A 10-Year Follow-Up Study of Titanium Dioxide–Blasted Implants

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ABSTRACT

Background: Dental implants with moderately rough surfaces are commonly used in the treatment of edentulous patients. However, long-term data on survival rates and marginal bone conditions are lacking.

Purpose: This prospective study evaluated the cumulative survival rate of the TiOblast™ implant (Astra Tech AB, Mölndal, Sweden) after 10 years of prosthetic loading.

Materials and Methods: A total of 199 TiOblast™ implants were placed in 36 consecutive edentulous patients (23 males and 13 females). All patients were treated at one clinic and by the same team. The patients were edentulous in either the maxilla (n = 16) or the mandible (n = 20). The average age of the patients at the start of the trial was 64 years (range, 59–82 years). Of the 199 implants inserted 108 were in the mandible and 91 were in the maxilla. Clinical evaluations were undertaken after completion of the prosthetic superstructure (baseline) and after 6 months, 1 year, 3 years, 5 years, 7 years, and 10 years. Mean marginal bone level was evaluated for the first 100 placed implants for up to 7 years.

Results: Six implants failed during the study (3 in the mandible and 3 in the maxilla). All failures occurred within the first year, giving a cumulative survival rate of 96.9% (96.6 % in the maxilla and 97.2 % in the mandible) after 10 years of follow-up. The survival rate for the superstructures was 100%. The mean marginal bone level in the measured sample was 0.2 mm (standard deviation [SD], 0.31) below the reference point at baseline, 0.28 mm (SD, 0.20) and 1.27 mm (SD, 1.15) below the same point 7 years later (mean, 0.15 mm per year).

Conclusion: This study showed that titanium dioxide–blasted implants offer predictable long-term results as supports for fixed prostheses in both the maxilla and mandible.

KEY WORDS: clinical study, dental implants, marginal bone resorption, survival analysis

A large number of long-term follow-up studies on implants with turned machined surfaces have been published over the years.[1–6] However, there is a lack of long-term studies on moderately rough implants. According to Albrektsson and Wennerberg a smooth implant surface has an average height of selected area (Sa value) of 0.5 to 1.0 μm, a moderately rough implant has an Sa value of 1 to 2 μm, and a rough implant has an Sa of > 2 μm.[7] Some clinical studies have reported high failure rates for machined implants in poor bone quality (eg, posterior segments in both jaws).[8,9]

In 1992 the first Astra Tech implants with a modified surface (TiOblast™, Astra Tech AB, Mölndal, Sweden) were tested in clinical trials. The screw-shaped implants are made from pure titanium (American Society for Testing and Materials [ASTM] grade 4) and are blasted with titanium dioxide (TiO_2) particles. The surface is moderately rough and has an Sa value of 1.10 μm.[10] The texture of this surface is highly uniform and has been proven to present a greater degree of bone-implant contact and regeneration of bone at defect sites when compared to a turned machined surface in experimental studies.[11,12] Additionally, a

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higher increase in stability as measured with resonance frequency analysis was found for the TiO_2-blasted implants than for turned machined components.[11] TiO_2-blasted implants have shown excellent clinical results in a 5-year study[13] even if the number of implants followed was rather small. To our knowledge moderately rough-surfaced implants placed both in the maxilla and the mandible have not yet been examined in long-term (10-year) studies.

The aim of the present investigation was to evaluate, after 10 years in function, the cumulative survival rates of 199 TiO_2-blasted implants placed both in the mandible and in the maxilla. Additionally, marginal bone level for the first 100 implants was analyzed for up to 7 years.

MATERIALS AND METHODS

This clinical investigation was designed as an open prospective study with a follow-up period of 10 years.

