

Maxillary Ridge Expansion with Simultaneous Implant Placement: 5-Year Results of an Ongoing Clinical Study

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With the technique of maxillary ridge expansion, 449 implants were placed in 150 patients and observed over a period of up to 93 months. Thin maxillary ridges of adequate height and comprising 2 separate cortical plates with intervening cancellous bone were selected for maxillary ridge expansion and simultaneous implant placement. Two-stage implants were used and allowed to heal in a closed environment for 6 months prior to loading. Single and multiple teeth were replaced using this technique, and an estimated mean survival rate better than 97% after a 5-year observation period was calculated (95% confidence interval of the mean survival estimation: 98% ± 1%). Good esthetic and functional outcomes were observed. (INT J ORAL MAXILLOFAC IMPLANTS 2000;15:491-499)

Key words: alveolar ridge augmentation, dental implants, endosseous dental implantation, osteotomes, ridge expansion

The patterns of bone resorption following tooth loss have been well established.^{1,2} Maxillary bone resorption as a result of disuse atrophy takes place predominantly at the expense of the labial plate. Consequently, there is minimal loss in ridge height accompanying the significant reduction in ridge width. This has been observed in patients who have been edentulous for a period of 25 years. Typically, a loss of 3 to 4 mm of ridge height takes place, leaving a ridge height of approximately 15 mm.³

Restoration of the edentulous maxillary ridge with implants often requires the ridge width to be augmented. Two techniques that have been reported to recreate the width are guided bone regeneration and the use of autogenous onlay grafts.⁴⁻⁶

The technique of maxillary ridge expansion was designed to widen the maxillary ridge using osteotomes and allow simultaneous placement of

implants into the socket that is created. At the same time, the labial cortical plate can be recontoured, providing the additional benefit of improved esthetics, particularly in those situations where single teeth may need to be replaced. Tatum originally developed the technique for the placement of D-shaped, finned, transmucosal implants.⁷ The technique described here has been modified for the placement of 2-stage screw-type implants that are allowed to integrate in a closed environment.⁸ It requires a second surgical procedure for implant exposure, at which time soft tissue manipulation can be carried out to produce a natural emergence profile. The technique of ridge splitting has also been described for the placement of grafts⁹ or implants.¹⁰

The ridge that needs to be expanded using this technique must have adequate height, because an increase in ridge height cannot be achieved. The ridge must have labial and palatal cortical plates that are not fused and are separated by intervening cancellous bone to facilitate the introduction of instruments for expansion of the ridge (Figs 1 to 3).

The main purpose of this article was to present preliminary results of the clinical long-term behavior of implants placed by means of ridge expansion in the maxilla. This was done by estimation of mean survival rates.

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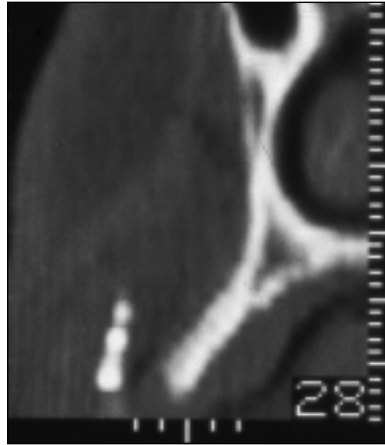
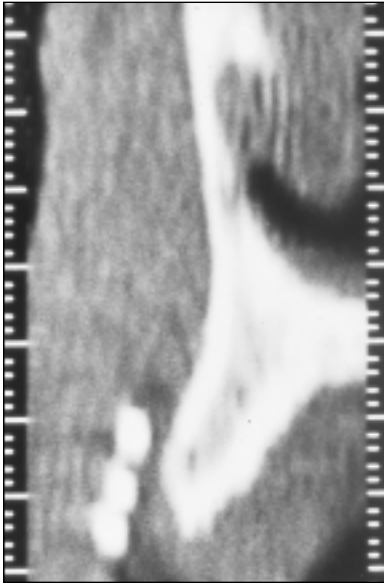


Fig 1 (Left) Computed tomographic scan showing cross section of maxillary ridge (Class IV, Cawood and Howell). The cortical plates are separated by intervening medullary bone. Note radiopaque markers relating the section to tooth position.

Fig 2 (Right) Class IV ridge showing fused cortical plates that cannot be expanded.



Fig 3 Labial view of missing central incisor. Resorption of the labial plate is evident; however, ridge height is adequate.

