examination was repeated 18 months later.

The intraoral radiographs were taken with an 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."[63] 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 the AFJ and the most apical level of the bone judged to be in contact with the fixture surface was measured.[14–16] The distance was assessed using a lens with a magnification factor of 7 and increments of 0.1 mm.

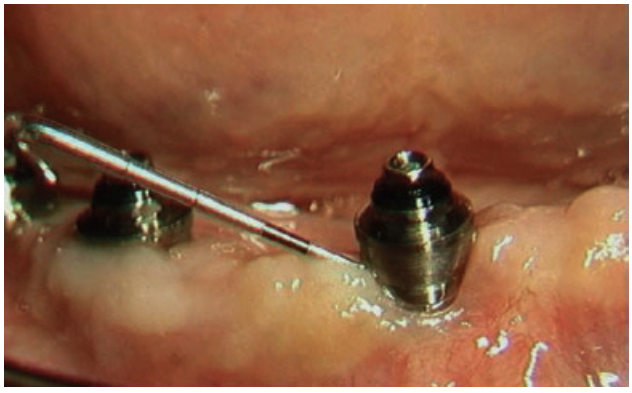

Figure 2 Clinical photo illustrating the run of the probe when recording the "angulated bleeding index."

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.[64]

Statistical 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, that is, means of all loaded implants in the right and left sides 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 Table 4.

No statistically significant difference could be detected between the two 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 and frequency distribution of the bone remodeling is reported in Table 5. No significant differences were found regarding changes in marginal bone level between the two groups of implants during the entire follow-up period ($p > 0.30$) (see Table 5).

Peri-implant Mucosa

In all patients, healing proceeded without complications and with minimal postoperative problems noticed for the patients. The absence of clinical peri-implant infection was observed at all sites. Irrespective of implant surface, similar figures were recorded regarding "bleeding on probing," that is, 15 to 25% of the sites at every follow-up examination except when the permanent

TABLE 4 Mean Implant Stability Quotient (Implant Stability Quotient [ISQ], SD, and Range) for All Turned and TiUnite™ Implants at Delivery of the Temporary Implant-Supported Fixed Partial Denture (IFPD) the Day of Surgery; the Permanent IFPD 10 Days Later; and Another 3, 6, 12, and 18 Months Later

Turned Surface						
	Fix Install	10 days	3 m	6 m	12 m	18 m
ISQ score mean	67.8	63.8	62.6	64.0	64.3	64.3
SD	7.3	6.2	4.8	4.5	4.6	4.5
Range	53–78	51–73	54–73	55–74	54–75	56–75
TiUnite Surface						
	Fix Install	10 days	3 m	6 m	12 m	18 m
ISQ score mean	67.2	64.2	63.3	64.7	65.0	64.6
SD	6.4	7.0	6.1	5.1	5.7	5.7
Range	52–78	48–78	50–75	54–74	55–76	56–75

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 (Figure 3).

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)

TABLE 5 Baseline = Marginal Bone Level Apical to the Reference Point, and Change in Marginal Bone Level (Mean, SD, Frequency Distribution) During the Observation Intervals After Implant Insertion

Turned Surface						
	Baseline		Change 0–12 m		Change 0–18 m	
	Mesial	Distal	Mesial	Distal	Mesial	Distal
Mean (mm)	0.80	0.93	0.81	0.41	0.89	0.60
SD (mm)	0.98	1.31	1.63	1.57	1.40	1.84
N	22	33	12	31	15	29
<0			2	9	3	8
0–1.0			5	11	3	8
1.1–2.0			2	9	7	9
2.1–3.0			2	1	2	3
>3.0			1	1	0	1
TiUnite™ Surface						
	Baseline		Change 0–12 m		Change 0–18 m	
	Mesial	Distal	Mesial	Distal	Mesial	Distal
Mean (mm)	1.06	0.92	0.89	0.77	0.89	0.70
SD (mm)	1.17	1.05	1.62	1.29	1.55	1.35
N	36	25	36	19	35	21
<0			4	2	6	3
0–1.0			15	6	12	8
1.1–2.0			8	9	9	8
2.1–3.0			8	2	8	2
>3.0			1	0	0	0