Patients

From June 1992 to March 1993, a total of 36 patients (23 men and 13 women) with edentulism in either the maxilla or the mandible were included in the study. The age distribution of the patients is shown in Figure 1. Patients were consecutively included, but all patients underwent a clinical and radiographic examination before inclusion. Exclusion criteria were a history of mental illness, chronic alcoholism, uncontrolled diabetes mellitus, and irradiation to the maxillofacial area. Four of the patients declared themselves to be smokers. If indicated, extractions were made at least 6 months before implant surgery. All patients had removable complete dentures in the edentulous jaw and had their own teeth or a fixed bridge in the opposite jaw. Written informed consent was obtained from all patients before they were included in the study. Treatment planning for all patients was carried out by means of plaster casts, panoramic radiography, and (for the maxillary cases) cross-sectional tomography. Patients were enrolled for annual clinical examinations including radiographic checkups. Three of the patients moved abroad; four patients called for great privacy and have therefore been observed only occasionally until the present examination in 2002. Three patients died from unrelated causes before 2002. At the 10-year follow-up, 28 patients, representing 155 implants, were examined.

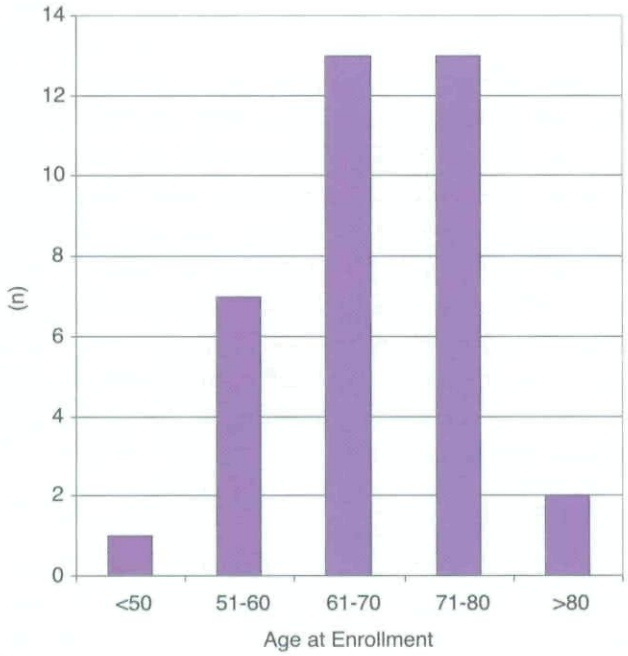

Figure 1 Age distribution.

Implants

Astra Tech implants (Astra Tech AB, Mölndal, Sweden) were used in the study. The fixtures are threaded, cylindrical, and self-tapping and were available in diameters of 3.5 and 4.0 mm. Both machined and TiO_2-blasted (TiOblast) fixtures were available from the manufacturer at the time of the study, but only TiOblast fixtures were used in the study. The lengths of the implants used were 11 mm, 13 mm, and 15 mm. The fixture-abutment connection is conical, and the upper part of the abutment has a 20°angled cone. The superstructure is screw-retained to the abutment. The distribution of the implants was 108 in the mandible and 91 in the maxilla.

Surgical Procedure

The surgical procedure was in two stages, and there was a healing period of 3 to 6 months before abutment connection. Fixture and abutment installations were performed with the patient under local anesthesia, and the alveolar crest was revealed via a crestal incision. Nonresorbable sutures (Supramid®, Resorba GmbH, Nuremberg, Germany) were used, and the sutures were removed after 10 days.

Radiographic Examination and Evaluation

Intraoral radiographic examinations were performed at baseline and annually thereafter, with a paralleling

technique. Care was taken to get a clear image of the threads on both sides of the implant. The first 100 implants placed were evaluated at baseline, after 1 year, and after 7 years. Each implant was evaluated separately with a light microscope equipped with a CCD camera. The image analysis program from the National Institutes of Health in the United States was used for measurements of the radiographs. Contrast and light were automatically optimized, whereafter the marginal bone level in relation to the reference point was measured. At each implant, the mesial and distal sides of the bone ridge meeting the implant were determined, and the distance from the reference point (ie, the uppermost point of the vertical coronal part of the implant) to the first bone in contact with the implant was noted (Figure 2). Bone levels above the reference point were registered as 0 (ie, zero).

