A Multicenter 12-Month Evaluation of Single-tooth Implants Restored 3 Weeks After 1-Stage Surgery

Lyndon Cooper, DDS, PhD[1]/David A. Felton, DDS, MS[2]/Carl F. Kugelberg, DDS, PhD[3]/
Stephan Ellner, DDS[4]/Nancy Chaffee, DDS, MS[2]/Anthony L. Molina, DDS, MS[2]/
John D. Moriarty, DDS, MS[5]/David Paquette, DMD, MPH, DMSc[5]/Ulf Palmqvist, DDS[6]

The time-intensive, multi-step process of dental implant therapy limits patient acceptance. This 3-year prospective multicenter study sought to determine the safety of an expedited therapy that consisted of loading unsplinted maxillary anterior single-tooth implants 3 weeks after 1-stage surgical placement, and determination of the peri-implant cortical bone and mucosal responses to the expedited procedure. Fifty-two patients missing 1 or 2 maxillary anterior teeth were enrolled in a study approved by the Institutional Committee on Human Subjects Research and based on strict inclusion and exclusion criteria. Astra Tech ST implants placed in a 1-stage procedure were restored 3 weeks later with ST abutments and a provisional crown (baseline); 7 to 9 weeks later, a porcelain-fused-to-metal or all-ceramic crown was cemented. Radiographic and clinical examinations were made at baseline and at 6 and 12 months. Implant survival was recorded. Cortical bone responses and peri-implant mucosal responses were evaluated. Fifty-eight implants were placed. During the 3-week period after implant placement, 4 patients were dismissed because of smoking cigarettes (a protocol deviation), and 1 patient was excluded because of deviation in loading time. Of the remaining 53 implants, 2 failed before definitive crown cementation. The resultant 96.2% survival rate was independent of implant length, tooth position, and bone quality/quantity. The mean change in marginal bone level was 0.4 mm at 12 months. The number of surfaces with plaque decreased from 3.4% at baseline to 0.5% at 12 months. The surfaces with inflammation also decreased. A mean gain in papilla length of 0.61 mm occurred, and a gain in buccal gingiva (x = 0.34 mm) was observed. A high success rate with positive tissue responses was achieved for maxillary anterior unsplinted single-tooth implants placed in a 1-stage surgery and restored at 3 weeks. This 2-component system is suited to a single-stage, rapid loading protocol for esthetic single-tooth replacement. (Int J Oral Maxillofac Implants 2001;16:182–192)

Key words: *early implant loading, endosseous dental implantation, implant-supported dental prosthesis, multicenter study, single-tooth dental implants*

Oral rehabilitation with implant-supported prostheses is a well-documented therapy that is viewed as a routine procedure. A prerequisite for successful implant treatment is the achievement and maintenance of osseointegration. The proof for osseointegration was originally derived from the edentulous mandible and was based upon a 2-stage surgical protocol with a healing period of 3 to 6 months.[1] In addition, biomechanical considerations favored splinting of implants with a rigid prosthesis.[2] The single-tooth implant was subsequently shown to be successful at the level of implant survival and osseointegration.[3] Early problems with screw loosening, particularly in molar replacements, have been resolved using new screws, abutments, and alternative implant/abutment connections.[4] Today, single-tooth implant therapy rivals edentulous mandible implant therapy in terms of implant success and prosthetic reliability.

Osseointegration is dependent on fundamental factors that include biocompatibility, primary stability

[1]Associate Professor, Department of Prosthodontics, University of North Carolina, Chapel Hill, North Carolina.
[2]Chairman, Department of Prosthodontics, University of North Carolina, Chapel Hill, North Carolina.
[3]Chairman, Department of Oral and Maxillofacial Surgery, Kalmar County Hospital, Kalmar, Sweden.
[4]Kalmar County Hospital, Kalmar, Sweden.
[5]Department of Periodontics, University of North Carolina, Chapel Hill, North Carolina.
[6]AstraTech AB, Mölndal, Sweden.

Reprint requests: Dr Lyndon F. Cooper, Department of Prosthodontics, University of North Carolina, 404 Brauer Hall CB#7450, Chapel Hill, North Carolina 27599. E-mail: Lyndon_Cooper@Dentistry.unc.edu

assured by implant design and surface characteristics, careful surgical technique, and the state of the host. Another factor affecting osseointegration is time. Immediate loading and rapid loading protocols take advantage of the observation that single-stage surgical procedures are successful and do not represent additional risk for the majority of implants. Recently, success has been documented for 1-stage surgical protocols in which transmucosal implant healing occurs for 2 to 3 months.[5–7]

Under conditions of primary stability of a well-designed implant, what is the minimal time required to achieve sufficient osseointegration for clinical function? If the biomechanical control of bone adaptation is relevant to the dental implant situation, and woven bone formation occurs within weeks of implant placement, then rapid loading of a dental implant may be beneficial to bone formation. Under conditions where primary stability is attained and maintained, loading of forming bone at implants may not be detrimental to the process of osseointegration. Because osseointegration may not be rapidly attained, a better question may be, "Under conditions of primary stability, how soon can an implant be placed into clinical function without risking the result of osseointegration?"

