Survival and Success of Sandblasted, Large-Grit, Acid-Etched and Titanium Plasma-Sprayed Implants: A Retrospective Study

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ABSTRACT

Objectives: The primary objective of this open, retrospective, nonrandomized study was to evaluate survival and success rates for sandblasted, large-grit, acid-etched (SLA) and titanium plasma-sprayed (TPS) implants placed by a single practitioner. The secondary objectives included evaluation of crestal bone loss and adverse events.

Materials and Methods: Implants were placed by a single practitioner between April 1994 and December 2005. All clinical data, including information about adverse events, were entered into an electronic database. Outcomes were evaluated with Kaplan–Meier survival and life table analyses.

Results: Over the study period, 342 patients received a total of 836 implants, comprising 533 SLA and 303 TPS implants. Maximum and median follow-up times were 7.2 and 0.8 years, respectively, for patients with SLA implants and 9.7 and 4.6 years, respectively, for those with TPS implants. A greater proportion of SLA implants than TPS implants were placed in type IV bone. Overall, 807 (96.5%) of the implants met the survival criteria, and 795 (95.1%) were classified as successful. Failure rates were 2.6% (14/533) for SLA implants and 5.0% (15/303) for TPS implants. Early failure rates (less than 1 year after implantation) were 2.1% (11/533) for SLA implants and 3.0% (9/303) for TPS implants. Kaplan–Meier survival and life table analyses showed similar cumulative survival rates for the 2 types of implants at up to 5 years. Crestal bone loss was more common with TPS implants than with SLA implants, affecting 27 (8.9%) of the TPS implants and 14 (2.6%) of the SLA implants. Complication rates were 7.7% (41/533) for the SLA implants and 13.5% (41/303) for the TPS implants.

Discussion and Conclusions: SLA and TPS implants had similarly good clinical outcomes in this retrospective study, but the frequency of crestal bone loss was lower among the SLA implants. Continued observation of SLA implants is required to confirm these findings over the long term.

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The surface characteristics of dental implants are recognized as an important factor in achieving rapid and reliable osseointegration.[1–5] Surfaces roughened by coating, surface blasting or acid treatments have greater contact between bone and implant than those with smoother, machined finishes[2,6]; roughened surfaces also have a greater rate and degree of osseointegration,[7,8] all of which results in harder, stiffer bone.[9]

As a consequence, the implants have greater resistance to dislodging forces,[1,6,10–12] which in turn translates into improved clinical performance for a range of patient indications,[2,13] along with superior survival and success rates.[4,14–16]

The good clinical outcome for titanium plasma-sprayed (TPS) implants has been well documented over the past 2 decades.[17] Recently, however, the micro-roughened surface of sandblasted, large-grit, acid-etched (SLA) implants has been shown to have even better early osseointegration. In animal studies, mean bone–implant contact was 30%–40% for TPS implants but 50%–60% for SLA implants.[18] Comparisons of the 2 surfaces in a canine study showed that, relative to TPS implants, SLA implants were associated with significantly less bone loss, measured radiographically, before and 3 months after loading,[19] a difference that persisted for at least 1 year after loading. These results were confirmed by histological studies in which the percentage of bone–implant contact after 3 and 15 months of healing was significantly greater for SLA implants than for TPS implants.[20] It was concluded that SLA implants "promote greater osseous contact at earlier time points compared to TPS-coated implants." In addition, in biomechanical tests, SLA implants had higher removal torque values than TPS implants.[1]

Several investigators have presented favourable clinical outcomes for SLA implants after early loading (6 weeks after implantation).[21–28] In particular, Baker and coworkers[10] suggested that early integration strength could be particularly advantageous in single-stage surgical protocols.

The aim of this open, retrospective, nonrandomized study was to evaluate the clinical outcome of SLA and TPS implants over time in a single private practice. The secondary objectives included the evaluation of crestal bone loss and adverse events.

Materials and Methods

All implants were placed by a single periodontist in one dental centre in Toronto, Ontario, between April 1994 and December 2005.

Patients, Treatments and Follow-up Examinations

The clinical indications for treatment included replacement of single teeth and rehabilitation of partially or fully edentulous arches with bridges or overdentures. The criteria for placement of an implant comprised a minimum bone height of 7 mm at the surgical site and the absence of medical contraindications to surgery. No patients were excluded from undergoing surgery because of smoking.