Statistical Evaluation

Because not all patients could be accounted for at the 10-year follow-up, a life table analysis was performed to estimate the true outcome for the entire trial. The life table method compensates for the lost data due to dropout patients.

RESULTS

During the total observation time of 10 years, 6 of the installed implants failed (3 in the mandible and 3 in the maxilla). In the mandible the lengths of the lost implants were 13 mm (1 implant) and 15 mm (2 implants); in the maxilla the lengths of lost implants were 11 mm (2 implants) and 15 mm (1 implant). All failures occurred during the initial healing period, and the implants were removed at second-stage surgery. This gave a cumulative survival rate of 96.6% in the maxilla and 97.2% in the mandible after 10 years in function. The life table analyses are presented in Tables 1 to 3.

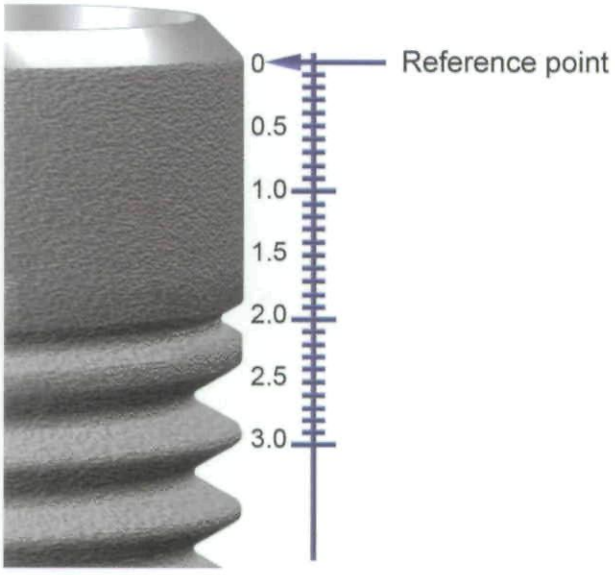

Figure 2 Reference point (mm).

Prosthetic Construction Survival

In one patient porcelain fractures occurred at several occasions, and the construction had to be remade. In another patient all bridge screws broke. A misfit of the construction was found to be the reason for the breakage. After adjustment of the bridge construction, the problem did not recur. All bridges remained in service at the end of the trial.

Soft Tissue Conditions

Slight periimplant mucosal redness was noticed around 6% of the implants at baseline. At two follow-up occasions one implant showed signs of more progressive soft tissue inflammation (ie, bleeding upon delicate probing around the implant); however, this did not increase the marginal bone loss for the implant. At the 10-year follow-up all sites appeared inflammation free.

Marginal Bone Changes

The mean marginal bone level at baseline was 0.2 mm (standard deviation [SD], 0.31; $n = 100$) from the reference point. The marginal bone loss around the implants was small, on average 0.28 mm (SD, 0.20; $n = 89$) from the reference point the first year after loading. The mean marginal bone loss around the implants was 1.27 mm (SD, 1.15; range, 0–5.21 mm; $n = 68$) after 7 years (Figures 3 and 4). The vast majority of the implants experienced negligible bone height changes during the observation period. There tended to be a higher degree of marginal bone resorption among the smokers, but this difference was not statistically significant.