This question can be experimentally evaluated under various biomechanical circumstances. The success already shown for immediate loading of the edentulous mandible might reflect a relatively high quality and quantity of bone and the splinting of implants associated with the reported procedures.[8–12] However, in a recent report, unsplinted implants placed by a single-stage procedure were successful when loaded by a mandibular overdenture prosthesis.[13] The primary objective of this study was to evaluate the clinical survival rate after rapid loading of unsplinted endosseous root-form implants replacing the loss of 1 or 2 teeth in the anterior maxilla.

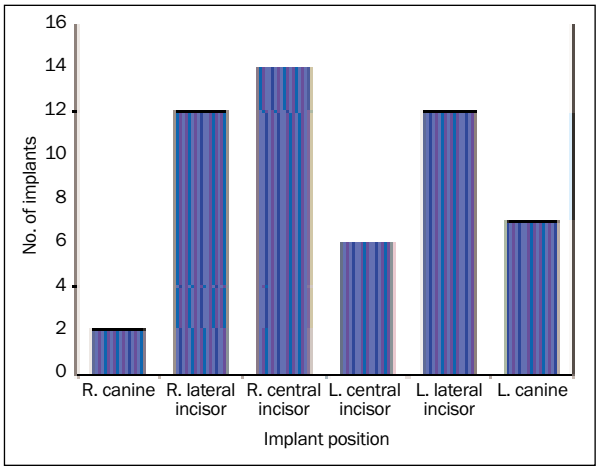
MATERIALS AND METHODS

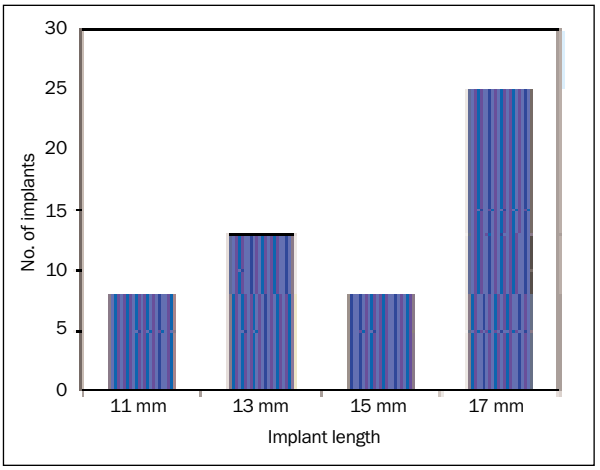
This clinical trial was conducted as an open, 3-year prospective trial at 2 centers: the Department of Prosthodontics at the University of North Carolina School of Dentistry, and the Department of Oral and Maxillofacial Surgery and Prosthodontics, Kalmar County Hospital, Sweden. Patients were identified at the 2 centers' faculty practice facilities. All recruitment and subsequent treatment was conducted under the auspices of an informed consent document approved by the centers' Internal Review Boards. This study was performed in accordance with the principles stated in the Declaration of Helsinki.

Treatment

Patients were initially screened according to the following inclusion criteria: age between 18 and 65 years, sufficient amount of bone to accommodate an implant at least 11 mm long, natural teeth present both mesial and distal to the missing tooth, and willingness to give informed consent. Patients were excluded if any of the following were evident: bruxism; unstable posterior occlusion; untreated caries or uncontrolled periodontal disease; adjacent teeth that exceeded Class I mobility; class 4 bone quality according to Lekholm and Zarb[14]; a daily smoking habit; any disease, condition, or medication that might compromise healing or osseointegration; unrealistic expectations for the treatment; or inability or unwillingness to return for follow-up visits. Patients conforming to the list of inclusion criteria and willing to provide informed consent were enrolled. Select patient characteristics were recorded, including age; sex; general and local medical history, including medications; oral status; bone quality and quantity at planned implant site; preoperative sedation; and postoperative antibiotics. After evaluation of articulated diagnostic casts, tomographic evaluation of the edentulous region was performed (ComCat, Model IS2000, Imaging Sciences International, Gwynedo, PA) using a tomographic/surgical template. Using this information, implants (Astra Tech, Lexington, MA) were placed by standard osteotomy procedures and a self-tapping procedure as recommended for this implant system.[15]

Measurements of the following surgical parameters were recorded: implant length, implant position, whether primary stability was achieved, healing abutment length, whether wound adaptation to the abutment was complete, and the distance of the implant from adjacent teeth (measured on the mesial and the distal at the bone crest). A healing abutment selected to extend through the mucosa was placed with finger pressure, and the peri-implant tissues were sutured to approximate the healing abutment. Fifty-two of 53 implant sites were closed with complete wound adaptation at the abutment. After 3 weeks, the healing abutment was removed and a restorative abutment (Abutment ST, Astra Tech), selected to provide a restorative margin approximately 1 mm below the gingival margin, was placed with finger pressure. A provisional crown was made using a bis-Acryl restorative material (Protemp, ESPE Dental Products, Plymouth Meeting, PA) and cemented with zinc oxide–eugenol cement (TempBond, Kerr Dental Products, Romulus, MI). At provisional crown placement, a baseline periapical (PA) radiograph was taken with the use of a film holder device to position the x-ray cone perpendicular to a film positioned parallel to the long axis of the implant.