Stage 1 surgery (implantation) was performed according to a strict surgical protocol, following the manufacturer's instructions. The basic principles of this method have been described by Buser and others.[29] Most of the implants were placed 3 months or more after tooth extraction, although some were placed within 6 weeks, the exact timing depending on bone quality. A nonsubmerged technique was used for all implants, and both SLA and TPS implants were loaded about 3 months after placement.

The patients were examined 1 week and 3 weeks after placement of the implants, again at 3–4 months (the stage 2 visit, for verification of osseointegration) and then shortly after completion of the prosthetic treatment. Thereafter, follow-up was conducted annually.

Assessments

At review appointments, implants were tested manually for mobility and were examined for signs of infection.

Crestal bone loss was assessed by manual probing and also by periapical radiographs, obtained by a nonstandardized, long-cone paralleling technique with use of an XCP positioner (Dentsply Rinn, Elgin, Ill.). Crestal bone loss (from baseline to the end of the observation period) was categorized as follows: 0 to 1 mm, > 1 to 2 mm, > 2 to 3 mm, > 3 to 4 mm, > 4 to 5 mm and > 5 mm. Implants were considered successful only if crestal bone loss was no more than 4 mm.

Any adverse events reported by the patients were recorded. Other assessments included oral hygiene and periodontal status, although the findings were documented only if they were considered outside the normal range.

Implant Outcome (Success, Survival and Failure Criteria)

Implants were classified in 1 of the following 3 categories according to outcome.

Surviving implant: Implant that remained in situ and in function, whether or not there were any complications, such as exudate, facial space abscess, local implant fistula, pain or swelling at the implant site, purulence, peri-implant radiolucency and/or crestal bone loss greater than 4 mm.

Successful implant: Surviving implants that also fulfilled the following criteria (adapted from Albrektsson and others,[30] Buser and others[17] and Cochran and others[27]):

- absence of mobility, assessed manually and by a manual torque test
- absence of peri-implant radiolucency
- absence of continuous pain or suppuration around the implant
- absence of deep (> 5 mm) pockets adjacent to the implant
- bone loss < 4 mm

Failed implant: Implant that had been removed for any reason, e.g., pain, mobility or advanced bone loss. Early failures were those occurring up to 1 year after the

Table 1 Distribution of implant designs according to implant type

Design	SLA implants *n* = 533 (%)	TPS implants *n* = 303 (%)	All implants *n* = 836 (%)
Angled (hollow) cylinder esthetic	0	9 (3.0)	9 (1.1)
Angled (hollow) cylinder	0	1 (0.3)	1 (0.1)
Narrow neck	1 (0.2)		1 (0.1)
Small diameter (3.3 mm diameter)	0	77 (25.4)	77 (9.2)
Small diameter, esthetic	1 (0.2)	0	1 (0.1)
Small diameter SLA (3.3 mm diameter)	62 (11.6)	0	62 (7.4)
Solid screw esthetic (4.1 mm diameter)	13 (2.4)	0	13 (1.6)
Solid screw standard (4.1 mm diameter)	0	166 (54.8)	166 (19.9)
Solid screw esthetic SLA (4.1 mm diameter)	21 (3.9)	0	21 (2.5)
Solid screw standard SLA (4.1 mm diameter)	271 (50.8)	0	271 (32.4)
TE implants 4 mm	78 (14.6)	0	78 (9.3)
Wide-body implants (4.8)	0	27 (8.9)	27 (3.2)
Wide neck	0	2 (0.7)	2 (0.2)
Wide-body SLA	59 (11.1)	0	59 (7.1)
Wide-neck SLA	48 (9.0)	0	48 (5.7)
Total	533 (100)	303 (100)	836 (100)

SLA = sandblasted, large-grit, acid-etched; TPS = titanium plasma-sprayed; TE = tapered effect.

surgery but before prosthetic restoration. Late failures were those occurring more than 1 year after implant placement or after restoration.

Statistical Analysis

All clinical data were entered into an electronic database (Triton DIMS; Martin Lumish, Yorktown Heights, N.Y.).

For surviving implants, the last follow-up date was defined as the date of last follow-up visit. If complications occurred, the time from implant placement to the most recent date of follow-up without complications was used to define the point at which the complication occurred.