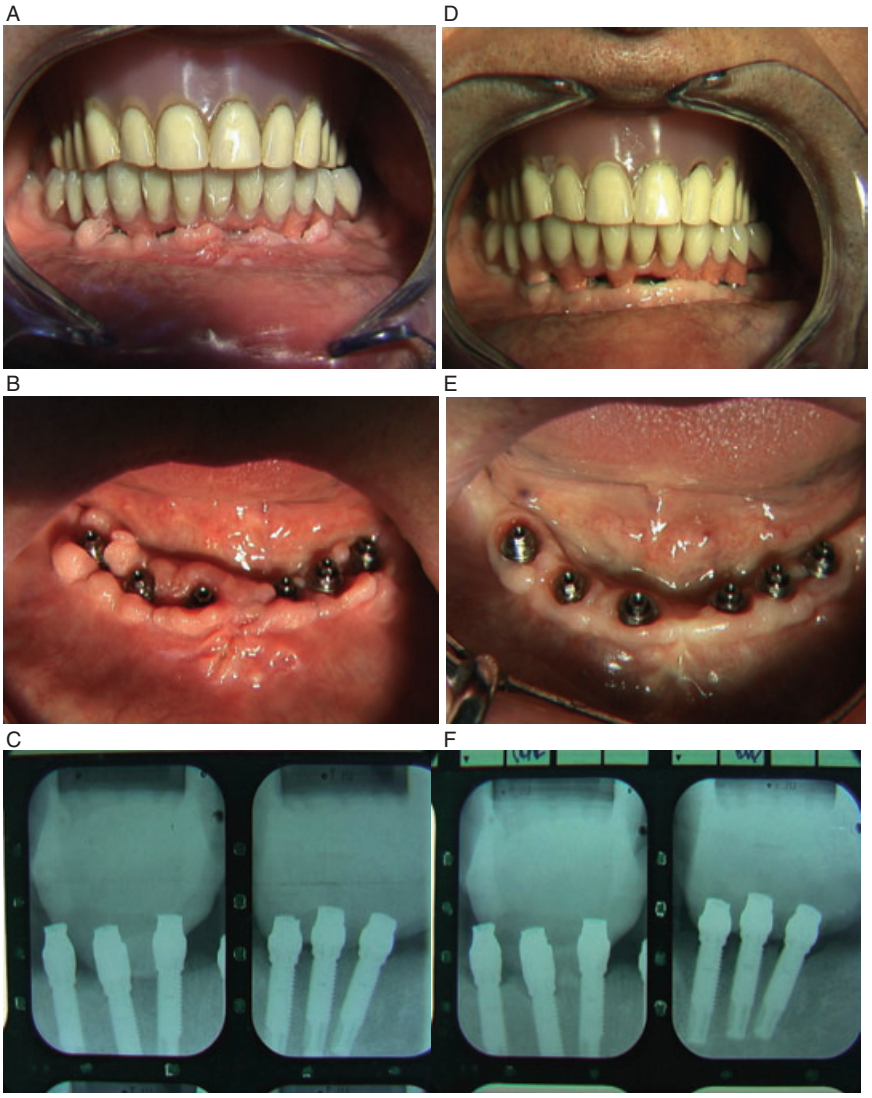

Figure 3 (A–C) Clinical and radiographic appearance at delivery of permanent implant-supported fixed partial denture (10 days postoperatively), to be compared to (D–F) illustrating the corresponding conditions at the 18-month following-up examination.

and a 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.[17,37–39,41]

Implant surface quality is known to be one out of several important factors to obtain osseointegration predictably.[65] 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.[48–50,66–69] 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.[53] It has also been observed that anodic oxidation of implants will result in an increased bone response (= bone-implant contact, removal torque) compared to turned implants.[70–71] 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 toward the two surfaces used.