Figs 1a and 1b Number and frequency of implants placed in this study. *(Left)* Location of implants; *(right)* distribution of implant lengths.

At 8 weeks after implant placement, the provisional crown was removed, the abutment screw was tightened with forceful finger pressure, and a final impression of the abutment and adjacent tissues was made using a transfer impression coping and polyvinylsiloxane impression materials (Extrude, Kerr Dental Products). A mandibular cast was prepared. Using the abutment analog, an InCeram (Vident, Brea, California) or porcelain-fused-to-metal (PFM) crown was fabricated. The crown was placed 10 to 12 weeks after implant placement. After characterization and glazing, the crown was cemented with glass-ionomer cement (Ketac Cem, Premier, Norristown, PA). The following clinical measurements and assessments were made after cementation of the definitive crown: implant mobility; papilla index; presence (yes/no) of redness or inflammation of the peri-implant mucosa (mesial, buccal, distal, and lingual); presence (yes/no) of plaque (mesial, buccal, distal, and lingual); and the width (in mm) of the attached keratinized tissue. Oral hygiene instructions were provided and a PA radiograph was made.

Evaluations were made at baseline (provisional restoration placement) and at 6, 12, 24, and 36 months after baseline. The following variables were recorded at baseline, delivery of the definitive crown, and at 6, 12, 24, and 36 months after provisional crown placement: peri-implant radiolucency (yes/no), marginal bone level, and distance between implant reference point and marginal bone level at the mesial and distal (mm). Complications (including mechanical or biologic failure of crown, abutment, or implant) and adverse events, if present, were recorded.

Patients with major protocol deviations were excluded from the efficacy analysis. In this study, daily smoking was identified as a major protocol deviation requiring patient exclusion.

RESULTS

Patient Characteristics

For the 2 centers, an even distribution of male and female patients was recruited and treated. The mean age was 30.6 years (SD 12.1). Among the 21 male and 26 female patients, there was no difference in mean age. Thirty-eight surgical sites were recorded as having type 2 bone and 15 were type 3 bone.[14] Three subjects had bone regeneration procedures prior to implant placement. Many sites represented congenitally missing teeth or long-standing residual alveolar ridges. The planned cementation of crowns further reduced concerns for implant angulation and potential augmentation needs. All but 3 sites were characterized as A or B quantity (the remaining 3 were characterized as C quantity). Two augmentations were performed using autogenous bone with an exclusion membrane (GoreTex, W. L. Gore & Associates, Flagstaff, AZ), and a third augmentation was performed with Bio-Oss (Osteohealth, Shirley, NY) and an exclusion membrane.

Implant Characteristics

There were 53 implants placed in 47 evaluable patients; 19 were placed into central incisor locations, 25 were placed into lateral incisor locations, and 9 were in canine locations. The distributions of implant location and implant dimensions are illustrated in Figs 1a and 1b.

Survival, Complications, and Adverse Events. One implant failure occurred following provisional

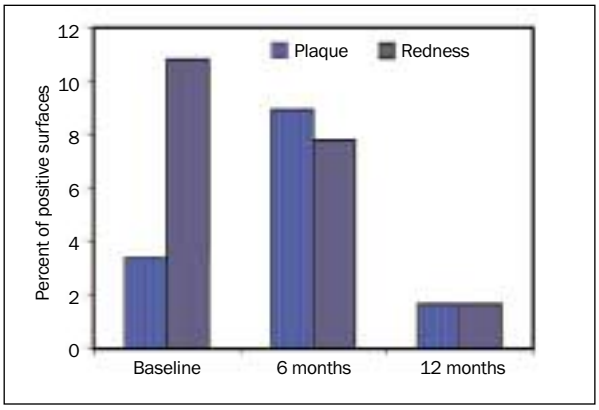


Fig 2 *(Left)* Peri-implant plaque and inflammation. The number of surfaces (mesial, buccal, distal, or lingual) clinically scored positive for presence of plaque or inflammation as indicated by redness.

Table 1 Relationship of Distance of Implant from Adjacent Tooth to Papilla Index

	Distance		
Papilla index	**< 1.0 mm**	**1.0 to 2.0 mm**	**> 2.0 mm**
Mean	1.09	0.59	0.46
SD	0.7	1.21	0.85
n	21	57	22

restoration placement (3 weeks after surgery). Mobility (rotation) was noted without pain, inflammation, or infection. The implant was removed and the osteotomy was augmented to assure adequate bone mass for subsequent implant placement. Another implant failure was determined prior to impression for an all-ceramic crown (8 weeks). A survival rate of 96.2% was calculated. There were no additional implant complications.

Three adverse events were identified. One patient displayed distal palatal migration of a central incisor tooth adjacent to an implant, which was corrected orthodontically. Another reported a transient slight pounding sensation in the palate adjacent to the implant site. One patient presented with a peri-implant mucosal infection that was resolved after systemic treatment with antibiotics, without loss of attachment.

Peri-implant Mucosal Responses. Plaque accumulation at implant abutments was low and decreased over the 12-month period (Fig 2). Initial redness scores (10.8% of sites), associated with newly formed and healing peri-implant mucosa, decreased during healing (7.5% at 6-month recall) to a level that was associated with a generalized absence of inflammation at the 12-month recall (3.6%).