MATERIALS AND METHODS

The study was designed prospectively and performed at the Centre for Implant and Reconstructive Dentistry, London, United Kingdom. A total of 150 patients (52% female) has been included in the study. Beginning in 1991, these patients were provided with a total of 449 implants in situations where maxillary ridges deficient in width were expanded using special osteotomes and socket formers so as to place implants in the same visit. Two-stage implants were used to ensure that integration could proceed with a minimal risk of force transmission to the implant during the healing period. Implants were placed in a variety of sites in the maxilla. These were restored using fixed cement-retained restorations.

Only patients with thin maxillary ridges of adequate height (Fig 3) and cortical plates separated by intervening cancellous bone were included in the study. The patients selected for the study exhibited no contraindications for implant treatment.

Preoperative Assessment

Single-Tooth Replacements. Where a single tooth needed to be replaced, or where there were up to 3 missing teeth, periapical radiographs in conjunction with panoramic radiographs were considered sufficient to provide adequate diagnostic information about ridge height. Ridge width was measured using calipers under local anesthetic.¹¹ The measurements were made directly by piercing the mucosa at 3 mm, 6 mm, and 9 mm from the crest of the ridge to provide a comprehensive outline of ridge width. For edentulous sites in the midline, lateral cephalographs were occasionally used to provide information about the ridge width and morphology.

Multiple-Unit Restorations. Panoramic radiographs formed the basis for the primary investigation. Computed tomographic scans were used as the investigation of choice because of the comprehensive diagnostic data provided, ie, the width of each implant site could be measured accurately in the cross-sectional images, the thickness and density of the cortical plates and the intervening cancellous bone could also be assessed, and the ridge angulation could be seen. Tooth position was shown in relationship to the cross-sectional images by means of radiopaque markers (Fig 1).^{12,13}

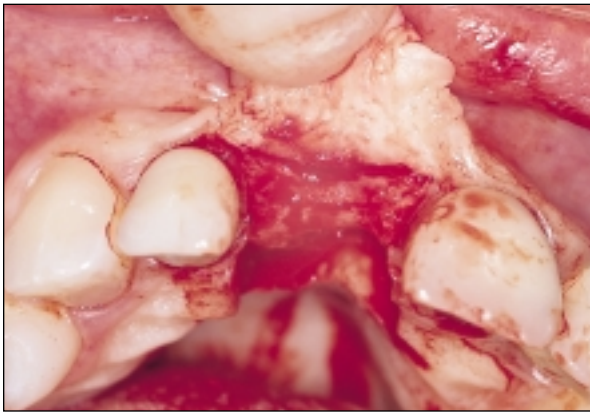


Fig 4 A remote palatal incision provides a buccally based flap with minimum reflection of the labial periosteum. The narrow 2-mm-wide ridge is visible.



Fig 5 Ridge expander in use, separating the cortical plates. The ridge expanders have a D-shaped cross section, and the convex surface can be seen oriented toward the labial.

Treatment Planning

Ideal tooth form and position were determined by arranging teeth in wax on a diagnostic cast. The trial wax prosthesis was transferred to the mouth so that the patient was able to see and approve the appearance. Careful assessment of crown length was made in patients with a high lip line by estimating an increase of 2 to 3 mm in ridge width. For patients with multiple missing teeth, a wax flange was used on the trial prosthesis to approximate the lip support that would eventually be provided. The tooth position that was established by the diagnostic arrangement was used when fabricating the provisional restoration and to functionally verify the selected restorative parameters.

A hard clear acrylic resin template was fabricated over the plaster duplicate cast of the diagnostic arrangement. This provided a hollow envelope that identified the position of the teeth to be replaced.¹³ The template was used to identify implant sites when multiple implants were placed. It was also used as a guide for selecting the abutment that could be placed within the prosthetic envelope by identifying the space available for the planned restoration.

Surgical Protocol

Remote palatal incisions were used to expose the ridge via a labially based flap (Fig 4). The palatal incision was beveled and positioned approximately 1 cm from the crest of the ridge, which enabled the flap to be repositioned for wound closure on completion of the expansion. To minimize interruption of the blood supply to the cortical bone, the periosteum was not reflected from the labial cortical plates.

