A 5-Year Prospective Study of Single-Tooth Replacements Supported by the Astra Tech® Implant: A Pilot Study

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ABSTRACT

Background: Implant-supported single-tooth replacements are an increasingly used method to replace teeth, especially in young patients. Therefore, long-term validation of different treatment modalities with different implant systems is of great importance.

Purpose: The aim of the present study was to make a biologic, technical, and aesthetic evaluation of single-tooth replacement supported by the Astra Tech® implant (Astra Tech AB, Mölndal, Sweden) during a 5-year period.

Materials and Methods: Twenty patients were divided into two consecutively treated groups. In group A the implants were placed ''early'' in the extraction sockets, and standard single-tooth abutments were used. In group B the implants were placed ''delayed,'' and preparable abutments were used. Clinical examinations including registration of plaque, bleeding, crown lengths, soft tissue marginal level, papilla height, complications, and radiography were performed yearly. At the 3-year control examination the patient and a dentist evaluated aesthetic appearance with a visual analog scale.

Results: An implant survival rate of 100% and a crown survival rate of 95% over a period of 5 years were found. The mean loss of marginal bone adjacent to implants and neighboring teeth was less than 0.5 mm during the 5-year period, and there was no significant difference after crown placement between the treatment modality for group A and that for B. There were fewer clinical complications and repairs in group B than in group A. Soft tissue dimensions were more natural around implant crowns in group B as compared to group A, but this was not reflected in the patients' satisfaction with aesthetic appearance. On the other hand the dentist judged the restorations in group B higher concerning aesthetics than in group A.

Conclusion: Implant-supported single-tooth replacement with the Astra Tech system is a reliable treatment resulting in a good 5-year prognosis and only few complications.

KEY WORDS: dental implant, implant-supported single-tooth replacement, marginal bone loss, prognosis, single-tooth implant, soft tissue dimensions, visual analog scale

Osseointegrated implants for the treatment of the edentulous jaw have been very well documented.[1,2] It is tempting to extrapolate these results to implant-supported single-tooth replacements, but there are differences between edentulous and partially edentulous patients, and these differences may have an impact on the final result. The presence of adjacent teeth and the difference in occlusal forces and prosthetic designs may influence the results. Furthermore the replacement of one tooth may be a great aesthetic challenge, and in contrast to the majority of cases of patients with edentulous jaws, single-tooth replacements are frequently performed in young patients. Success rates of single-tooth replacements supported by implants have been very promising and have been better than for implant-supported fixed partial prostheses in the edentulous jaw, especially for implants placed in the upper jaw.[3–7] In a meta-analysis by Esposito and colleagues, consisting of 13 studies, 19 failures were reported among 781 implants, with loading

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times of 3 months to 8 years.[8] Another meta-analysis, by Lindh and colleagues, reported a survival rate of 97% after 6 to 7 years among 570 single-tooth implants from nine studies and a loading time of 1 to 8 years.[9] In these meta-analyses no difference between the upper and the lower jaw was reported. However, a number of the included studies were retrospective and dealt with only one implant system over a short period of time. Therefore, more long-term results from prospective studies with different implant systems are needed.

It is also important to recognize that the success of a single-tooth replacement depends not only on implant survival but also on other biologic, technical, and aesthetic criteria. Such criteria could include changes in marginal bone level at the teeth adjacent to the implant, soft tissue measurements, prosthetic complications, and aesthetic measurements and opinions.

The aim of the present study was to make a biologic, technical, and aesthetic evaluation of implant-supported single-tooth replacements during a 5-year period.

MATERIALS AND METHODS

Patients and Implant Treatment Procedures

A total of 20 patients were recruited for the study and divided into two consecutively treated groups. Both groups consisted of 10 patients (5 men and 5 women). The first 10 treated patients (group A) had a mean age of 35 years (range, 19–59 years) at implant installation whereas the mean age in group B was 31 years (range, 18–57 years). The inclusion criteria for both groups were good health and a need for single-tooth replacement in the anterior region of the upper jaw. All patients were to have good tooth arch stability and no periodontal disease or temporomandibular dysfunction. Skeletal growth, evaluated by hand radiography, was to be complete. Furthermore, a minimal mesiodistal bony width of 6.5 mm and a vertical height of at least 10 mm were to be available. The regions for implant placement are listed in Table 1; causes of the tooth loss are listed in Table 2. All root fractures were in endodontically treated teeth.