Changes in peri-implant gingival architecture following 1-stage implant placement were measured clinically. A 0.34-mm (± 0.94 mm) increase in buccal gingiva was recorded. The keratinized tissue at the buccal aspect of each implant restoration was stable (0.35 mm ± 1.56 mm). Within 6 months, a net gain of 0.52 mm (± 0.70 mm; range –1.25 to +2.0 mm) in papilla length at implant restorations was calculated from the measured interproximal distances from tissue to incisal edges. By 12 months, tissue measures were unchanged, with a 0.61-mm gain (± 0.95 mm). Most important, 74 of the 100 papilla measures were positive, 8 were unchanged, and only 18 were negative. When the distance from the adjacent tooth to the implant was considered in terms of the papilla index, no relationship was apparent (Table 1).

Radiographically Detectable Changes in Cortical Bone. On the radiographs, the location of cortical bone was measured at the implant reference point (mesial and distal aspects). Measurements taken at baseline (provisional crown placement) were compared with those taken at the 6- and 12-month recall appointments. At baseline, the average distance from the implant reference point to the marginal bone level was 0.18 mm (± 0.31 mm). The corresponding distance at definitive crown placement 7 to 9 weeks later was 0.59 mm (± 0.47 mm). Subsequently, little change was seen in the relationship of cortical bone to the implant reference point (Fig 3).

The incidence of cortical bone loss was also considered (Fig 4). There were 19 implants with 0 to 0.5 mm of cortical bone loss, 18 with 0.5 to 1.0 mm of cortical bone loss, 8 implants with 1.0 to 2.0 mm of cortical bone loss, and 3 implants with more than 2.0 mm of cortical bone loss measured radiographically. When the measured changes in cortical bone levels were considered in terms of the distance of the implant from the adjacent tooth, there was no relationship between the proximity of the implant and the tooth and the response of the bone to the implant (Table 2).

Abutment and Prosthesis Complications

None of the 53 abutments (in 47 patients) came loose during the provisional restoration phase (up to 12 weeks). At delivery of the definitive crowns,

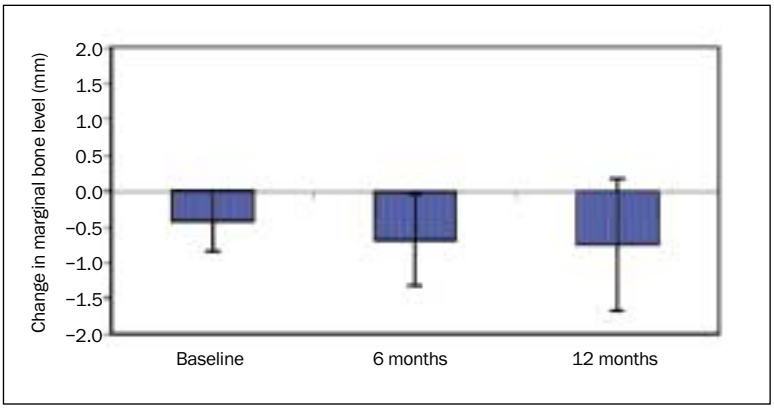


Fig 3 Changes in marginal bone level following implant placement. The alteration in marginal bone level was measured from the implant reference point to the crest of the bone. Bone levels incisal to the reference point were scored as zero. Note that from time of implant placement, the total change in marginal bone levels was less than 0.4 mm.

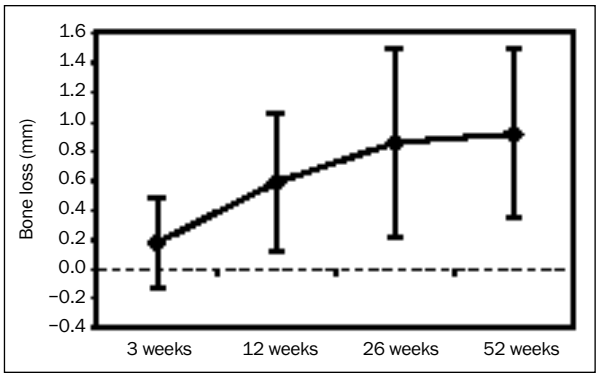


Fig 4 Cortical bone responses following implant placement. Measurements (mm) were calculated from radiographs taken at recall appointments (times indicated on x-axis). The dashed line indicates the baseline level of cortical bone.

Table 2 Relationship of Distance of Implant from Adjacent Tooth to Marginal Bone Levels

Marginal bone level	Distance		
	< 1.0 mm	1.0 to 2.0 mm	> 2.0 mm
Mean	–1.11*	–0.62	–0.84
SD	1.53	0.69	0.73
n	18	52	21

*The patient with a supposed bone loss of 5.05 mm is in the < 1.0 mm group. Exclusion of this patient changes the mean from –1.11 to –0.62 mm.

abutments were tightened to 20 Ncm. There was no incident of abutment screw loosening during the 12-month observation period. During the first 6 months, several other complications associated with prosthetic treatment were reported. These included broken provisional crowns and replacement of all-ceramic crowns to improve fit or for esthetic reasons. A summary of complications is presented in Table 3.