As no differences between the two 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 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 and colleagues[23]

and Jungner and colleagues.[72] Both teams reported a higher success rate for implants with TiUnite surface than for the turned ones. Rocci and colleagues[23] placed 66 Brånemark TiUnite implants in the posterior mandible and were immediately loaded via 24 partial FPDs. Corresponding figures for Brånemark turned 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 turned implants." Jungner and colleagues[72] reported on 63 patients who had a one-stage surgical session, out of who 24 were exposed to early functional loading. The remaining patients (73) participating in the study were treated according to the original two-stage protocol. A total number of 394 (199 TiUnite and 195 turned) implants were installed. Both types of implants were placed in all four 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 turned 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 (see 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[61] and Friberg and colleagues[21] 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 and colleagues[73] and Zechner and colleagues[74] 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.[75–76] Rompen and colleagues[73] 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 two surfaces tested, most likely due to the design of the study.

The bone level measured at baseline and 18 months after loading showed a slight reduction of bone, mean 0.60 to 0.89 mm, although there was a wide variation between implant surfaces, which also has been observed in other studies.[28] 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 two 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. Because 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 (see Figure 3).

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REFERENCES

1. Brånemark P-I, Breine U, Adell R, Hansson B-O, Ohlsson, Å. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J Plast Reconstr Surg 1969; 3:81–100.

2. Zarb GA, Jansson T. Prosthodontic procedures. In: Brånemark PI, Zarb G and Albrektsson T, eds. Tissue-integrated prosthesis. Chicago, IL: Quintessence, 1985:241–282.
3. Brånemark P-I, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, Öhman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstructive Surg 1977; 11(Suppl 16):7–132. (Monograph from Almqvist & Wiksell International, Stockholm, Sweden).
4. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edetulous jaws. Int J Oral Maxillofac Implants 1990; 5:347–359.
5. Lekholm U, van Steenberghe D, Herrmann I, et al. Osseointegrated implants in the treatment of partially edentulous jaws: a prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1994; 9:626–635.
6. Lekholm U, Gunne J, Henry P, et al. Survival of the Brånemark implant in partially edentulous jaws: a 10-year prospective multicenter study. Int J Oral Maxillofac Implants 1999; 14:639–645.
7. Schroeder A, Pohler O, Sutter F. Gewebsreaktion auf ein Titan-Hohlzylinder-Implantat mit Titan-Spritzschichtoberfäche. Schweizerische Monatschrift für Zahnheilkunde 1976; 86:713–727.
8. Schroder A, Stich H, Straumann F, Sutter F. Über die Anlagerung Osteocement an einem belasteten Implantatkörper. Schweizerische Monatschrift für Zahnheilkunde 1978; 88:1051–1058.
9. Schroder A, Maeglin B, Sutter F. Das ITI-Hohlzylinderimplantat Typ F zur Prothesenretention beim zahnlosen Kiefer. Schweizerische Monatschrift für Zahnheilkunde 1983; 93: 720–733.
10. Gotfredsen K, Rostrup E, Hjorting-Hansen E, Stoltz K, Budtz-Jörgensen E. Histological and histomorphometric evaluation of tissue reactions adjacent to endosteal implants in monkeys. Clin Oral Implants Res 1991; 2:30–37.