Group A patients were given Astra Tech ST® implants (Astra Tech AB, Mölndal, Sweden) in 3 lengths: 11 mm (1 implant), 13 mm (3 implants), and 15 mm (6 implants). All implants were placed in the extraction socket 4 weeks after tooth extraction (early implant placement). The extraction socket was closed immediately after extraction by elevation of the soft tissue. At implant installation the upper limit of the implant was leveled with the crest of the extraction socket. The distance from the implant-abutment connection to the proximal cementoenamel junction of the neighboring teeth was measured with a caliper gauge (Figure 1). The bone defects around the implant were covered with a GORE-TEX® membrane (W.L. Gore & Associates Inc., Flagstaff, AZ, USA). A healing abutment was placed 6 months after implant installation and was replaced by a first-generation Astra Tech single-tooth abutment. An acrylic removable partial denture was used as temporary replacement from tooth extraction to final restoration.

TABLE 1 Replaced maxillary teeth

	Group A	Group B
Central incisor	5	9
Lateral incisor	1	1
Canine	2	0
Premolar	2	0
Total number	10	10

Group B patients were also given Astra Tech ST implants in 3 lengths: 11 mm (1 implant), 13 mm (4 implants), and 15 mm (5 implants). All implants were placed after a healing period of 12 weeks, and no soft tissue closure was performed after extraction. At implant installation the upper limit of the implants was leveled with the mesiodistal bone crest. The distance from the implant-abutment connection to the proximal cementoenamel junction of the neighboring teeth was measured with a caliper gauge (see Figure 1). The buccal bone dehiscence was covered with a GORE-TEX membrane. A healing abutment was inserted 6 months after implant placement, with the same technique as used for the patients in group A. Thereafter a first-generation preparable abutment from Astra Tech was

TABLE 2 Cause of tooth loss

	No. of Patients	
Diagnosis	Group A	Group B
Root fracture	8	7
Agenesi	2	1
Trauma (Exarticulatio)	0	2
Total	10	10

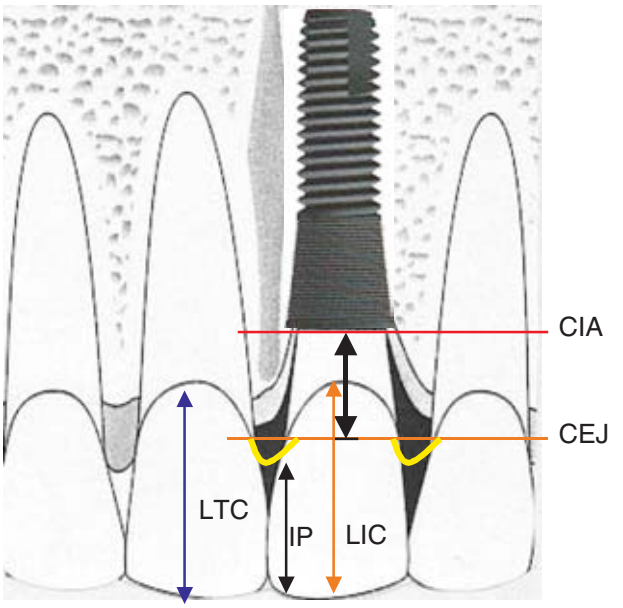

Figure 1 Reference points and distances of clinical and radiologic measurements. (CEJ = cementoenamel junction; CIA = connection between implant and abutment; IP = distance from incisal edge of implant crown to top of papilla; LIC = length of implant crown; LTC = length of contralateral natural tooth crown).

used for prosthetic restoration in patients in group B (Figure 2A). The preparation was performed 1.5 mm submucosally around the tooth. Resin-bonded bridges were placed immediately after implant installation as temporary replacements until the final restoration.

In both groups the final restoration was a single porcelain-fused-to-metal crown cemented to the abutment (see Figures 2A and B). To avoid unfavorable loading of the implants and crowns, the occlusal scheme was designed to have only light centric occlusion (ie, implant crowns were relieved, corresponding to a 40 μm occlusal foil). No lateral guidance or balancing contacts were created at the implant crowns.