DISCUSSION

The TiO_2-blasted implants functioned well in this long-term study of fixed prostheses. Only 3 of the 108 mandibular implants and 3 of the 91 maxillary implants were lost. The high cumulative survival rates of 97.2%

TABLE 1 Life Table Analysis of the Outcome over 10 Years of Observation: All Implants (*N* = 199)

Followed Up to: (yr)	Number at Interval Start	Number at Risk	Withdrawn Implants (Total, including Dropouts and Failures)	Failed Implants in Interval	Cumulative Survival Rate (%)
1	199	195	8	6	96.9
2	191	186	10	0	96.9
3	181	176	10	0	96.9
4	171	165.5	11	0	96.9
5	160	160	0	0	96.9
6	160	160	0	0	96.9
7	160	160	0	0	96.9
8	160	157.5	5	0	96.9
9	155	155	0	0	96.9
10	155	155	0	0	96.9
11	155	77.5	65		

in the mandible and 96.6% in the maxilla after 10 years in function can be considered very satisfactory. These survival rates are similar to or better than those found in earlier studies that evaluated the predictability of implant systems[14–17]; however, the follow-up period was longer in the present study. In a review and meta-analysis of the incidence of complications in implant dentistry, Berglundh and colleagues found overall survival rates of 94.05 to 95.12% in prospective studies of at least 5 years.[18]

All of the six failed implants in the present study were removed at the second surgery because they were found to be mobile at the abutment connection. Of the patients with failures, one patient had one implant in the maxilla removed. It was suspected that the implant had been traumatically loaded by the temporary prosthesis. The same patient has repeatedly fractured the veneer (porcelain) of the fixed restoration, which has been remade.

Another patient, with a history of severe periodontal disease and with poor bone volume and quality, lost two maxillary implants. One patient was provided with an extra implant in the mandible because of questionable bone volume for supporting the future

TABLE 2 Life Table Analysis of the Outcome over 10 Years of Observation: Maxillary Implants (*N* = 91)

Followed Up to: (yr)	Number at Interval Start	Number at Risk	Withdrawn Implants (Total, including Dropouts and Failures)	Failed Implants in Interval	Cumulative Survival Rate (%)
1	91	88.5	5	3	96.6
2	86	84	4	0	96.6
3	82	79	6	0	96.6
4	76	70.5	11	0	96.6
5	65	65	0	0	96.6
6	65	65	0	0	96.6
7	65	65	0	0	96.6
8	65	65	0	0	96.6
9	65	65	0	0	96.6
10	65	65	0	0	96.6
11	65	32.5	65	0	

TABLE 3 Life Table Analysis of the Outcome over 10 Years of Observation: Mandibular Implants (*N* = 91)

Followed Up to: (yr)	Number at Interval Start	Number at Risk	Withdrawn Implants (Total, including Dropouts and Failures)	Failed Implants in Interval	Cumulative Survival Rate (%)
1	108	106.5	3	3	97.2
2	105	102	6	0	97.2
3	99	97	4	0	97.2
4	95	95	0	0	97.2
5	95	95	0	0	97.2
6	95	95	0	0	97.2
7	95	95	0	0	97.2
8	95	92.5	5	0	97.2
9	90	90	0	0	97.2
10	90	90	0	0	97.2
11	90	45	35		

construction; this implant was not stable at second surgery and was therefore removed. For unknown reasons two mandibular implants in two patients were removed at second surgery.

The survival rate for implants in the maxilla in the present study (96.6%) is better than rates observed in earlier long-term studies with machined implants.[9,19] It can be speculated that implants with a TiO_2-blasted surface have a slightly better prognosis in low-density bone than do those with a smooth machined surface. On the other hand the results in the present long-term study are also slightly better than the outcomes for other moderately rough implants that were followed for only 3 years.[17]

In a prospective comparative study of Astra Tech implants and Brånemark implants (Nobel Biocare AB, Göteborg, Sweden), the survival rate after 3 years was