During the expansion, the labial and palatal cortical plates were supported to prevent fracture. To reduce the risk of fracture, a specific sequence of instruments was used to ensure that the expansion took place in gradual increments. The technique varied depending on the density and thickness of bone that was to be expanded. The instruments used for this technique consisted of ridge expanders, which are D-shaped in cross section, and socket formers corresponding to implant diameter, which are round in cross section.

Instrumentation. A scalpel was used to score the crest of the ridge and define the plane of expansion. This also facilitated the use of subsequent instruments in providing a point of application. An osteotome with a sharp point was used to mark the implant site. It was introduced into the ridge to approximately 10 mm and aligned between the labial and cortical plates and between the adjacent teeth to indicate the direction of the proposed osteotomy. A series of 4 flat osteotomes (Harley Dental Technical Centre, London, United Kingdom) with sharp paraboloid tips was used to progressively separate the cortical plates by increasing the depth and width of the osteotomy (Fig 5). These are D-shaped in cross section and were used with the convex surface toward the labial aspect to recontour the labial plate. The creation of a D-shaped osteotomy enabled the expansion to be carried out over a broader circumference, reducing sharp angles and the chance of fracture of the cortical plate (Fig 6a). The ridge expanders were inserted using a surgical mallet with a controlled (pulled) tap, which allowed the force applied during expansion to be controlled.

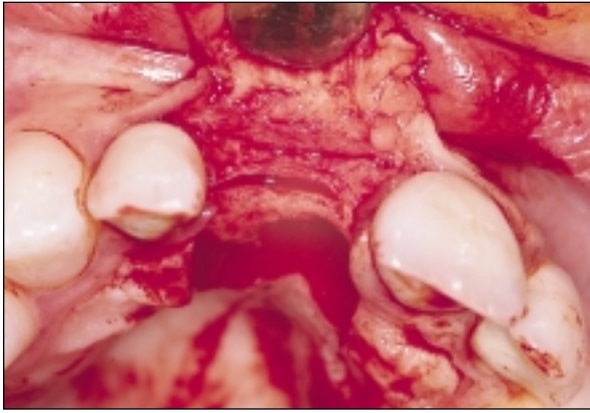


Fig 6a Occlusal view of the ridge showing the D-shaped osteotomy created by the ridge expander.

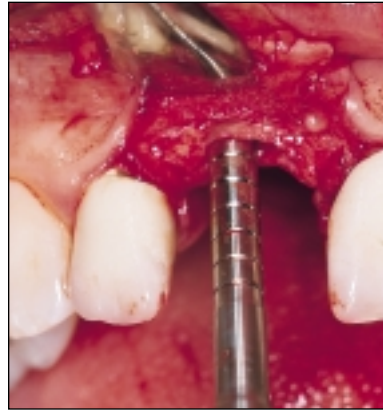


Fig 6b View of socket former, which is round in cross section and matched to implant diameter.



Fig 6c Expanded maxillary ridge with the labial plate repositioned to recreate a more natural contour.



Fig 6d The implant is placed in the osteotomy and is seated level with the crest of the bony ridge.

A sharp-tipped, tapered instrument, which is round in cross section, was introduced to 10 mm to widen the ridge sufficiently for a 2-mm pilot osteotomy bur to be introduced when required without damaging the crestal bone. In addition, it confirmed the direction of the osteotomy that was established by the site marker and allowed the introduction of the socket formers, which enabled the osteotomy to be completed. The osteotomy bur was used where indicated by high-density bone. It was introduced into the osteotomy commenced by the pilot socket former to facilitate the insertion of subsequent socket formers. Osteotomy burs were used only in those situations where adequate width of bone was available apical to the ridge crest.

Socket formers are round in cross section and have varying diameters, which allows the placement of implants with a variety of diameters (Fig 6b).

They have tapered tips, which enables them to be introduced into the osteotomy and allows the expansion to be carried out gradually (Fig 6c). An osteotomy probe was used subsequent to the use of each instrument to ensure that no dehiscence or perforation took place, either labially, palatally, or apically.

Implant Placement. The implants were placed into the osteotomy until they were level with the crest of the bone. Rigid primary fixation was obtained in all cases (Fig 6d) and considered fundamental to the success of the procedure. Fracture of the labial or palatal cortical plates was avoided. Although the labial plate was manipulated to gain an increase in width, it was never detached either from the periosteum or the bony ridge. Minor fractures at the crest that did not extend beyond 2 to 3 mm were considered acceptable.