Exclusion of Patients from Efficacy Analysis

In addition to the 47 patients and 53 implants evaluated in this report, 5 patients were recruited and subsequently dismissed. Four patients were dismissed at the time of provisional restoration placement because it was evident that they did not comply with the inclusion criterion of not smoking. Another patient was excluded because the implant was not loaded at 3 weeks.

DISCUSSION

In some situations, eg, the loss of a maxillary incisor or canine, it might be desirable to shorten the time between implant placement and placement of the definitive restoration. The single-tooth implant situation is associated with a high rate of success. Lindh and coworkers indicated by meta-analysis and life table analysis that the 1-year survival rate for single implants was 97.2%.[3] Survival rates were the same for the following 6 years.

With the goal of expedited treatment, the present study sought to evaluate the safety and efficacy of rapid loading (3 weeks after 1-stage placement) of unsplinted single-tooth implants. Unlike previous investigations of immediate or rapid loading,[8–13,15] the present single-tooth implant protocol involved unsplinted implants and prostheses. The unsplinted approach to treatment further tests the

Table 3 Abutment and Prosthesis Complications

Complication	Incidence	Solution
Loose provisional crown	2	Crown recemented
Fracture of provisional crown	4	New provisional crown cemented
New permanent crown	1	Crown replaced for esthetic demand
Loose permanent crown	1	Crown placed initially with temporary cement, then cemented permanently
Adjacent tooth migration	1	Orthodontic treatment prior to cementation of permanent crown
Implant discomfort	1	Transient pounding subsided
Peri-implant mucosal infection	1	Recovered uneventfully

limits of implant therapy. The 96.2% survival rate of this rapid loading implant procedure indicates equivalence with conventional 2-stage or 1-stage procedures for maxillary anterior implants.[3,5,16–19]

The failures in this study were not restricted to a particular length of implant or implant position. Interestingly, there were no implant failures in the canine positions. While the probability of increased lateral load was of initial concern in the design of this study, it is possible that the increased bone density and excellent primary stability achieved when placing implants into this region of the maxilla contributed to implant survival.

As an exclusion criterion for all evaluable subjects, the observation and admission of smoking by included patients resulted in dismissal. Four subjects enrolled with intent to treat were subsequently excluded from further analysis. Three were excluded after implant placement and restoration, and 1 was excluded following implant placement. In these 4 subjects, 2 implant failures were observed prior to definitive restoration. Based on these limited observations and the previously defined risks associated with smoking by dental implant candidates,[20–22] smoking should be considered a principal contraindication to 1-stage, rapid loading protocols until further evaluation in prospective studies.

When an unsplinted single-tooth implant is rapidly loaded, the implant-abutment connections must be stable and readily reversible. Practical issues limit the force that may be applied to place or remove an abutment from an immediately placed implant. Additionally, the relevant historical problems associated with fistula formation at healing abutments and with abutment screw loosening must be reconciled. Abutment screw loosening problems occur at rates above 5% when flat-top hex implant designs are employed.[4] Infection in the presence of loosened healing abutments is a major complication identified in some implant systems.[23] Such features are not suitable for immediate or rapid loading of 1-stage surgically placed dental implants.

In this study, the implant system used provided a conical seal design abutment/implant connection that did not loosen, both here and in prior clinical investigations of single-tooth applications.[19] This behavior has also been noted for other conical implant-abutment connections.[24] Another desired feature of an implant system for single-stage surgeries is the ability to alter the restorative margin location relative to possible changes associated with mucosal healing. A 2-component system allows the abutment dimension to be changed to accommodate diverse tissue dimensions or unanticipated tissue changes following healing.

The abutment system provided a 4.5-mm restorative platform. The transition contours required to establish esthetic crown contours were created within the cervical contours of the crowns. When ceramic crowns were used, attempts were made to establish the transition contours within the aluminous ceramic core materials. The restorative goal used to define the transition contour was the recapitulation of the contralateral tooth's cementoenamel junction (CEJ) and the position of this CEJ relative to the gingival margin.

Tissue responses measured following this rapid loading protocol demonstrated an important clinical advantage (Figs 5a to 5d). The rapid placement of the provisional crown provided an opportunity for papilla formation and peri-implant mucosal adaptation to anatomic form. Unlike 2-stage procedures, where tissues approximate the residual alveolar ridge, and 1-stage procedures, where the use of a tissue-supported provisional could limit appropriate papilla formation, the rapid loading procedure allowed for healing and maturation of the peri-implant mucosa in the absence of mechanical pressure (per a tissue-supported prosthesis) or plaque accumulation on an apposing interim prosthesis (Figs 6a to 6c). This situation was found to be associated with papilla formation and maintenance in locations where gingival architecture included papilla present at adjacent teeth. For nearly every

Figs 5a to 5d The sequence of early loading treatment.

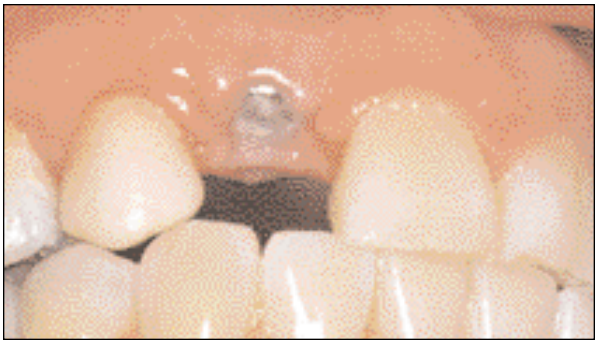


Fig 5a Clinical condition of surgical site 3 weeks after 1-stage placement of an Astra Tech ST implant with a healing abutment.

