Analysis of 164 Titanium Oxide–Surface Implants in Completely Edentulous Arches for Fixed Prosthesis Anchorage Using the Pterygomaxillary Region

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Purpose: *The purpose of the article was to evaluate the survival rates of TiUnite implants and then compare them to a previous similar study of machined-surface implants.* ***Materials and Methods:*** *This report presents the results of 82 consecutive patients treated since the introduction of Nobel Biocare's TiUnite surface. The patients were treated with complete-arch restorations using bilateral pterygomaxillary implants in edentulous maxillae. A total of 840 implants were placed in immediate extraction or healed sites, with a mean of 10 implants placed per patient.* ***Results:*** *In all, 826 of the 840 implants osseointegrated, for a cumulative survival rate (CSR) of 98.3%. One hundred fifty-eight of 164 pterygomaxillary implants successfully osseointegrated, yielding a 96.3% survival rate.* ***Discussion and Conclusion:*** *The results of this complete-arch maxillary prospective study suggest that Brånemark System TiUnite implants are more predicable than implants with a machined surface. Compared to a similar 1999 study in which the survival rate for machined-surface implants was 92.1%, the present study had a significantly higher survival rate of 98.6% with the TiUnite surface (*$P < .001$*). In the pterygomaxillary region, there was an increase of 8% with the TiUnite surface as opposed to the machined surface (*$P < .001$*). In addition, 62% of the implants in the present study were immediately loaded, compared to 0% in the machined-surface implant study. The titanium oxide surface appears to assist the healing response of the bone-implant interface.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:946–952

Key words: *immediate loading, implant surfaces, osseointegration, pterygoid, zygomatic implants*

The Brånemark System has demonstrated high success rates for implants placed in completely edentulous jaws since its introduction to clinical dentistry in 1965.[1] Adell and coworkers[2] reported 15 years of functional and successful results in the treatment of edentulous jaws in 1981; however, the majority of implants placed in the maxilla were placed anterior to the maxillary antrum. According to Zarb and researchers,[3] the posterior maxilla is the most difficult and problematic intraoral area for treatment with osseointegrated implants.

The anatomy of the maxillary posterior quadrant presents many limitations to implant placement, including poor bone quality and decreased bone quantity,[4] location of the antrum,[5] and accessibility of the area,[6] particularly in the pterygomaxillary region. Originally thought to be inoperable or unsuitable for implant treatment because of large fatty marrow spaces, limited trabecular bone, and biomechanical factors,[7] the pterygomaxillary region was expected to have a lower success rate for implants than the anterior portions of the maxilla. Using a larger number of implants[8] to distribute the loading forces or wider-diameter implants[9] to obtain greater surface area for bone contact were some initial options for treating the posterior maxilla.

Jaffin and Berman[10] reported on implants used specifically in the posterior maxilla and noted a higher failure rate attributable to less dense bone. Schnitman and associates[11] explained that the posterior maxilla was the least successful area for

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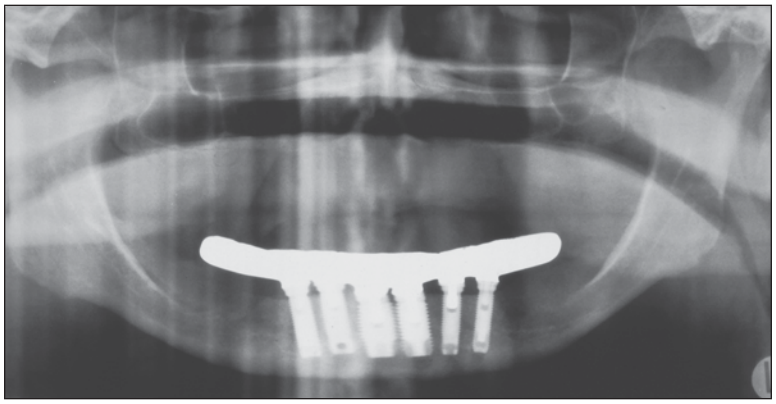

Fig 1 Preoperative panoramic radiograph illustrating the need for a maxillary implant-supported restoration.