The follow-up time (time to outcome) was calculated using the Kaplan–Meier survival function analysis. Life table analysis was undertaken, and cumulative survival rates were calculated according to the method of Smith.[31]

The statistical analysis was performed with SPSS software, versions 12 and 14 (SPSS Inc, Chicago, Ill.).

Results

Over the study period, 342 patients received a total of 836 implants, 533 of the SLA type and 303 of the TPS type (**Table 1**). The patients consisted of 152 males (44.4%) and 190 females (55.6%), with a mean age (± standard deviation [SD]) of 57.2 ± 12.8 years (range 13–95 years).

The number of implants per patient ranged from 1 to 18 (mean 2.4, SD 1.9, median 2). A total of 311 patients received only 1 type of implant (SLA or TPS), whereas 31 patients received both types.

The maximum follow-up was 2,656 days (7.2 years) for SLA implants (median 290 days or 0.8 years) and 3,548 days (9.7 years) for TPS implants (median 1,673 days or 4.6 years).

Of the 836 implants, 126 were placed in an edentulous arch (28 patients), and 710 were used for single-tooth replacements or partially edentulous indications. Of the 126 implants placed in edentulous patients, 89 (70.6%) were of the SLA type and 37 (29.4%) were of the TPS type. The distribution was 62.4% (443/710) and 37.6% (267/710), respectively, for SLA and TPS implants used for single-tooth replacements and partially edentulous patients.

The distribution of SLA and TPS implants in the maxillary and mandibular arches is represented in **Fig. 1**. Overall, the SLA implants had a greater diameter than the TPS implants, whereas the TPS implants were generally longer than the SLA implants (**Fig. 2**).

A greater proportion of SLA implants (230/533 or 43.2%) involved placement in type IV bone, compared with TPS implants (58/303 or 19.1%) (**Table 2**).

The overall use of bone grafts was similar for SLA and TPS implants (59/533 or 11.1% and 24/303 or 7.9%, respectively).

Outcomes

Of the 836 implants placed, 807 (96.5%) survived and 795 (95.1%) met the criteria for success at the end of follow-up. Of the 29 failed implants (3.5%), 20 (69%) occurred early and 9 (31%) presented late (after restoration).