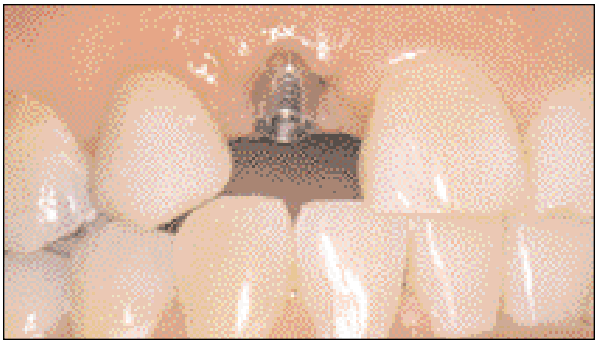


Fig 5b At 3 weeks after placement, the healing abutment was replaced by an ST abutment selected to place the restorative margin 1 mm below the buccal crest of peri-implant mucosa.

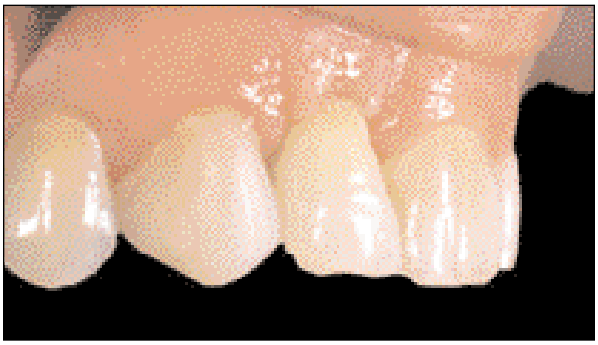


Fig 5c A provisional crown was fabricated and cemented onto the abutment.

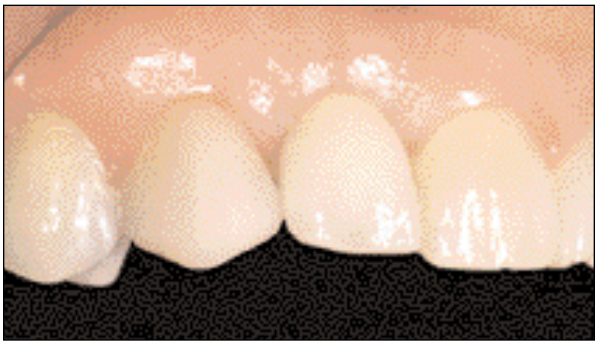


Fig 5d At 12 weeks after implant placement, an all-ceramic crown was permanently cemented onto the ST abutment.

Figs 6a to 6c Peri-implant mucosal responses to early loading.

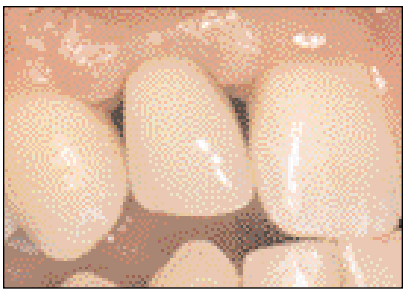


Fig 6a Clinical condition of peri-implant mucosa at 3 weeks (provisional crown placement). While the provisional crown form established cervical contours of the buccal tissue, note the blunted papilla.

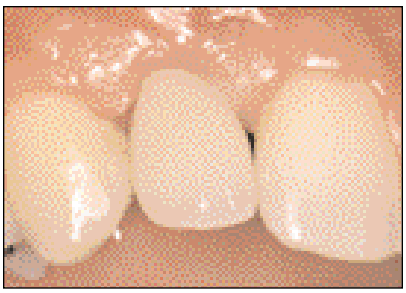


Fig 6b Clinical condition of peri-implant mucosa at 12 weeks (permanent crown placement). The interproximal mucosal tissue continues growth.

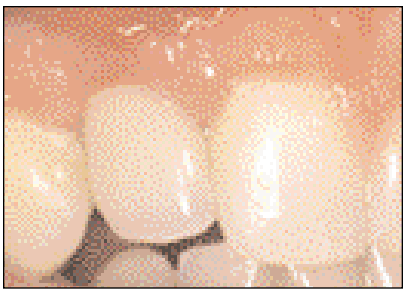
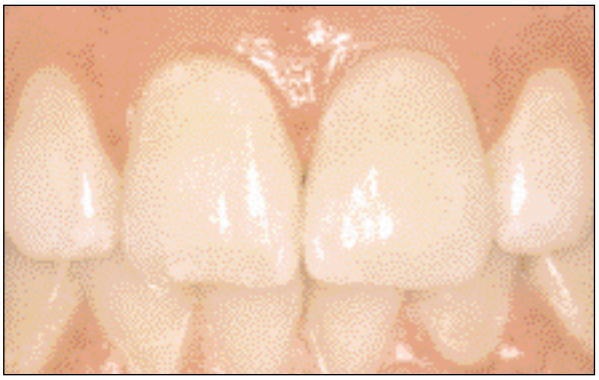


Fig 6c Clinical condition of peri-implant mucosa at 23 weeks. This example illustrates the typical filling in of interproximal spaces to the contact point following early restoration and loading.