Table 1 Frequency Distribution of Implants in Maxillary and Pterygomaxillary Sites

Implant type and size	All maxillary tooth positions	Pterygomaxillary tooth positions 1 and 16
Mk III TiURP		
3.75 × 7.0	1	0
3.75 × 8.5	3	0
3.75 × 10.0	31	0
3.75 × 13.0	92	2
3.75 × 15.0	62	13
3.75 × 18.0	14	1
4.00 × 10.0	6	0
4.00 × 13.0	31	0
4.00 × 15.0	38	11
Mk IV TiURP		
4.00 × 7.0	1	0
4.00 × 8.5	17	0
4.00 × 10.0	113	2
4.00 × 13.0	128	6
4.00 × 15.0	182	90
4.00 × 18.0	75	39
Zygoma		
30.0	2	NA
35.0	16	NA
40.0	8	NA
42.5	8	NA
45.0	8	NA
47.5	2	NA
50.0	2	NA
Total	840	164

Dimensions of TiU RP implants given in mm (width × length).
RP = regular platform; NA = not applicable.

osseointegration to occur. In their study, only 72% of implants placed in the posterior maxilla achieved osseointegration.

The influence of higher biomechanical forces in the posterior region can also affect the long-term stability of implants placed there.[12] Posterior cantilevers on implant prostheses produce complications, including screw fracture, prosthesis fracture, bone loss, and loss of osseointegration,[13] all resulting from poor biomechanical force and load distribution. Rangert and colleagues[14,15] reported that improving biomechanical stability and load distribution by means of noncantilevered, bone-anchored restorations should enhance the long-term prognosis of implant restorations in the posterior maxilla. If implants placed in the compact bone of the pterygomaxillary plate[16] successfully osseointegrate, they can provide support and retention for implant restorations and eliminate posterior cantilevers that are seen when only anterior implants are used to support a full complement of teeth in a complete-arch restoration. There is now a manageable way to treat patients with an edentulous posterior maxilla.[17]

The intention of this retrospective study was to calculate the survival rate of Brånemark implants with TiUnite surfaces (Nobel Biocare USA, Yorba Linda, CA) in edentulous maxillary sites, including the pterygomaxillary region, restored with complete fixed maxillary prostheses. Furthermore, the survival rates are compared to the results of a previously published report by the same authors[18] which determined the survival rate of machined-surface Brånemark System implants placed in the pterygomaxillary region supporting the same types of complete fixed maxillary restorations.

MATERIALS AND METHODS

Patients

Eighty-two healthy patients (50 women, 32 men) with a mean age of 58.1 years (range, 13 to 86 years) in need of complete restoration of the maxillary arch (Fig 1) were consecutively treated following the introduction of the TiUnite surface. These patients were treated at a private practice facility from 1999 to 2004. Inclusion criteria were based on the patient's current stable medical condition and his or her ability to undergo dental implant surgery. Exclusion criteria included metabolic bone disease, an unstable systemic condition such as uncontrolled diabetes or untreated hypothyroidism, or the discovery of a malignancy.

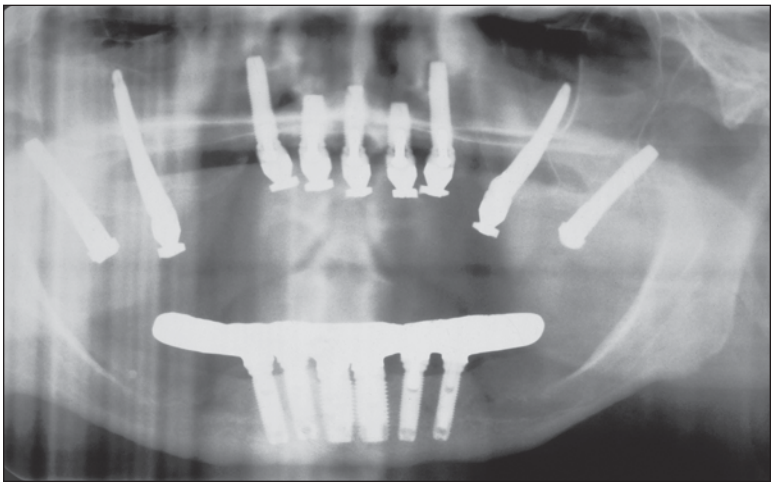

Fig 2a *(Left)* Panoramic radiograph after maxillary implant placement of 5 anterior implants, 2 zygoma implants, and 2 pterygomaxillary implants.

Fig 2b *(Below)* Palatal view of implants and abutments.