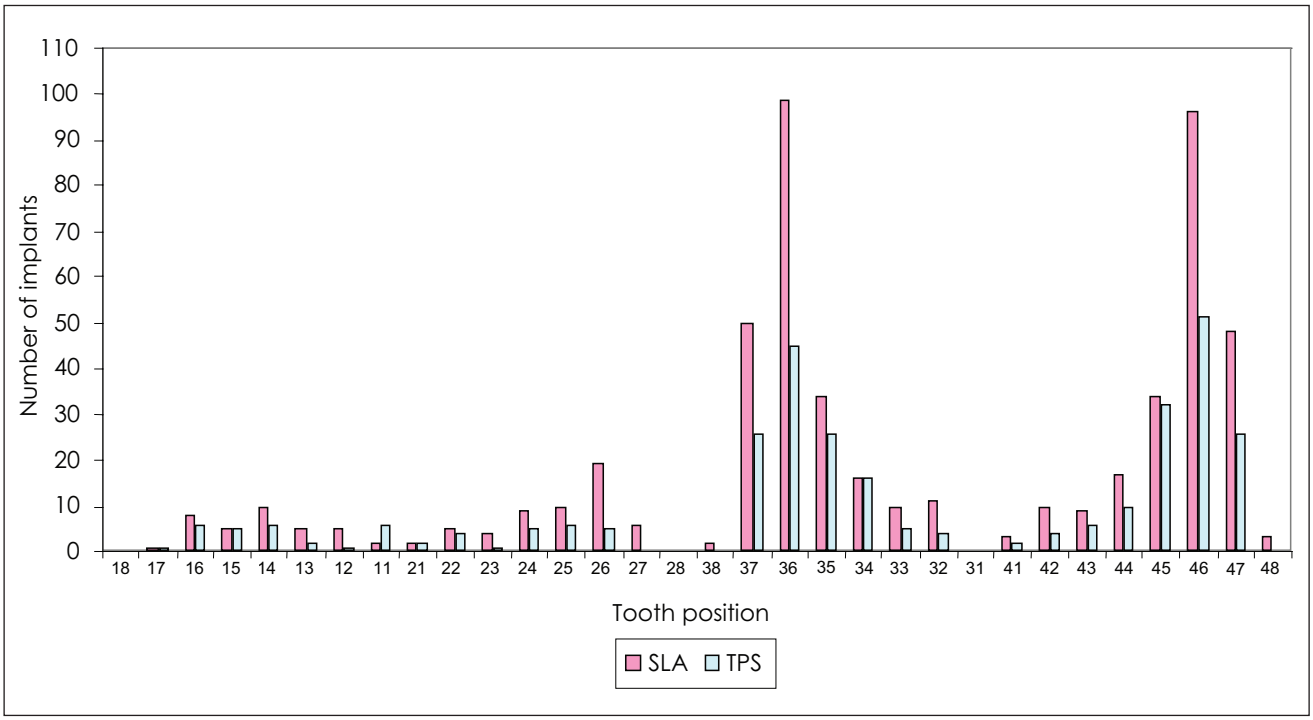

Figure 1: Distribution of sandblasted, large-grit, acid-etched (SLA) and titanium plasma-sprayed (TPS) implants

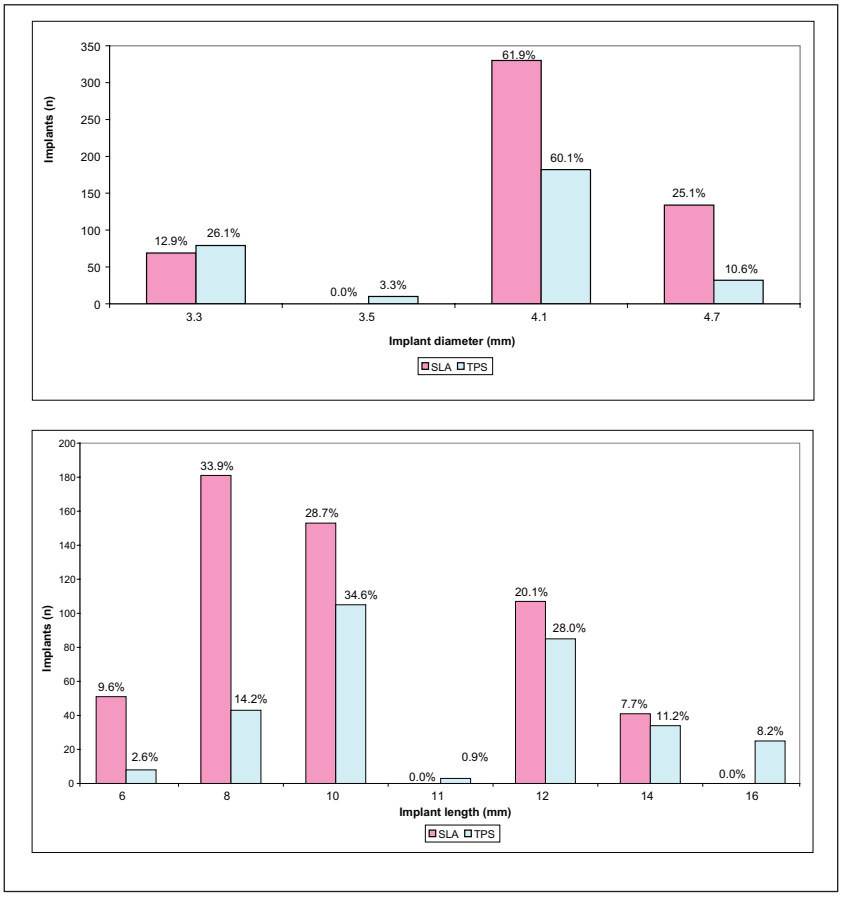

Figure 2: Distribution of sandblasted, large-grit, acid-etched (SLA) and titanium plasma-sprayed (TPS) implants according to diameter (top) and length (bottom)

Of the 533 SLA implants, 519 (97.4%) survived, 512 (96.1%) were successful, and 14 (2.6%) failed. Of the 303 TPS implants, 288 (95.0%) survived, 283 (93.4%) were successful, and 15 (5.0%) failed. Early failure rates (less than 1 year after implantation) were 2.1% (11/533) and 3.0% (9/303) for the SLA and TPS implants, respectively.