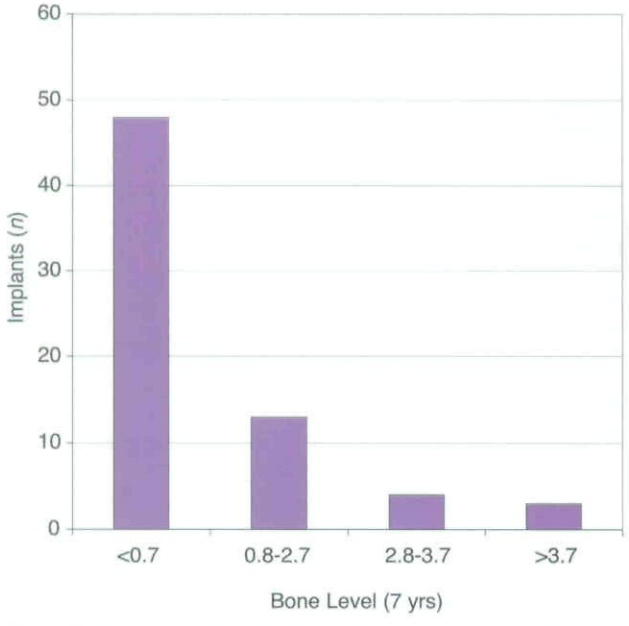

Figure 3 Frequency distribution of the mean radiographic bone level after 7 years (n = 68).

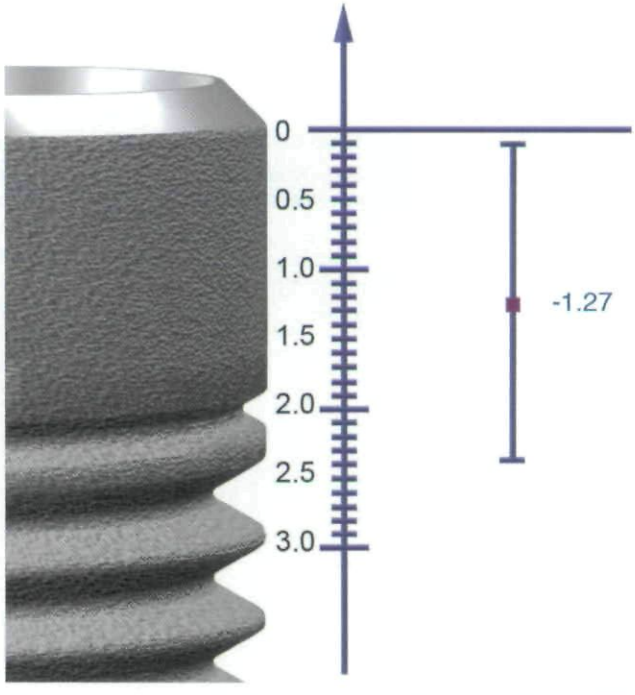

Figure 4 Mean marginal bone level after 7 years, 1.27 mm (SD 1.15 mm) from reference point.

98.9% for the Astra Tech system and 95.2% for the Brånemark system.[20] The difference in survival rates between the two systems was statistically significant. With respect to the mean marginal bone levels after 3 years in the same study, Astra Tech implants had a slightly higher bone level than did Brånemark implants. However, the difference between the systems was not statistically significant. In the present study, the marginal bone loss was on average 0.28 mm during the first year, and then there was a slow progression, reaching a mean of 1.27 mm after 7 years. This means an annual bone loss of approximately 0.15 mm, which confirms other reports of stable marginal conditions for TiO_2-blasted implants.[13,21,22] The stable marginal conditions may be explained by several factors, such as the implant surface, where the roughness is believed to increase the interlocking capacity between bone and titanium, but also such as the healing of the soft tissue around the implants. On the other hand, in a prospective 5-year study of machined turned and TiO_2-blasted Astra Tech implants, no significant differences were found in survival rates or marginal bone loss.[23]

The one-piece abutment system and the conical relation between fixture and abutment make the circulation of bacteria unlikely, which can explain the rarity of clinical signs of periimplant inflammation in the present study. A third factor that may influence the marginal bone level is the load transfer in a conical fixture-abutment interface situation. The load is transferred to an inner conical surface on the fixture, which decreases interfacial shear stress at the top of the fixture neck.[24,25]

CONCLUSION

The present study showed that TiO_2-blasted implants offer predictable long-term results as support for fixed prostheses in both the maxilla and the mandible.

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