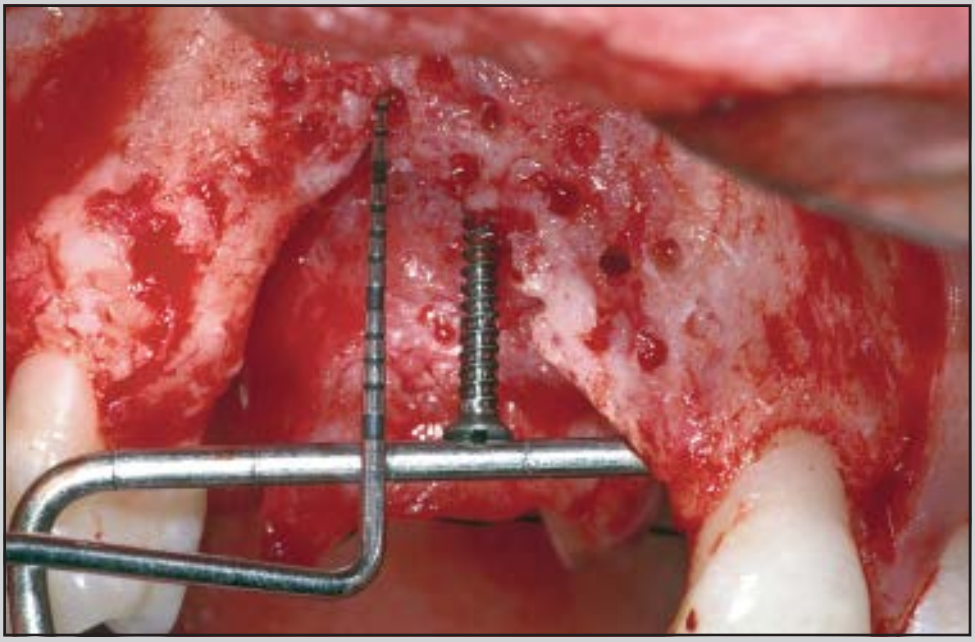

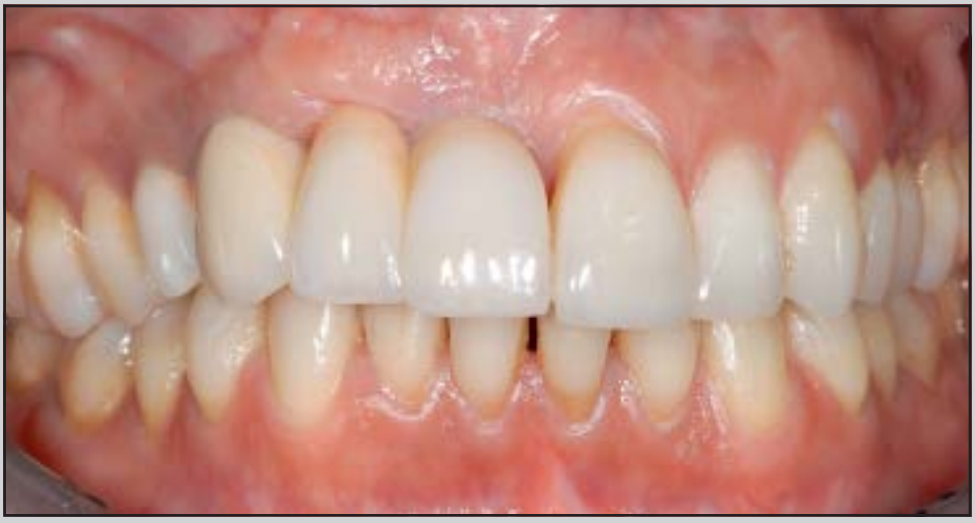

Turned Implants in Vertical Augmented Bone: A Retrospective Study with 13 to 21 Years Follow-Up