Life Table Analysis

Life table analysis showed that, over time, the performance of the SLA and TPS implants was similarly good (**Table 3**). The cumulative proportion of successful and surviving implants after 2 and 4 years was 96.1% for both SLA and TPS implants. Implants for which 2 and 4 years of follow-up was completed totalled 123 and 35, respectively, in the SLA group and 238 and 178 in the TPS group (**Table 3**). One failure occurred among the 178 TPS implants that were followed for between 4 and 5 years, which resulted in a cumulative survival rate after 5 years of 95.4% for this type of implant. Although some implants were followed for longer periods (up to 9–10 years), these longer-term survival data are not presented

Table 2 Implant failures relative to bone quality, as number and percentage data[a]

	SLA implants (n = 533)		TPS implants (n = 303)	
Bone quality	**Total**	**Failures**	**Total**	**Failures**
Type I	2 (0.4)	1 (50)	14 (4.6)	3 (21.4)
Type II	17 (3.2)	0 (0)	55 (18.3)	6 (10.9)
Type III	279 (52.3)	7 (2.5)	174 (57.4)	4 (2.3)
Type IV	230 (43.2)	6 (2.6)	58 (19.1)	2 (3.4)

SLA = sandblasted, large-grit, acid-etched; TPS = titanium plasma-sprayed.
[a]*The percentages in the "Total" columns are calculated on the basis of the number of each type of implant (533 SLA and 303 TPS implants); bone quality was not available for 7 of the implants (5 SLA and 2 TPS implants). For the data on failures, the percentages are calculated according to the number of implants in each bone type.*

Table 3 Life table analysis of SLA and TPS implants

Time interval (since implantation)	No. entering interval	No. withdrawn during interval[a]	No. exposed to risk[b]	No. of failures	Interval survival rate[b] (%)	Cumulative survival rate[b] (%)
SLA implants						
0–1 years	533	292	387	11	97.2	97.2
1–2 years	230	105	177.5	2	99.0	96.1
2–3 years	123	62	92	0	100	96.1
3–4 years	61	26	48	0	100	96.1
4–5 years	35	16	27	0	100	96.1
TPS implants						
0–1 years	303	32	287	9	96.9	96.9
1–2 years	262	22	251	2	99.2	96.1
2–3 years	238	36	220	0	100	96.1
3–4 years	202	24	190	0	100	96.1
4–5 years	178	68	144	1	99.3	95.4

SLA = sandblasted, large-grit, acid-etched; TPS = titanium plasma-sprayed
[a]*Number of implants with observation periods shorter than the particular time interval.*
[b]*Number of cases entering the respective interval, minus half the number of cases lost or censored in the respective interval.*[31]
[c]*For implants with the outcomes of survival and success.*

in Table 3, because of the relatively high proportions of censoring (i.e., implants not completing the observation period that were recorded in each time interval, which would reduce the robustness of the results).

Crestal Bone Loss

Crestal bone loss affected 27 (8.9%) of the TPS implants and 14 (2.6%) of the SLA implants. Of the 27 cases of crestal bone loss with TPS implants, a total of 15 (55.6%) involved loss of 0 to 1 mm (6 cases or 22.2%) or > 1 to 2 mm (9 cases or 33.3%). In contrast to the situation for SLA implants, some TPS implants showed progression of crestal bone loss over time; hence, a total of 44 episodes of crestal bone loss were recorded among the 27 TPS implants affected by this type of bone loss. In total, 43 of these 44 observations were made 1 year or more after implantation, whereas only 7 of 14 observations of crestal bone loss with SLA implants occurred in this timeframe. The number of episodes of crestal bone loss reported during the first 2 years was 11 (2.1%) for SLA implants and 19 (6.3%) for TPS implants; the number of episodes reported during the first 4 years was 12 (2.3%) for SLA implants and 28 (9.2%) for TPS implants. Overall, crestal bone loss exceeded 4 mm in 7 (1.3%) of the SLA implants and 4 (1.3%) of the TPS implants.

The implant design types most commonly affected by crestal bone loss were the solid screw standard 4.1-mm diameter, the wide-body implant 4.8-mm diameter and the wide-body SLA implant, with crestal bone loss frequencies of 21/166 (12.7%), 2/27 (7.4%) and 4/59 (6.8%), respectively.

Adverse Events

A total of 82 complications were reported, 41 (7.7%) affecting SLA implants and 41 (13.5%) affecting TPS implants.