Clinical Examination

The baseline examination was performed 1 week after cementation of the single crown. At the baseline and yearly follow-up examinations, the presence or absence of visible plaque at the soft tissue margin was registered. The bleeding index was recorded according to the criteria defined by Mombelli and colleagues.[10] The clinical examinations also included the following assessments (see Figure 1):

1. Length of the implant crown (ie, the distance between the most apical point of the soft tissue margin and the incisal edge of the implant crown)
2. Length of the contralateral natural tooth (ie, the distance between the most apical point of the soft tissue margin and the incisal edge of the natural contralateral crown)
3. Distance from the incisal edge of the implant crown to the top of the mesial and distal papilla

Intraoral radiography was performed with film holders and paralleling technique at the baseline examination and yearly follow-up examinations. The marginal bone level was estimated from the radiographs, with reference set at the implant-abutment connection. The distance from the implant-abutment connection to the cementoenamel junction of the neighboring teeth was also measured on the baseline radiographs (see Figure 1).

Periimplant radiolucencies and changes in crestal bone level were registered at the implants as well as at

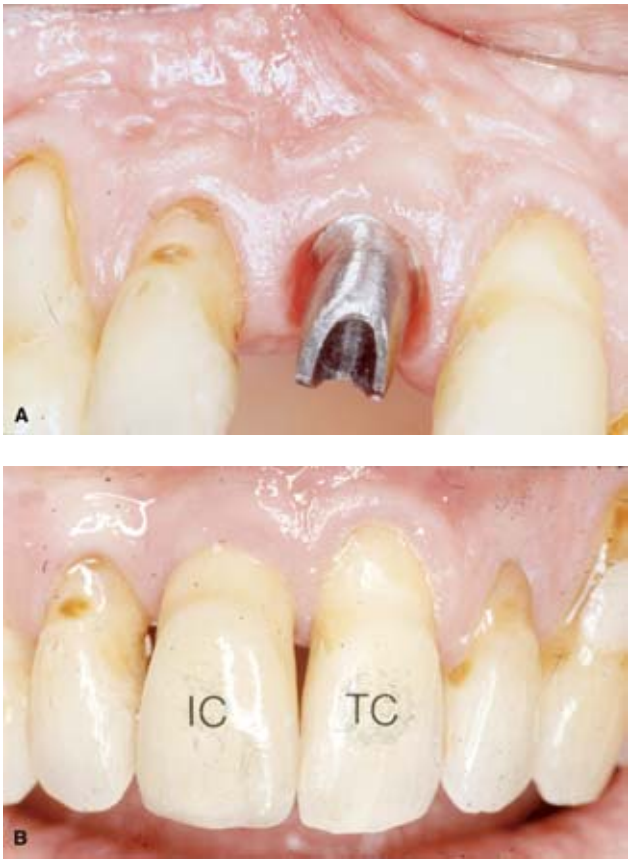

Figure 2 *A,* Preparable Astra Tech abutment in place before cementation. *B,* Implant-supported porcelain-fused-to-metal crown cemented to the preparable abutment in one of the few cases in which the implant crown (IC) was shorter than the contralateral natural tooth crown (TC).

the neighboring teeth and were assessed at baseline examination and at the yearly follow-up examinations.

Complications (including implant failure, soft tissue dehiscence, periimplantitis, fistulae, and other biologic complications) during extraction, implant installation, and the postoperative healing phase were recorded.

Technical and Aesthetic Evaluation

Technical complications (including abutment screw loosening and ceramic fracture) during the 5-year follow-up period were recorded.

Before cementation the patients accepted the aesthetic results. At the 3-year control assessment, the patients were asked to evaluate the aesthetic appearance and the functioning of the implant-supported single crown. Patients answered according to a 10 cm visual analog scale (VAS) labeled "very unsatisfied" at the zero point and "very satisfied" at the 10 point. The distance in millimeters between the zero point and the sign given by the patient was measured. A dentist who was not involved in the study but who worked with implants also evaluated the aesthetic appearance of the implant-supported crowns by means of the VAS.

Statistics

Descriptive statistics including frequencies, mean values, ranges, and standard deviations were calculated for the different assessments. A paired *t*-test was used to test for differences between time intervals, and an unpaired *t*-test was used to test for differences between groups. The threshold for significant differences was set at 5%.

RESULTS

All implants showed signs of stable osseointegration at the baseline examination as well as at the 5-year follow-up examination. All 20 patients were followed for 5 years; one patient, however, did not attend the 3-year follow-up examination but returned at the 4-year registration.