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The aim of this retrospective clinical trial was to evaluate the performance of 91 turned implants placed in vertically augmented ridges in 33 patients by means of guided bone regeneration techniques after a mean follow-up of 15 years. A total of 88 implants were in function (97% survival rate), whereas 9 showed peri-implantitis (9.9%). A mean radiographic bone loss of 1.02 mm between the baseline evaluation (1 year after loading) and the final visit (13 to 21 years later) was recorded. In conclusion, turned implants placed in vertically augmented bone seem to remain stable after many years of function.
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Vertical ridge augmentation by means of guided bone regeneration (v-GBR) was introduced in the early 1990s for the treatment of partial edentulism in the maxilla and mandible.[1–5] The treatment concept was to create a secluded space over the bone defect to allow osteoblasts to regenerate without competition from the surrounding epithelial and connective tissues. The main indications are treatment of esthetic areas compromised by traumatic events and atrophic ridges in the posterior mandible and maxilla. The efficacy of the technique in such indications has been recently confirmed by different authors, demonstrating short-term bone stability and relatively low morbidity for the patient.[6] The most recent literature review on v-GBR has demonstrated a lack of data on long-term follow-up.[7] In fact, a few articles are available with follow-ups limited to 5 to 6 years.[1,2,8–11]

Simion et al in 2001 presented the data of 123 turned surface implants with a relatively smooth surface inserted in vertically augmented bone in 49 patients with a follow-up from 1 to 6 years.[12] Radiographic examinations demonstrated stable crestal bone levels with a mean bone loss of 1.35 to 1.87 mm, depending on the bone grafting materials associated with the expanded polytetrafluoroethylene (e-PTFE) membrane. The

Table 1 Recalled Patients Asked to Participate in the Study

Total patients	76
Total implants	197
No. osseointegrated implants (%)	5 (3)
Patients visited for follow-up (implants)	33 (91)
Mean follow-up (range), y	16 (13–21)
Mean age (range), y	62 (31–80)
Men/Women (n)	10/23
Maxilla/Mandible (n)	55/36
Smokers, n (%)	9 (27)
SPT participation, n (%)	10 (30)
History of periodontal treatment, n (%)	6 (18)

SPT = supportive periodontal therapy.

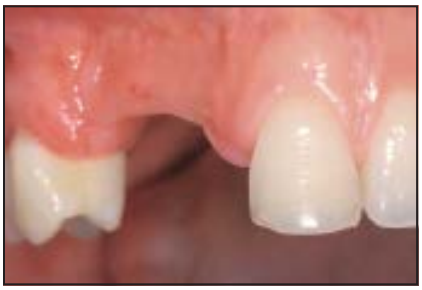


Fig 1 *Clinical photograph of a 21-year-old female patient who was involved in a car accident in 1996 and lost the maxillary right canine and lateral and central incisors.*

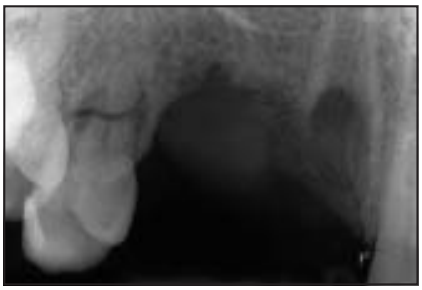


Fig 2 *Periapical radiograph demonstrating the extensive bone loss in the area of the trauma. The first premolar root is fractured.*

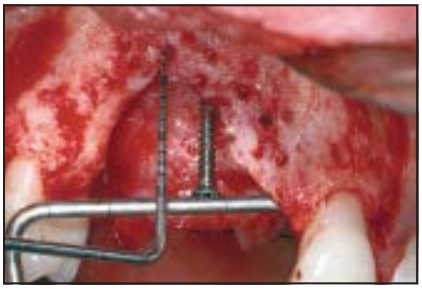


Fig 3 *After full-thickness flap elevation, a 17-mm-high bone defect is evident.*

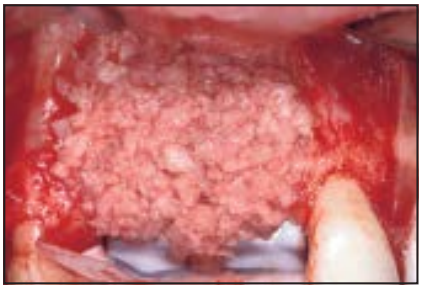


Fig 4 *An e-PTFE titanium-reinforced membrane has been fixed with tacks to the palatal aspect of the defect, and autogenous bone chips have been positioned.*

overall success rate was 97.3%. Similar results were reported by Simion et al in 2004[2] and more recently by Urban et al in 2009.[9]