11. Abrahamsson I, Berglundh T, Wennström J, Lindhe J. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. Clin Oral Implants Res 1996; 7:212–219.
12. Weber H-P, Buser D, Donath K, Fiorellini JP. Comparison of healed tissues adjacent to submerged and non-submerged unloaded titanium dental implants. A histomorphometric study in beagle dogs. Clin Oral Implants Res 1996; 7: 11–19.
13. Piatelli A, Paoloantonio M, Corigliano M, Scarano A. Bone reactions to early occlusal loading of two-stage titanium plasma-sprayed implants. A pilot study in monkey. Int J Periodont Res Dent 1997; 17:163–169.
14. Ericsson I, Nilner K, Klinge B, Glantz P-O. Radiographical and histological characteristics of submerged and nonsubmerged titanium implants. An experimental study in the Labrador dog. Clin Oral Implants Res 1996; 6:20–26.
15. Ericsson I, Randow K, Glantz P-O, Lindhe J, Nilner K. Some clinical and radiographical features of submerged and non-submerged titanium implants. Clin Oral Implants Res 1994; 5:185–189.
16. Ericsson I, Randow K, Nilner K, Petersson A. Some clinical and radiographical features of submerged and non-submerged titanium implants. A 5-year follow-up study. Clin Oral Implants Res 1997; 8:422–426.
17. Henry P, Rosenberg J. Single-stage surgery for rehabilitation of the edentulous mandible. Preliminary results. Practical Periodontics Aesthetic Dent 1994; 6:1–8.
18. Bernard J-P, Belser UC, Martinet J-P, Borgis SA. Osseointegration of Brånemark fixtures using a single-step operating technique. A preliminary prospective one-year study in the edentulous mandible. Clin Oral Implants Res 1995; 6:122–129.
19. Becker W, Becker BE, Israelson, H et al. One-step surgical placement of Brånemark implants: a prospective clinical multicenter study. Int J Oral Maxillofac Implants 1997; 12:454–462.
20. Collaert B, De Bruyn H. Comparison of Brånemark fixture integration and short-term survival using one-stage or two-stage surgery in completely and partially edentulous mandibles. Clin Oral Implants Res 1998; 9:131–135.
21. Friberg B, Sennerby L, Lindén B, Gröndahl K, Lekholm U. Stability measurements of one-stage Brånemark implants during healing in mandibles. A clinical resonance frequency analysis study. Int J Oral Maxillofac Surg 1999; 28:266–272.
22. Bogaerde L, Padretti G, Dellacasa P, Mozzati M, Rangert B, Eng M. Early function of splinted implants in maxillas and posterior mandibles using Brånemark System®, machined-surface implant: an 18 month prospective multicenter study. Clin Implant Dent Relat Res 2003; 5(Suppl 1):21–28.
23. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System with TiUnite and machined surfaces in the posterior mandible: a randomized, open-ended trial. Clin Implant Dent Relat Res 2003; 5(Suppl 1):57–63.
24. Engquist B, Åstrand P, Anzén B, et al. Simplified methods of implant treatment in the edentulous lower jaw: a 3-year follow-up report of a controlled prospective study of one stage versus two-stage surgery and early loading. Clin Implant Dent Relat Res 2005; 7:95–104.
25. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Part I: 8-year life table analysis of a prospective multicenter study with 2359 implants. Clin Oral Implants Res 1997; 8:161–172.
26. Åstrand P, Almfeldt I, Brunell G, Hamp S-E, Hellem S, Karlsson U. Non-submerged implants in the treatment of the edentulous lower jaw. A 2-year longitudinal study. Clin Oral Implants Res 1996; 7:337–344.
27. Hellem S, Karlsson U, Almfeldt I, Brunell SE, Åstrand P. Non-submerged implant in the treatment of the edentulous lower jaw: a 5-year prospective longitudinal study of ITI hollow screws. Clin Implant Dent Relat Res 2001; 3:20–29.