The mean distance from the implant-abutment connection to the cementoenamel junction (see Figure 1) was 3.7 mm (range, 2.5–5.0 mm) in group A patients and 4.5 mm (range, 2.5–7.0 mm) in group B patients. The mean marginal bone losses at implants and neighboring teeth are shown at baseline and at 1, 3, and 5 years in Table 3. Most marginal bone loss adjacent to the implants was registered from fixture placement to crown placement. After crown placement the mean marginal bone change was less than 0.5 mm during the 5-year period. No significant differences in bone level changes adjacent to implants were seen between group A and group B patients. Significantly more marginal bone loss adjacent to the neighboring teeth was registered from implant placement to crown placement in group B patients (12 weeks' healing after extraction) than in group A patients (4 weeks' healing after extraction). After crown placement no significant difference in marginal bone levels adjacent to neighboring teeth was registered.

Soft Tissue Conditions and Crown Relations

No significant difference in oral hygiene status around the implant-supported crowns was registered between group A and group B patients; therefore the figures were pooled. At the baseline registration 16% of all surfaces had visible plaque. After 3 years this percentage was increased to 24%. At the 5-year registration 21% of all surfaces had visible plaque. Seventy percent of all surfaces had no signs of mucositis (a bleeding score of 0) at the baseline registration. At the 3-year and 5-year examinations 54% and 62% of all surfaces, respectively, had a bleeding score of 0.

TABLE 3 Marginal bone loss at implants and neighboring teeth

	Implants mm (mean ± SD)		Neighboring teeth mm (mean ± SD)	
Time	Group A	Group B	Group A	Group B
At CP	0.42 ± 0.62	0.29 ± 0.33	0.13 ± 0.58	0.57 ± 0.48
1 year after CP	0.21 ± 0.49	0.11 ± 0.12	0.11 ± 0.28	0.16 ± 0.31
3 years after CP	0.31 ± 0.50	0.25 ± 0.24	0.28 ± 0.41	0.23 ± 0.47
5 years after CP	0.34 ± 0.57	0.26 ± 0.38	0.35 ± 0.45	0.22 ± 0.38

CP = Crown placement.

TABLE 4 Crown lengths and soft tissue dimensions

	Group A (mm)		Group B (mm)	
Time	mean	SD	mean	SD
LIC/LTC	0.6	1.2	0.7	1.4
Change LIC (I) 0–5 years	0.3	0.5	−0.3	0.6
Change IP 0–5 years	−0.3	0.4	−1.0	0.7

IP = distance from top of the papilla to incisal edge of the implant crown; LIC = length of implant crown; LTC = length of natural, contralateral tooth crown.

In group A 9 of the 10 implant-supported crowns were longer than the contralateral natural tooth crowns at the baseline examination. In group B 8 of the 10 implant crowns were longer. At the baseline registration the mean difference in length between implant-supported crowns and contralateral natural crowns was 0.6 mm in group A patients and 0.7 mm in group B patients.

The length of the implant-supported crowns in group A increased 0.3 mm from baseline to 5-year registration whereas the crown length in group B decreased 0.3 mm in the same 5-year period (Table 4). A range from −1.5 to 1.5 mm was measured at the 20 implants in the 5-year interval.

The mean distance from the top of the papilla to the incisal edge of the implant crown decreased 0.3 mm in group A and 1.0 mm in group B from baseline to the 5-year registration (see Table 4). No IP distances increased (corresponding to papilla shrinkage) during the 5 years (see Figure 2A and B).

Biologic and Technical Complications

All implants were in situ after 5 years. In group A two soft tissue dehiscences were registered during healing (Table 5). In both situations flaps were elevated, the membranes were removed, and healing abutment was placed. No soft tissue dehiscences were registered in group B. One fistula 1.5 mm below the mucosal margin was registered at one implant in group A 1 year after crown placement (Figure 3A). The radiograph indicated that a gap existed between the implant crown and

TABLE 5 Number of clinical complications/repairs

	Group A	Group B
Soft tissue dehiscence	2	0
Retightening abutment screw	2	0
Recementation of crown	2	0
Buccal fistula	1	0
Minor porcelain fracture	1	1
Crown remade	1	0