Surgical Procedure

Any natural teeth with a poor or hopeless prognosis were extracted. All 840 implants in this study were surgically placed in healed bone or fresh extraction sites by a board-certified prosthodontist following the Brånemark standard protocol.[1] The frequency distribution of implants placed appears in Table 1. Ninety-five percent (794 of 840) of the implants were Brånemark System TiUnite implants; the remaining 46 implants (5%) were machined-surface Brånemark System zygoma implants that were used to aid in the reconstruction of the complete fixed maxillary prosthesis. An average of 10 implants (range, 7 to 14) was placed in each maxilla. For 522 of these implants (62.1%), abutments were connected immediately following implant placement prior to flap closure, and a Teeth In A Day prosthesis was fabricated as previously described in the literature,[19–21] thereby immediately loading each implant. The remaining 318 implants (37.9%) were submerged for a healing period of approximately 4 to 6 months, at the prosthodontist's discretion, largely because of poor primary stability and/or inferior bone quality at the implant site. If an implant was placed in soft bone and it was deemed a critical implant for the success of the fixed prosthesis, the implant was submerged. The determination of the loading protocol was not a function of insertion torque. Implants that were treated with a delayed loading protocol were provisionally restored with 1 of 3 types of prostheses, depending on the patient: a temporary complete denture, a fixed restoration on natural tooth abutments, or a fixed provisional restoration on other implants in the arch.

Of the 840 implants placed in the maxilla, 164 implants were placed in the pterygomaxillary region. All 164 pterygomaxillary implants had the titanium oxide (TiUnite) surface. Eighty (48.8%) of the pterygomaxillary implants were immediately loaded following the Teeth In A Day protocol (Figs 2a and 2b). The most frequent implant used in this sample was the 4 × 15 mm Mk IV TiUnite Regular Platform implant (21.7%). All 82 patients received a prosthesis that spanned from second molar to second molar, often with a bar extension to the most distal implant.

Prosthetic Procedure

After abutment connection, the implants were immediately loaded with a Teeth In A Day prosthesis, a screw-retained acrylic resin fixed prosthesis. All patients were instructed to maintain a soft diet for the first 12 weeks or until the definitive porcelain-fused-to-gold prosthesis was fabricated (Figs 3a and 3b).

All patients with submerged implants had second-stage uncovering surgery to connect abutments and put loading forces on these implants using a conversion prosthesis. A definitive prosthesis was fabricated and delivered within 3 weeks of abutment connection.

RESULTS

Of the implants placed, 826 of the 840 implants osseointegrated, for a cumulative survival rate (CSR) of 98.3%; 783 of 794 (98.6%) TiUnite implants osseointegrated. Three zygoma implants failed to osseointegrate, for a survival rate of 93.5%. The immediately loaded implants (n = 522) had a survival rate of 99.0%, while the 318 implants that underwent the conventional 2-stage approach had a survival rate of 97.2%. One hundred fifty-eight of 164 pterygomaxillary implants successfully osseointegrated, yielding a survival rate of 96.3% (Tables 2a and 2b). Three implants in the pterygomaxillary implant population that failed to osseointegrate were immediately loaded; the other 3 failed implants were sub-

Fig 3a *(Above)* Maxillary occlusal view of porcelain-fused-to-gold prosthesis with a bar extension to the pterygomaxillary implants

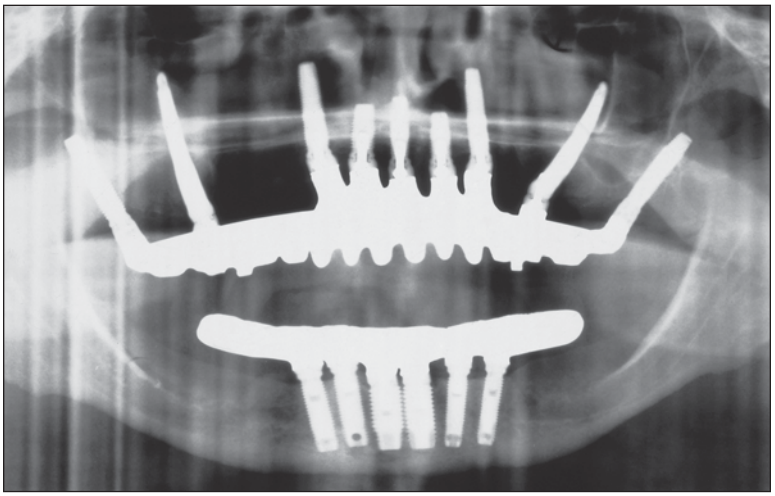

Fig 3b *(Right)* Panoramic radiograph following delivery of the definitive prosthesis.

merged for a healing period. The implant types and anatomic locations of the 14 failed implants are seen in Table 3.