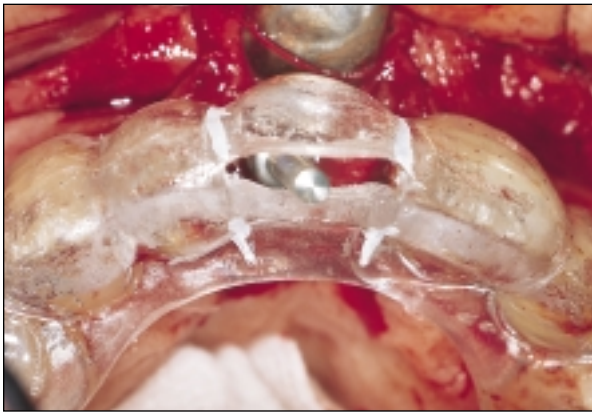


Fig 7 A diagnostic template (hollow prosthetic "envelope") was used to identify the space within which the abutment must lie. The trial abutment can be seen emerging through the incisal tip.

The implants were placed between the cortical plates. It was not possible to vary the labiopalatal angle of the osteotomy because of the narrow ridge width. Therefore, the implants were often placed at an angle to the long axis of the proposed restoration. Angled abutments were required to restore these implants.¹⁴ A set of trial abutments (ranging from 0 to 45 degrees, in 5-degree increments) was used to measure the angle of the abutment that would be required to restore the missing tooth. This was carried out at Stage I surgery by selecting a trial abutment to fit within the prosthetic envelope (Fig 7).¹³ Alternatively, it would have been necessary to fabricate an abutment¹⁵ or modify a prefabricated abutment in the laboratory.

Wound Closure. Hydroxyapatite (Osteograft 300 μm or 700 μm , Ceramed, Lakewood, CO) was used to create a dense non-resorbable pad under the gingiva to provide a stable gingival margin around the definitive restoration. The hydroxyapatite was mixed with bone harvested from the osteotomy site, whenever this was available. The hydroxyapatite and the particulate bone obtained from the osteotomy site were also used to fill the space created by expansion adjacent to the implants. In a limited number of patients, the particulate material was obtained from the coagulum trap (bone filter) instead of the flutes of the osteotomy burs. A sudden increase in the incidence of infections (2 patients) was noted, and this practice was terminated. The wound was closed using vicryl 3/0 sutures to secure the flap once it was accurately positioned.

Second-Stage Surgery. The implants were allowed to integrate for 6 months and were then exposed via an incision on the palatal aspect of the ridge. This allowed the attached tissue to be manipulated, either to increase the labial bulk of attached

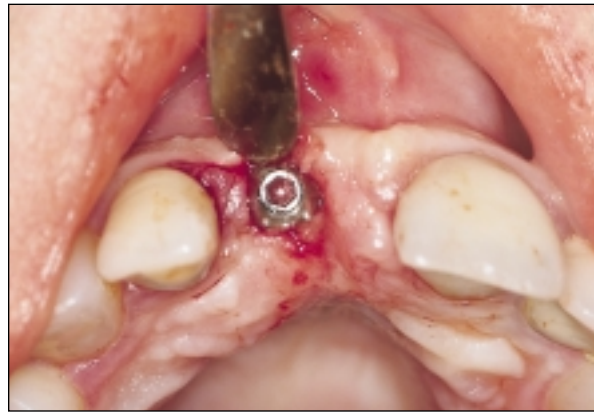


Fig 8 Occlusal view of the seated abutment at second-stage surgery. Note the labial repositioning of attached tissue.

mucosa or to recreate papillae, depending on the clinical needs. Hard and soft tissues were removed from over the cover screw, the cover screw was removed, and the preselected angled abutment was attached (Fig 8). The wound was sutured using vicryl and provisionally restored by means of a transitional acrylic resin restoration, which was fabricated in the laboratory or in the surgery. Sutures were removed after 7 to 10 days.

Restorative Phase

Soft tissues were allowed to mature for a minimum of 1 month prior to the restorative phase (Fig 9). Conventional cement-retained restorations were fabricated (Fig 10). Wherever possible, multiple implants were restored using splinted crowns and fixed partial prostheses. Temporary luting agent (Temp Bond, Kerr, Romulus, MI) was used to ensure that the restoration could be removed to facilitate monitoring and maintenance.