28. Bergkvist G, Sahlholm S, Nilner K, Lindh C. Implant-supported fix prostheses in the edentulous maxilla. A 2-year clinical and radiological follow-up of treatment with non-submerged ITI implants. Clin Oral Implants Res 2004; 15:351–359.
29. Albrektsson T, Zarb G, Worthington P, Eriksson RA. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11–25.
30. Cameron H, Pilliar RM, Macnab I. The effect of movement on the bonding of porous metal to bone. J Biomed Mater Res 1973; 7:301–311.
31. Brunski JE. Biomechanical factors affecting the bone-dental implant interface. Clin Materials 1992; 3:153–201.
32. Brunski JE. In vivo bone response to biomechanical loading at the bone/dental implant interface. Adv Dent Res 1999; 13:99–119.
33. Pilliar RM. Quantitative evaluation of the effect of movement at a porous coated implant-bone interface. In: Davies EJ, ed. The bone-biomaterial interface. Toronto, Canada: University of Toronto Press, 1995:380–387.
34. Søballe K, Hansen ES, Brockstedt-Rasmussen H, Bønger C. The effects of osteoporosis, bone deficiency, bone grafting and micromotion on fixation of porous-coated hydroxyapatite-coated implants. In: Gesink, RGT, Manley MT, eds. Hydroxypatite coatings in orthopaedic surgery. New York: Raven Press, 1993:107–136.
35. Glantz P-O, Strandman E, Svensson SA, Randow K. On functional strain in fixed mandibular reconstructions. I. An in vitro study. Acta Odontol Scand 1984a; 42:241–249.
36. Glantz P-O, Strandman E, Randow K. On functional strain in fixed mandibular reconstructions. II. An in vivo study. Acta Odontol Scand 1984b; 42:269–276.
37. Randow K, Ericsson I, Nilner K, Petersson A, Glantz P-O. Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. Clin Oral Implants Res 1999; 10:8–15.
38. Ericsson I, Randow K, Nilner K, Petersson A. Early functional loading of Brånemark dental implants. A 5-year follow-up study. Clin Implant Dent Relat Res 2000; 2:70–77.
39. Chow J, Hui E, Li D, Liu J. Immediate loading of Brånemark system fixtures in the mandible with a fixed provisional prothesis. Appl Osseointergration Res 2001; 2:30–35.
40. Ericsson I, Nilner K. Early functional loading using Brånemark dental implants. Int J Periodontics Restorative Dent 2002; 22:9–19.
41. Schnitman PA, Wöhrle PS, Rubenstein JE, Da Silva JD, Wang N-H. Ten year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997; 12:495–503.
42. Balshi TJ, Wolfinger GJ. Immediate loading of Brånemark implants in edentulous mandibles: a preliminary report. Implant Dent 1997; 6:83–88.
43. Brånemark P-I, Engstrand P, Öhrnell L-O, et al. A new treatment concept for rehabilitation of the edentulous mandible. Preliminary results from a prospective clinical follow-up study. Clin Implant Dent Relat Res 1999; 1:2–16.
44. Van Steenberghe D, Molly L, Jacobs R, Vandekerckhove B, Quirynen M, Naert I. The immediate rehabilitation by means of a ready-made final fixed prosthesis in the edentulous mandible: a 1-year follow-up study of 50 consecutive patients. Clin Oral Implants Res 2004; 15: 360–365.
45. Hatano N. The Maxis New. A novel one-day technique for fixed individualized implant-supported prosthesis in the edentulous mandible using Brånemark System implants. Appl Osseointergration Res 2001; 2:40–43.
46. Kasemo B, Lausmaa J. Biomaterial and implant surface science: a surface science approach. Int J Oral Maxillofac Implants 1988; 4:247–259.
47. Kasemo B, Lausmaa J. Aspects of surface physics on titanium implants. Swed Dent J 1985; 28(Suppl):19–36.
48. Wennerberg A. On surface roughness and implant incorporation. PhD thesis, Department of Biomaterials/Handicap Research, Göteborg University, Sweden, 1996.
49. Larsson C. The interface between bone and implants with different surface oxide properties. Appl Osseointegration Res 2000; 1:9–14.
50. Schüpbach P, Glauser R, Rocci A, et al. The human bone-oxidized titanium implant interface: a light microscopic, scanning electron microscopic, black-scatter scanning electron microscopic, and energy-dispersive X-ray study of clinically retrieved dental implants. Clin Implant Dent Relat Res 2005; 7(Suppl 1):36–43.
51. Karlsson U, Gotfredsen K, Olsson C. A 2-year report on maxillary and mandibular fixed partial dentures supported by Astra Tech dental implants. A comparison of 2 implants. Clin Oral Implants Res 1998; 9:235–242.
52. Cordioli G, Majzoub Z, Piattelli A, Scarano ATI. Removal torque and histomorphometric investigation of 4 different titanium surfaces: an experimental study in the rabbit tibia. Int J Oral Maxillofac Implants 2000; 15:668–674.
53. Gotfredsen K, Berglundh T, Lindhe J. Anchorage of titanium implants with different surface characteristics: an experimental study in rabbits. Clin Implant Dent Relat Res 2000; 2:70–77.
54. Gotfredsen K, Karlsson U. A prospective 5-year study of fixed partial prosthesis supported by implants with machined and TiO_2-blasted surface. J Prosthodont 2001; 10:2–7.
55. Hall J, Lausmaa J. Properties of a new porous oxide surface on titanium implants. Appl Osseointegration Res 2000; 1:5–8.
56. Rocci A, Martignoni M, Sennerby L, Gottlow J. Immediate loading of a Brånemark System implant with the TiUnite surface. Histological evaluation after 9 months. Appl Osseointegration Res 2002; 3:25–28.