Figs 7a and 7b The esthetic value of implant-supported single-tooth restorations is dependent on soft tissue responses to therapy. The left central incisor is a ceramic crown restored in this trial. At 23 weeks, this restoration is adjacent to full contoured papilla and peri-implant mucosa that is coral pink and displays stippling, 2 characteristics of the peri-implant mucosa typically observed in this study.

implant restoration, papilla length increased and buccal mucosal dimension increased during the first 6 months of the healing period. This indicates that there is little risk in the relatively shallow placement of the restorative margins in the peri-implant mucosa. This enhanced the esthetic outcomes and expedited treatment (Figs 7a and 7b).

The presently measured cortical bone responses could be responsible for support of the peri-implant mucosa. Another important factor in the formation and maintenance of papilla height is preservation of marginal bone from the time of implant placement. Soft tissue dimension is limited to approximately 5 mm above cortical bone.[25] The possible loss of 1 to 2 mm of bone in the adaptation phase, followed by an additional 0.2 to 0.5 mm in the first year following loading, could limit the ability to form and maintain papillae at implant crowns. Here, the cortical bone response was evaluated following placement of a provisional crown. The bone adaptation following provisional crown placement 3 weeks after implant placement was limited to approximately 0.6 mm within the first 6 months of the evaluation. Additional bone adaptation was not observed at 12 months (Figs 8a to 8d). Consequently, the excellent papilla form observed is likely related to the observed bone maintenance.

The finding that bone adaptation is limited to the first 6 months after implant placement is consistent with other reports of various implants.[26] In a study that compared 2 screw-shaped systems with different surfaces and implant/abutment connections, the marginal bone adaptation showed a similar pattern for both systems, ie, bone adaptation occurred within the first 6 months following implant placement, with no additional significant adaptation for up to 2 years of follow-up.[26] However, the degree of marginal bone adaptation differed significantly between the 2 systems, with the external hex design showing more bone loss during the first 6 months. Papilla measures were not provided in these reports.

Vascular ischemia associated with periosteal reflection for second-stage surgery has been implicated as a potential source of cortical bone loss in 2-stage implants.[27] However, when an external-hex titanium screw-type implant with a machined transcortical implant surface was used in a 1-stage procedure, radiographic evidence of cortical bone adaptation to the first thread was presented.[6,7] This adaptation of cortical bone has been reported to occur also following loading after only 2 months of healing.[7] Based on these observations, the authors believe that the degree of marginal bone adaptation is related to implant design rather than the surgical protocol or the time to loading.[28,29]

Several design features of the implant could account for the relatively limited cortical bone adaptation noted in this study.[28,29] Because of the limited initial bone adaptation, it is speculated that the abutment-implant connection for the Astra Tech ST implant is not recognized as a microgap and has little influence on the resultant position of cortical bone. Beyond the microgap theory to account for cortical bone adaptation at dental implants, the presence of machined or smooth titanium surfaces in the transcortical region of an implant is also associated with cortical bone loss. Hämmerle and colleagues observed cortical bone adaptation at the machined surface of submerged ITI implants.[30] Levy and associates observed this at the machined collar of the Endopore implant,[31] and

Figs 8a to 8d Radiographic assessment of cortical bone responses to early loading of an Astra Tech ST implant.

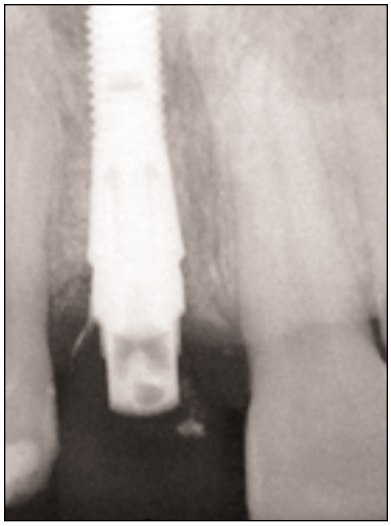


Fig 8a Relative position of cortical bone and the implant-abutment interface at 3 weeks (provisional crown placement).

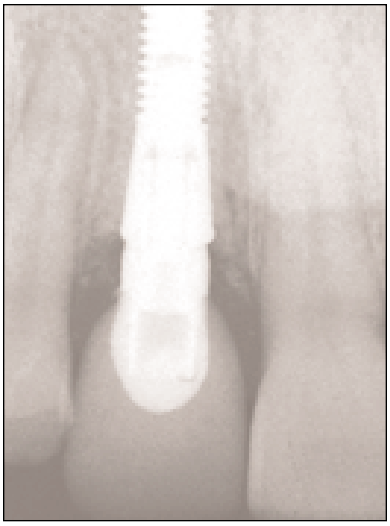


Fig 8b Relative position of cortical bone and the implant-abutment interface at 12 weeks (permanent crown placement). Note the adaptation of the cortical bone lateral to the abutment.