Radiographic and Clinical Monitoring

Clinical monitoring was carried out at 1 week, 1 month, 3 months, 6 months, and 12 months after restoration and annually thereafter. The clinical examination involved visual examination of the crown margins for any signs of inflammation, percussion to check for mobility or pain, and probing of the permucosal site to determine the tissue depth.

Radiographic examination was carried out using periapical radiographs taken with Rinn x-ray holders (Rinn, Elgin, IL) using a paralleling long-cone technique. These examinations occurred directly after first-stage surgery, on completion of the restoration, 6 months after completion of the restoration, and annually for those restorations that had been functional for longer than 6 months (Figs 11a and 11b).



Fig 9 Mature gingival tissue around preangled abutment post. Note the gingival contours created by the provisional restoration.



Fig 10 Labial view of the finished restoration showing an acceptable esthetic outcome.

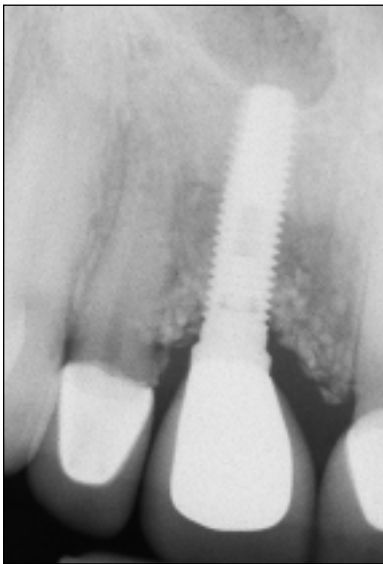


Fig 11a (Left) Postoperative periapical radiograph taken 2 years after completion of a single-unit restoration. A stable bone level is seen.

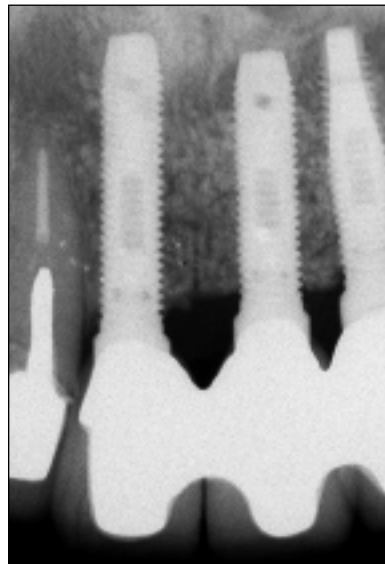


Fig 11b (Right) Postoperative radiograph taken 4 years after completion of a multiple-unit restoration showing stable bone levels.

Statistical Analysis

All calculations were carried out using a personal computer. The data were transferred into a database format (Microsoft Access, Microsoft, Redmond, WA). Statistical analyses were made with a statistical program (JMP, SAS Institute Inc, Cary, NC). A Kaplan-Meier survival analysis was performed.¹⁶ Because certain patients contributed multiple survival data, a dependence of the data could not be excluded. Therefore a mean survival estimation according to Aalen et al¹⁷ was additionally performed using SAS software (SAS Institute Inc).

RESULTS

There were 150 patients included in the study. A total of 449 implants was placed in maxillary ridges

ranging from 2 mm to 4 mm in original width. An increase in the width of the maxillary ridge was achieved that allowed the simultaneous placement of implants into the osteotomy created by expansion.

Twenty-four patients (16%) with a total of 78 implants (17%) were lost to follow-up. Sixteen patients were referred patients who did not attend the recall program and were monitored by their referring dentist, 4 patients did not comply with requests to attend for monitoring, and 2 patients moved away from the area and were unable to attend regularly. An additional 2 patients died during the follow-up period.

Abutment Angulations

The distribution of angles varied considerably (Fig 12). Angled abutments ranging from 5 to 30 degrees were predominantly used (407 abutments, or 90.6%).

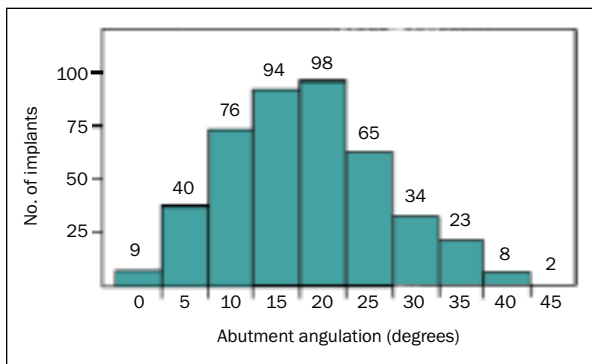


Fig 12 Frequency of abutment angulations.