CSRs were calculated for: *(1)* submerged maxillary and pterygomaxillary implants, *(2)* immediately loaded maxillary and pterygomaxillary implants, *(3)* submerged zygoma implants, *(4)* immediately loaded zygoma implants, *(5)* all TiUnite implants, and *(6)* all zygoma implants. These CSRs are given in Table 4. All 82 patients experienced a prosthesis survival rate of 100% for an average of 2.6 years (range, 6 months to 4.6 years). The presence and types of occlusal loading varied from patient to patient. No patient in this study wore a mandibular complete denture.

Table 2a Implant Survival Rates by Implant Type

	No. of implants placed	No. of implants osseointegrated	CSR (%)
Maxillary tooth positions			
Mk III TiURP 3.75	186	186	100.0
Mk III TiURP 4.00	65	64	98.5
Mk IV TiURP 4.00	379	376	99.2
Zygoma	46	43	93.5
Total	676	669	99.0
Pterygomaxillary tooth positions			
Mk III TiURP 3.75	17	16	94.1
Mk III TiURP 4.00	11	11	100.0
Mk IV TiURP 4.00	136	131	96.3
Zygoma	NA	NA	NA
Total	164	158	96.3

Maxillary tooth positions = positions 2 through 15; pterygomaxillary positions = positions 1 and 16.

Table 2b Implant Survival Rates by Implant Type for Tooth Positions 1 to 16—TiUnite Versus Total

	No. of implants placed	No. of implants osseointegrated	CSR (%)
TiUnite implants	794	783	98.6
All implants	840	826	98.3

DISCUSSION

The bone surrounding implants placed in the posterior maxilla may be inferior in quality, particularly in the premolar or molar region.[21] A distinct advantage of placing implants in the pterygomaxillary region is the ability to provide bone anchorage in the posterior maxilla without sinus augmentation, supplemental grafting, or the possibility of detrimental effects of cantilevered loading forces. Engaging the cortical bone of the pterygoid plate with long implants can improve primary stability, thereby providing long-term success.[22]

One major factor in the success and biocompatibility of an implant is its surface.[23,24] The TiUnite surface has a unique combination of controlled oxide texture and porosity for an enhanced biologic effect, which improves the environment for osseointegration and clinical success. Textured surfaces are known to accelerate the initial healing process through the adsorption of protein, the accumulation and activation of platelets, and fibrin retention, thus leading to an increased amount of surrounding bone.[25] Ivanoff and coworkers[26] observed significantly higher bone-implant contact for oxidized implants in a histomorphometric evaluation, regardless of whether the implants were placed in the maxilla or mandible. They theorized that these findings were a result of *(1)* the oxide layer itself, *(2)* increased surface roughness, and *(3)* different surface morphology in terms of porosity. No TiUnite implants in that

Table 3 Dimensions of Failed Implant and Tooth Positions

Implant type and size	Tooth position
4.00 × 15.0 MKIV TiURP	1 (18)
4.00 × 15.0 MKIV TiURP	1 (18)
4.00 × 15.0 MKIV TiURP	1 (18)
4.00 × 18.0 MKIV TiURP	1 (18)
4.00 × 8.5 MKIV TiURP	2 (17)
35.0 Zygoma	3 (16)
35.0 Zygoma	3 (16)
4.00 × 13.0 MKIV TiURP	5 (14)
4.00 × 13.0 MKIII TiURP	6 (13)
4.00 × 10.0 MKIV TiURP	11 (23)
4.00 × 15.0 MKIV TiURP	12 (24)
42.5 Zygoma	14 (26)
4.00 × 18.0 MKIV TiURP	16 (28)
3.75 × 10.0 MKIII TiURP	16 (28)

Universal (FDI) tooth numbers shown. Dimensions of TiU implants given in mm (width × length).
RP = regular platform.

Table 4 Cumulative Survival Rates

	No. of implants	No. of failures	Survival rate (%)	CSR (%)
Submerged				
0–1 y	301	4	98.7	98.7
1–2 y	181	0	100.0	98.7
2–3 y	138	0	100.0	98.7
3+ y	43	0	100.0	98.7
Immediately loaded				
0–1 y	493	7	98.6	98.6
1–2 y	267	0	100.0	98.6
2–3 y	82	0	100.0	98.6
3+ y	22	0	100.0	98.6
Submerged zygoma				
0–1 y	17	1	94.1	94.1
1–2 y	12	0	100.0	94.1
2–3 y	8	0	100.0	94.1
3+ y	5	0	100.0	94.1
Immediately loaded zygoma				
0–1 y	29	2	93.1	93.1
1–2 y	14	0	100.0	93.1
2–3 y	1	0	100.0	93.1
3+ y	1	0	100.0	93.1
TiUnite				
0–1 y	794	11	98.6	98.6
1–2 y	448	0	100.0	98.6
2–3 y	220	0	100.0	98.6
3+ y	65	0	100.0	98.6
Zygoma				
0–1 y	46	3	93.5	93.5
1–2 y	26	0	100.0	93.5
2–3 y	9	0	100.0	93.5
3+ y	6	0	100.0	93.5

study were lost. Knobloch and researchers[27] demonstrated a doubled failure rate in early loaded machined-surface implants as opposed to early loaded oxidized-surface implants in the premolar region of adult dogs.