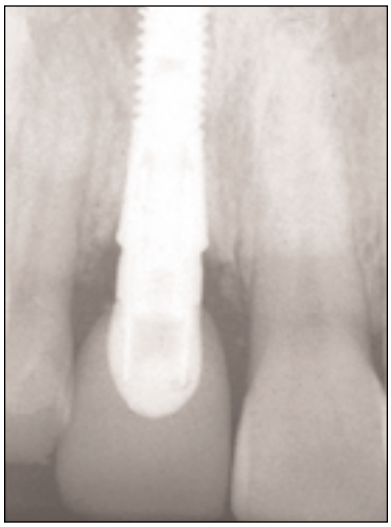


Fig 8c Relative position of cortical bone and the implant-abutment interface at 23 weeks. There is continued adaptation of cortical bone laterally, while there is little or no movement of cortical bone at the horizontal level of the implant-abutment connection.

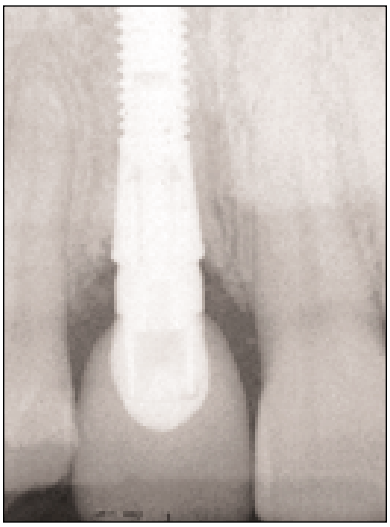


Fig 8d Relative position of cortical bone and the implant-abutment interface at 1 year. The stable relationship of the cortical bone with the implant at the level of the cortical bevel is demonstrated by comparison with Fig 8a above.

Quirynen and coworkers described this phenomenon at the machined surface of a tapered single-tooth implant.[32] The TiOBlast surface, microthreads, and the abutment/implant connection may be individually important in this response, which is common to 2-stage, single-stage, and immediate loading protocols.[33]

The presence of a provisional crown of ideal cervical contours was well tolerated and could be beneficial. The obvious practical benefit of providing an esthetic tooth replacement is recognized. This reported gain in papilla length and preservation of cortical bone is congruent with the goal of a "tooth-like" single implant restoration.[34,35]

Salama and associates suggested guidelines for 1-stage surgery and immediate loading.[36] These included bone quality, macro- and micro-structure of the implant, initial stability of the implant, and the occlusal loading situation. Initial stability is essential, and bicortical fixation is preferred. Screw-type implants provide stronger immediate mechanical retention than cylindric implants. A roughened implant surface (eg, titanium plasma-sprayed or titanium dioxide–blasted) has demonstrated stronger initial anchorage and closer bone-to-implant contact compared to a machined or smooth surface. The implant should be axially congruent with the crown to minimize horizontal forces. Finally, the provisional restoration should be rigid to avoid flexure.

The present investigation demonstrated that these guidelines may also be suitable for the treatment of single-tooth implants using a rapid loading protocol. However, the current results demonstrate that splinting of an implant is not necessary for successful healing of rapidly loaded titanium dioxide–blasted implants that attain primary stability. A single-tooth implant cannot always be axially aligned with the clinical crown. Yet in this study, osseointegration occurred despite non-axial and early loading. The loading of single implants within tooth-bound edentulous spaces may reflect occlusal protection from natural teeth and a stable occlusion. The inclusion criteria presented reflect a concern for limited and controlled occlusal forces. It is further suggested that the mechanical attributes of the implant-abutment connection be included as guidelines. Specifically, it is suggested that *(1)* connections demonstrate a relative absence of loosening after assembly using procedures that can accommodate the early loading protocol (light pressure assembly and disassembly of components), and *(2)* implant placement should accommodate a variety of tissue dimensions and tissue changes associated with healing (ie, 2-component systems for 1-stage surgeries).

CONCLUSIONS

Under the guidelines for treatment established by the inclusion and exclusion criteria, rapid loading of implants (3 weeks after placement into the edentulous maxillary anterior alveolar bone) is a safe and efficacious procedure when measured in terms of implant survival. The use of a single-stage surgical procedure followed by provisional restoration with an ideal crown form can facilitate the formation of gingiva-like contours by the peri-implant mucosa at the implant abutment. The use of 2-component systems for single-stage procedures enhances the ability to create favorable abutment/crown/mucosa/cortical bone relationships. The early cortical bone responses observed here are identical to the unique absence of cortical bone adaptation or bone loss identified in prospective and retrospective analysis of the same implant placed in a conventional 2-stage procedure. Limited experience with patients who smoke indicates that smoking is an absolute contraindication for the single-stage surgery followed by loading of the implant 3 weeks after placement. The present data are quite promising regarding the potential use of the Astra Tech ST implant for rapid/immediate replacement of single missing maxillary anterior teeth. The careful evaluation of all data at the 3-year time point is warranted.

ACKNOWLEDGMENTS

The authors thank Astra Tech AB, Mölndal, Sweden, for the inclusive support of this ongoing clinical study. We also thank Dr Rex Smith and Dr Charlotte Almgren for their efforts in collection of clinical research files data and assistance in organization of this trial. We are most grateful to Ms Gigetta Jenkins, the University of North Carolina study coordinator, for assisting with clinical treatment, data collection, and study management.

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