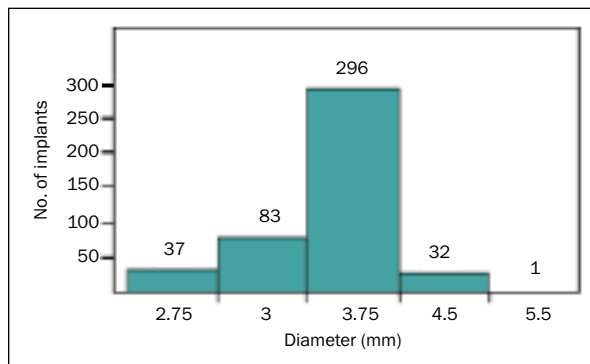


Fig 13 Frequency of implant diameters.

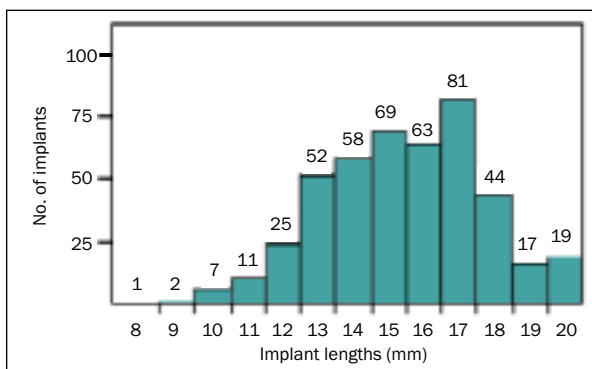


Fig 14 Frequency of implant lengths.

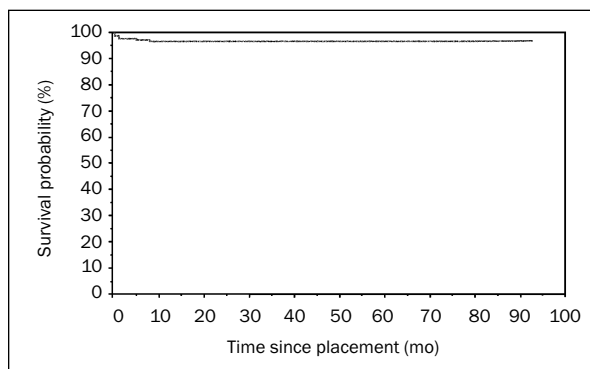


Fig 15 Survival analysis according to Kaplan-Meier.¹⁶

A small number of 0-, 35-, 40-, and 45-degree abutments were also used (42 abutments, or 9.4%).

Implant Diameters

Figure 13 depicts the frequency of different implant diameters used. The majority of ridges were expanded to receive 3.75-mm-diameter implants (296 implants, or 66%). A smaller number of 2.75-mm and 3.00-mm implants (120 implants, or 27%) were used in thinner ridges or ridges with denser cortical plates. Implants that were 4.5 mm in diameter were used predominantly in the posterior quadrants, where greater loads would be sustained and where slightly broader ridges were present.

Implant Lengths

Figure 14 depicts the different implant lengths used. The most common lengths used were between 12 and 18 mm (392 implants, or 87%). This was consistent with the observations made by Tallgren³ related to the residual ridge height of edentulous patients.

Survival Analysis and Implant Loss

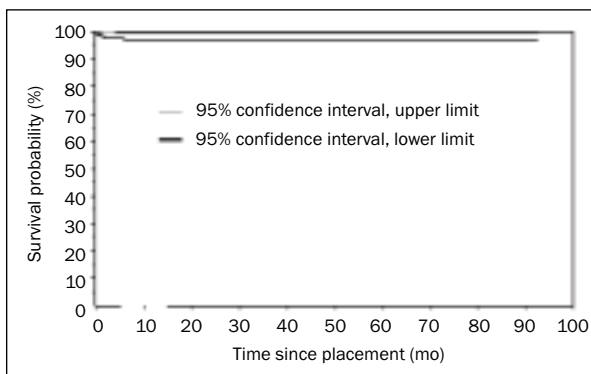
A Kaplan-Meier survival analysis¹⁶ was conducted for all 449 implants following placement (Fig 15).