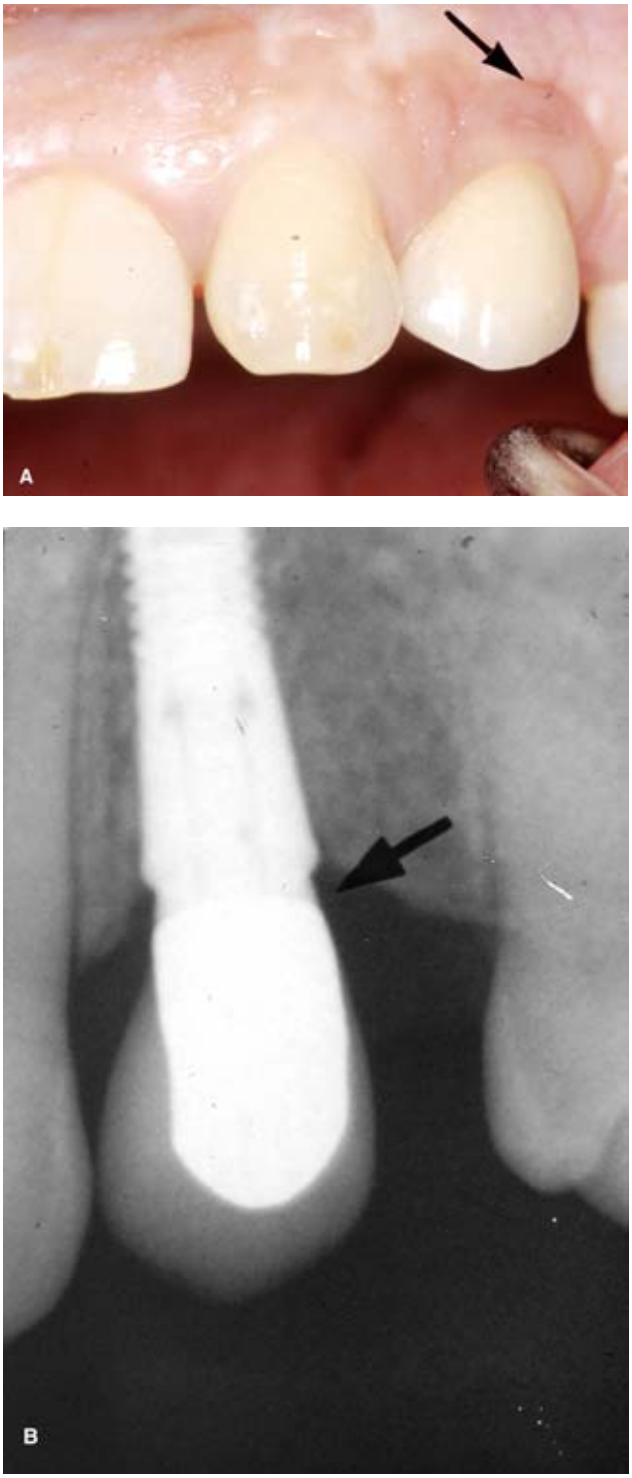

Figure 3 *A,* Fistula (*arrow*), registered 1.5 mm from the mucosal margin. *B,* Radiograph registered a small gap (*arrow*) between crown and abutment but no marginal bone loss.

the abutment (see Figure 3B). As no changes in marginal bone level were seen during the 5-year observation period and as the patient had no problems with the crown, the crown was not replaced. The area was irrigated with 0.2% chlorhexidine regularly, and oral hygiene practices were followed as instructed.

Two abutment screws were observed to loosen during the 5-year interval (see Table 5). Both loosening screws appeared in group A patients. One of the loosening screws was managed by tightening the abutment screw through a hole made on the lingual side of the implant crown. In the other case of screw loosening, a new implant crown had to be made because the screw hole was located on the buccal side of the implant crown.

Two minor porcelain fractures were registered during the 5-year observation period. Both were repaired by grinding and polishing and did not influence the aesthetic evaluation.

Functional and Aesthetic Evaluation

The VAS scores for the general function of the implant-supported crowns were 9.4 (range, 7.1–9.9) for group A and 9.3 (range, 7.0–10.0) for group B. Five of the 20 patients frequently felt a difference between the implant-supported crown and the natural contralateral tooth when biting or chewing.

The patient VAS score for the aesthetic appearance of the implant-supported crowns in group A was 9.8 (range, 9.1–10.0). The dentist VAS score for implant-supported crowns in group A was 5.9 (range, 2.9–9.5). In group B the patient aesthetic VAS score was 8.8 (range, 5.1–10.0) and the dentist VAS score was 8.4 (range, 6.1–9.7).