Among the SLA implants, 11 (26.8%) of the complications occurred at stage 1 and 23 (56.1%) at stage 2; 7 (17.1%) were observed at follow-up visits. Most of the complications were related to loose, lost or unseated abutments (n = 8), implant mobility (n = 5), periapical bone loss (n = 3) and rotation (n = 8), the latter defined as cases in which the implant lacked initial stability and could be rotated with hand pressure. All of the rotations occurred in just 2 patients, and all occurred at stage 2. Seven of these rotatable SLA implants were ultimately successful; only 1 failed.

Among the TPS implants, 17 (41.5%) of the 41 complications occurred at stages 1 or 2, with the remainder distributed among visits 1 to 6. The most frequent complications were loosening, loss, unseating or fracture of the abutment or prosthesis (n = 19), rotations (n = 8) and early implant mobility (n = 4). TPS implants in posterior mandibular sites were more prone to complications than those in other locations.

Discussion

In this retrospective study, life table analyses showed equally good survival rates for SLA and TPS implants. The good clinical outcome of both SLA and TPS implants reported here is broadly consistent with the literature,[28,32] although recent investigators have focused chiefly on the performance of early-loaded SLA implants.[21,22] In the current study, the cumulative survival rates for SLA and TPS implants were equivalent after 4 years, at 96.1%.

In this single private practice study, one finding of interest was the substantial difference in overall failure rate for SLA and TPS implants (2.6% and 5.0%, respectively). Although it is not possible to draw any firm conclusions about relative failure rates from these data, the findings might be of clinical relevance, given that the SLA implants had about 50% fewer failures than the TPS implants. The possibility of a significant difference in failure rate merits further investigation in a multicentre setting, with long-term follow-up.

Overall, the TPS implants were associated with a higher frequency of crestal bone loss than the SLA implants. Although this result might have been influenced by the disparity in observation periods for the 2 types of implant, the difference was notable at 2 years (2.1% versus 6.3%) for SLA and TPS implants, respectively, and at 4 years (2.3% versus 9.2%). Furthermore, progression of crestal bone loss was observed with TPS but not SLA implants. This result is similar to data from comparative studies in animals, in which crestal bone loss was less for SLA than for TPS implants.[19] However, the proportion of implants with more than 4 mm of crestal bone loss was equivalent in the 2 groups (1.3%).

Rotations were an early (stage 2) complication for a small proportion (1.5%) of SLA implants in this study, but were not observed among TPS implants. Just 2 individuals accounted for a total of 8 SLA rotations, 1 of which resulted in implant failure. The failed implant was 1 of 6 anterior maxillary implants (all of which rotated) in a patient with type IV bone. However, the remaining implants that underwent rotation experienced no further complications and fulfilled the criteria for success at the end of the observation period. Rotation of SLA implants has been observed in studies of early loading, and the results suggest that this complication may have little or no impact on outcome, particularly if additional healing time is allowed.[21,22,27] Cochran and others[27] reported successful restoration of rotating implants, whereas Roccuzzo and others[28] and Salvi and others[21] reported that, after 1 year, early "spinners" were indistinguishable, radiographically and clinically, from other implants.

A limitation of this analysis is the shorter follow-up time for SLA implants relative to TPS implants: far fewer SLA implants than TPS implants were followed for more than 3 years. This difference was due to the later commercial availability of SLA implants. Furthermore, because this was an open, retrospective study in a "real-life" practice setting, it was not feasible to correct for the possible influence of splinting or multiple implants on implant outcomes, as would be appropriate in a randomized prospective study.

Other potential drawbacks of the practice setting for this study include the possibility of errors in patients' charts and bias associated with patients dropping out (patients may be more likely to return for follow-up appointments if they are very satisfied or, conversely, very dissatisfied). In addition, assessor bias is a potential risk in a single-handed practice study.

It could be argued that the good outcomes achieved with SLA implants in this study reflect the clinical expertise and experience gained by the author during previous years working with TPS implants, rather than the performance of the newer implant type. However, the author had almost 10 years of experience in implantology before using the implant types featured in this study; as such, it is unlikely that clinical experience was an important factor influencing implant outcome.

Conclusions

In this retrospective study of 533 SLA and 303 TPS implants, cumulative survival rates were equally good for the 2 implant types. However, the failure rate for SLA implants was lower than that for TPS implants; this finding, if substantiated in long-term follow-up, could be of considerable clinical relevance. The frequency of crestal bone loss was lower for SLA implants than for TPS implants. Given that the mean follow-up time was shorter for SLA than for TPS implants, continued observation is required to establish the long-term clinical outcome of SLA implants.

THE AUTHOR

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