57. 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.
58. Lekholm, U. The surgical site. In: Lindhe J, Karring T, Lang NP, eds. Clinical periodontotogy and implant dentistry. 4th ed. United Kingdom: Blackwell Munksgaard, 2003:852–865.
59. Adell R, Lekholm U, Brånemark P-I. Surgical procedures. In: Brånemark P-I, Zarb G, Albrektsson T, eds. Tissue-integrated prosthesis. Osseointegration in clinical dentistry. Chicago, IL: Quintessence, 1985:211–232.
60. Lausmaa J, Kasemo B, Mattsson L. Surface spectroscopic characterization of titanium implant materials. Appl Surface Sci 1990; 44:133–146.
61. Meredith N. On the clinical measurement of implant stability and osseointegration. PhD thesis, Göteborg University, Göteborg Sweden, 1997.
62. van der Weijden GA, Timmerman MF, Nijboer A, Reijerse E, Van Der Velden U. Comparison of different approaches to assess bleeding on probing as indicators of gingivitis. J Clin Periodontol 1994; 21:589–594.
63. Eggen S. Standardiserad intraoral röntgenteknik. Tandläkartidningen 1976; 17:867–872.
64. Rangert B, Renourd F. Practical guidelines based on biomechanical principles. In: Palacci P, Ericsson I, eds. Estehtic implant dentistry. Soft and hard tissue management. Berlin, Germany: Quintessence, 2001:47–68.
65. Albrektsson T, Brånemark P-I, Hansson H-A, Lindström JJ. Osseointegrated titanum implants. Requirements for ensuring a long-lasting direct bone-to-implant anchorage in man. Acta Orthop Scand 1981; 52:155–170.
66. Lausmaa J, Kasemo B, Rolander U, Bjursten LM, Rosander L, Thomsen P. Preparation, surface spectroscopic and electron microscopic characterization of titanium implant materials. In: Ratner BD, ed. Surface chatacterization of biomaterials. Amsterdam, the Netherlands: Elsevier Science Publishers, 1988:161–173.
67. Binon P, Weir D, Marshall S. Surface analysis of an original Brånemark implant and there related clones. Int J Oral Maxillofac Implants 1992; 7:168–175.
68. Davis JE. Mechanisms of endosseous integration. Int J Prosthodont 1998; 11:391–401.
69. 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.
70. Albrektsson T, Johansson C, Lundgren AK, Sul Y, Gottlow J. Experimental studies on oxidized implant. A histomorphometrical and biomechanical analysis. Appl Osseointegration Res 2000; 1:21–24.
71. Henry P, Tan A, Allen B, Hall J, Johansson C. Comparison of TiUnite and turned implants in the grayhound dog mandible. Appl Osseointegration Res 2000; 1:15–17.
72. Jungner M, Lundqvist P, Lundgren S. Oxidized titanium implants (Nobel Biocare® TiUnite™) compared with turned implants (Nobel Biocare® mark III™) with respect to implant failure in a group of consecutive patients treated with early functional loading and two-stage protocol. Clin Oral Implants Res 2005; 16:308–312.
73. Rompen E, DaSilva D, Lundgren AK, Gottlow J, Sennerby L. Stability measurements of a double-threaded titanium implant design with turned or oxidized surface. An experimental resonance frequency analysis study in the dog mandible. Appl Osseointegration Res 2000; 1:18–20.
74. Zechner W, Tangl S, Fürst G, et al. Osseous healing characteristics of three different implant types. A histological and histomorphometric study in mini-pigs. Clin Oral Implants Res 2003; 14:150–157.
75. Glauser R, Lundgren AK, Gottlow J, et al. Loading of Brånemark TiUnite™ implants placed predominantly in soft bone: 1-year result of a prospective, clinical study. Clin Implant Dent Relat Res 2003; 5(Suppl 1):47–56.
76. Glauser R, Ruhstaller P, Windisch S, et al. Loading of Brånemark System® TiUnite™ implants placed predominantly in soft bone: 4-year result of a prospective, clinical study. Clin Implant Dent Relat Res 2005; 7(Suppl 1):52–59.