In a study of immediately loaded improved titanium oxide and machined-surface implants in the posterior mandibles of humans, Rocci and associates[28] reported on 44 patients receiving a 2- to 4-unit prosthesis; 22 patients received TiUnite implants and 22 patients received machined-surface implants. The results of their study revealed a cumulative success rate of 95.5% for the TiUnite implants and 85.5% for machined-surface implants under immediate loading.

Numerous data have been documented supporting the success of osseointegration in the pterygomaxillary region.[16-18,22,29–33] Machined-surface implants used in the studies referenced had relatively consistent CSRs between 86.0% and 97.0%. One particular report[18] in 1999 by the present authors had a success rate of 88.2% for 356 pterygomaxillary implants placed in completely edentulous maxillary arches. The protocol for the current report is very similar to the one used in that study, in that all pterygomaxillary implants evaluated were anchoring full-arch prostheses. There were 3 differences between the 2 studies: the type of implant surface used, the loading protocol, and the average number of implants per prosthesis. The current study involved all TiUnite implants, except for the zygoma implants which currently are not available with the enhanced titanium oxide surface. In the present study, 62% of the implants were immediately loaded, whereas in the 1999 study, all implants were placed using the conventional 2-stage loading procedure. Finally, this study had an average number of 10 implants per prosthesis, which is an average of 1 implant more than the study performed in 1999. However, the addition of 1 implant per prosthesis did not appear to contribute to the increased survival rate seen in this study. Complete maxillary rehabilitation was achieved with as few as 7 implants in the current study.

The survival rate for the 164 pterygomaxillary implants placed in this study was 96.3% —8 percentage points higher than the 1999 study conducted with machined-surface implants. This difference was found to be statistically significant (analysis of variance; $P < .001$). Only 6 pterygomaxillary implants failed to osseointegrate in this report. Eighty of the 164 pterygomaxillary implants were immediately loaded in this study following the Teeth in a Day protocol. Three of these immediately loaded implants failed to osseointegrate (96.3% survival rate). A

96.4% survival rate was calculated for the remaining 84 implants, which were placed following the conventional 2-stage protocol. The comparable survival rates demonstrated between the 2 loading protocols support immediate loading as a viable option, even in the posterior maxilla, where the quality of bone may be poorer and the primary stability of the implant may be lower.

It is apparent from the data in this report and others in the literature[26–28,34,35] that a titanium oxide surface can be an effective surface in terms of achieving successful osseointegration, especially in the pterygomaxillary region, where bone is usually soft and primary stability is weak. The survival rate for all titanium oxide implants in this study was 98.6%; this is statistically significant from the 92.1% CSR seen in the 1999 report using machined-surface implants ($P < .001$).[18] If the pterygomaxillary positions are excluded, the survival rate for titanium oxide implants in this study was 99.0%, compared to the 93.0% success rate from the machined-surface implant study, which again is statistically significant ($P < .001$).

The time frame for this report (average of 2.6 years) and other studies regarding the titanium oxide surface on the implant are preliminary reports.

With an average postloading period of 2.6 years, this report and other reports regarding the titanium oxide surface[26–28, 34, 35] are preliminary reports. Longer follow-up studies have been reported for the machined surface; however, the TiUnite implant has not yet been in use long enough for long-term studies to have been completed. Long-term follow-up studies reporting high osseointegration rates similar to those indicated in this preliminary study are necessary to further validate these findings.

CONCLUSION

Pterygomaxillary implants are beneficial in restoring the entire maxillary arch with a prosthesis that is biomechanically stable and free of cantilevered pontics. Despite the compromised quality of bone and increased potential for force exerted on implants placed in the posterior maxilla, osseointegration can occur in the pterygomaxillary region and provide posterior bone support without sinus augmentation or supplemental grafting. The titanium oxide surface appears to enhance the bone remodeling process in all areas of the maxilla. Long-term follow-up studies that show consistent high osseointegration rates are necessary to further validate the data in this report.

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