Twelve implants have failed thus far; 8 implants were lost within 3 months of placement because of infection (7 implants in 3 patients in whom the graft originated from a coagulum trap and 1 implant as a result of an infection of unknown cause), and 4 implants were lost at exposure. Table 1 summarizes the essential details of the 12 lost implants.

No further implants have been lost in function after exposure. The period of observation since placement of the implants ranged from 0 to 93 months, with a mean observation time of 27 months. After an observation time of 60 months (5 years), the estimated survival probability calculated according to Kaplan-Meier was 97%. Figure 16 depicts the mean survival estimation calculated according to Aalen et al.¹⁷ For each patient who contributed multiple survival data, the data were considered dependent. After an observation time of 60 months (5 years), the calculated 95% confidence interval of the mean survival estimation according to Aalen et al was 98% ± 1%. Therefore, with a certainty of 95%, the mean survival probability after 5 years can be considered better than 97%.

Table 1 Analysis of Lost Implants

Implant no.	Position	Smoker	Length (mm)	Diameter (mm)	Abutment angle (deg)	Time since placement (mo)	Cause
1	Left first premolar	Yes	14	3.75	20	4.3	Non-integration
2	Left central incisor	No	18	2.75	10	2.3	Infection
3	Left canine	Yes	16	3.00	25	8.4	Non-integration
4	Right central incisor	No	15	3.00	30	1.5	Infection
5	Left central incisor	No	14	3.00	35	1.5	Infection
6	Left lateral incisor	No	14	3.75	0	1.5	Infection
7	Right central incisor	No	14	3.75	10	5.7	Non-integration
8	Left central incisor	Yes	16	3.75	20	0.7	Infection
9	Right central incisor	No	16	3.75	10	0.5	Infection
10	Right lateral incisor	No	15	3.75	20	0.5	Infection
11	Right canine	No	15	3.75	20	0.5	Infection
12	Right central incisor	No	17	3.75	20	6.3	Non-integration

**Fig 16** Mean survival estimation according to Aalen et al.¹⁷

DISCUSSION

Very few long-term clinical studies of ridge expansion techniques have been published to date. Simion et al¹⁸ reported on 5 patients in which a split-crest technique combined with guided tissue regeneration was performed. A 5-year clinical study was carried out by Scipioni et al.¹⁹ Ninety-six Tübingen implants and 233 IMZ implants (Interpore International, Irvine, CA) were placed in combination with ridge expansion, showing a survival rate of 88.5% for Tübingen implants and a 99% survival rate for IMZ implants. However, a survival analysis with regard to the time under risk and calculation of confidence intervals were not performed. Implants were considered successful if they survived for 5 months after prosthodontic loading. Engelke et al²⁰ presented a clinical study using 24 Brånemark System implants (Nobel Biocare, Göteborg, Sweden) and 97 ITI implants (Straumann, Waldenburg, Switzerland) placed with a ridge-splitting technique with microfixation. A survival rate of 86.2% after 5 years was reported.

The present study involved a very specific technique that allowed primary fixation of the implants to be achieved. Remote palatal incisions with minimum reflection of the labial periosteum and mucosa may be significant, since the blood supply to the labial plate is not interrupted. Furthermore, because of the mean observation time of 27 months, less than half of the 449 placed implants could be considered for the calculation of the survival probability after 5 years. These factors may contribute to the high survival rate of 97% after a 5-year observation period, considering the 95% confidence interval of the mean survival estimation according to Aalen et al (98% \pm 1%). Additionally, as a result of the lack of events (failures) after exposure, the estimated survival rate after 5 years must be considered preliminary. However, these results are comparable to survival rates reported for implant placement when adequate bone is present. A broad range of survival rates, ranging from 85% to 100% after an observation period of 5 years, has been reported.²¹⁻³² This technique further offers the advantages of reducing the number of surgical interventions and complications seen with guided bone regeneration and autogenous bone grafting.^{4-6,33,34}

CONCLUSION

Treatment of the thin maxillary ridge can be carried out predictably using the ridge expansion technique described. Surgical trauma to the patient is minimized by reducing the number of procedures and augmentation materials used, which in turn has a bearing on financial considerations as well. Narrow maxillary ridges with 2 cortical plates separated by cancellous bone that require no additional ridge height are suitable for this treatment. Careful

assessment of crown length for patients who have a high lip line is necessary to avoid esthetic compromise. Good esthetic and functional outcomes can be achieved predictably as long as the surgical principles and protocols described are followed carefully without compromising the surgical site.

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