DISCUSSION

This prospective 5-year study demonstrated a 100% implant survival rate and a 95% crown survival rate. The changes in marginal bone level at implants and neighboring teeth were low during the 5-year period. The aesthetic appearance of the periimplant soft tissue was better after 5 years than at the baseline examination.

The implant survival data of this study are in accordance with a number of other studies of implant-supported single-tooth replacements, which demonstrated a 5-year implant survival of 96 to 100%.[5,7,9,11,12]

In a systematic review of single-tooth restorations supported by implants, Creugers and colleagues found a 4-year implant survival rate of 97%.[13] In the same review, however, an uncomplicated crown maintenance rate of only 83% was reported. In a 5-year multicenter study on implant-supported single-crown restorations, the overall cumulative success rate for crowns was 91.1.[6] In a long-term follow-up study with the same implant system, a cumulative success rate of 96.5% was reported for the restorations over a period of 11 years.[4] In the present study a 95% survival rate for the implant-supported crowns was found after 5 years. The reason for the great differences reported in implant crown survival is not known, but differences in the size and selection of patient material and differences in registration method as well as region, implant system, and time for the start of the study may have an impact.

The average marginal bone loss adjacent to the implants in the present study fully meets the criteria of Albrektsson and Isidor.[14] It is also in accordance with other reports on the same implant system.[5,12,15] The periimplant change in bone level after crown placement was limited in both groups, and no significant difference was found, indicating that "early" implant placement also may give a successful outcome. Before crown placement, however, a tendency for less marginal bone loss and for a lower standard deviation was observed in group B when compared to group A. This indicated a more predictable bone level by "delayed" implant placement as compared to "early" implant placement. On the other hand the bone levels adjacent to the neighboring teeth were higher in group B than in group A before crown placement. This may be related to deeper implant positioning in group B patients than in group A patients. However, other confounding factors may also have an impact, and the limited size of the material should be taken into consideration. After crown placement the marginal bone loss adjacent to implants as well as to neighboring teeth was low in the present study. In a study by Thilander and colleagues 15 adolescent patients had 29 single-tooth implants.[16] A reduction of the marginal bone level at the teeth adjacent to the implants was observed in some patients, especially relating to central incisors when implants replaced lateral incisors in narrow spaces. Mean marginal bone losses of 3.2 mm after 3 years and 4.3 mm after 10 years were reported for the area adjacent to the central incisors. This indicated that to

avoid marginal bone loss at neighboring teeth, craniofacial growth has to be completed and the implant region should have sufficient mesiodistal dimensions. These were two of the inclusion criteria for the present study. Furthermore, the vertical positioning of the implants and the surface configuration of the implants may have an impact on the marginal bone preservation. This latter consideration could also explain the limited bone loss at the adjacent teeth in the present study as compared to the study by Gibbard and Zarb.[3]

Good oral hygiene and healthy periimplant tissues were seen in the present study and correlate well with other studies of single-tooth implants.[11,17] In the present study 17 of the 20 implant crowns were found to be longer than the contralateral natural crowns at the baseline examination. This observation is in accordance with other reports.[17,18] In the study by Chang and colleagues, the implant-supported crowns were 1.0 mm longer on average than the clinical crowns of the contralateral teeth.[17] This difference was greater than that found in the present study, in which another implant system was used and in which half of the patients had their implants placed soon after extraction. However, the difference in time for implant placement did not influence the implant crown length significantly in the present study. On the other hand, the ''early'' implants with standard abutments resulted in a higher number of complications than did the ''delayed'' implants with preparable abutments. While the two soft tissue dehiscences in group A were directly related to the surgical procedure, the other complications were related more to the type of abutment. Although the total number of complications was low, the study indicated fewer complications with preparable abutments than with the standard abutments.

The increased volume of the papillae with time seen in the present study has also been reported in other studies.[17–20] Buccal soft tissue shrinkage resulting in a longer crown length with time was observed in only a few cases in the present study, in which most crown lengths were stable or became shorter with time.

The aesthetic outcome of the implant-supported single-tooth replacement was evaluated as very good by most of the patients. The judgments made by the dentist were lower than those made by the patients, especially in group A. In a more detailed evaluation of the aesthetic outcome of implant-supported single-tooth replacements, Chang and colleagues also found a difference in ratings made by patients and those made by a prosthodontist.[21]

CONCLUSION

Implant-supported single-tooth replacement with the Astra Tech system is a reliable treatment that yields a very good 5-year prognosis for both the implant and the implant crown, with few complications.

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