Different results were presented by Fontana et al in 2015. In a retrospective study on 21 patients treated with 75 moderated surface roughness implants placed in vertical augmented bone with a 1- to 6-year follow-up, they reported 11 out of 75 implants affected by marginal bone resorption with a cumulative success rate of 72.1%. The authors considered as a possible explanation for bone resorption the higher incidence of peri-implant tissue inflammation associated with the rougher implant surfaces used in the study.[8]

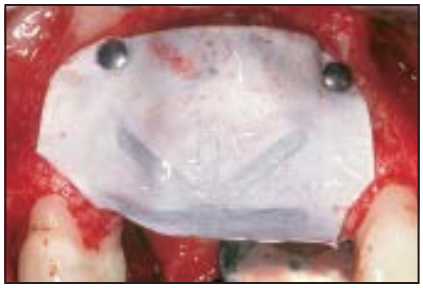
The aim of the present retrospective study is to document the clinical and radiographic outcomes of turned implants placed in vertically augmented bone by means of vertical GBR (v-GBR) with a follow-up ranging from 13 to 21 years.

Materials and methods

This study was designed as a single-arm retrospective clinical study. From 1993 to 2000, 76 patients were consecutively treated with v-GBR. A total of 197 implants were placed in the augmented area, with an osseointegration rate of 97% (Table 1). Between April 2013 and December 2014, all these patients were recalled for a follow-up visit and were included in this study.

Surgical procedure

All v-GBR procedures and subsequent implant placements were performed by the same surgeon using the surgical technique previously described[2] (Figs 1 to 12). A titanium-reinforced e-PTFE membrane (W.L. Gore) was placed over the vertical bone defect and the



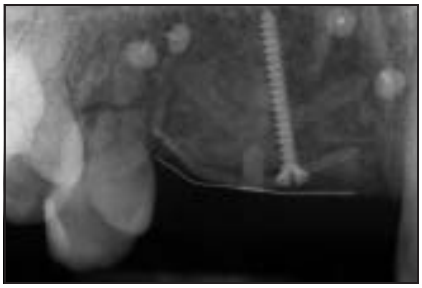
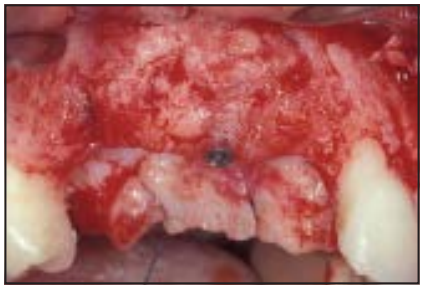


Fig 5 (left) *The membrane has been fixed to the buccal aspect to protect and stabilize the bone chips.*

Fig 6 (right) *Postsurgical periapical radiograph showing the filling of the defect.*



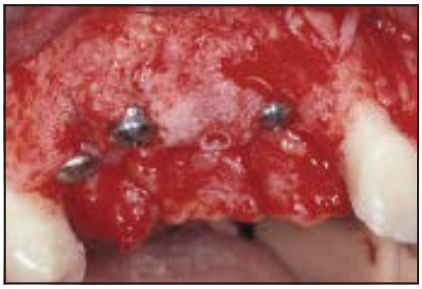


Fig 7 (left) *After 7 months of healing the membrane is removed, demonstrating a complete filling of the defect with newly formed bone. The first premolar was previously extracted.*

Fig 8 (right) *Three turned Brånemark implants placed at the level of the tooth at sites 11, 13, and 14.*

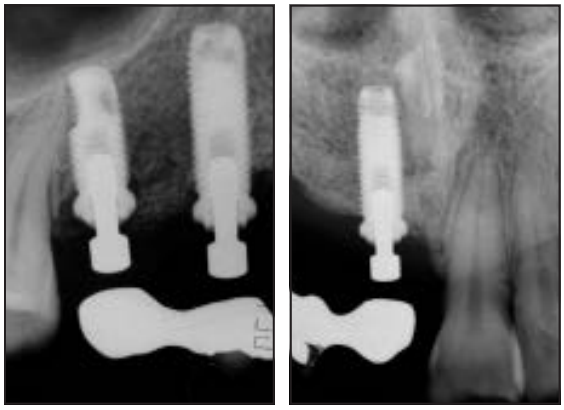


Fig 9 *Periapical radiographs 6 months after provisional acrylic restoration: 2.5 mm of bone remodeling is evident mesial to the implant at site 13.*

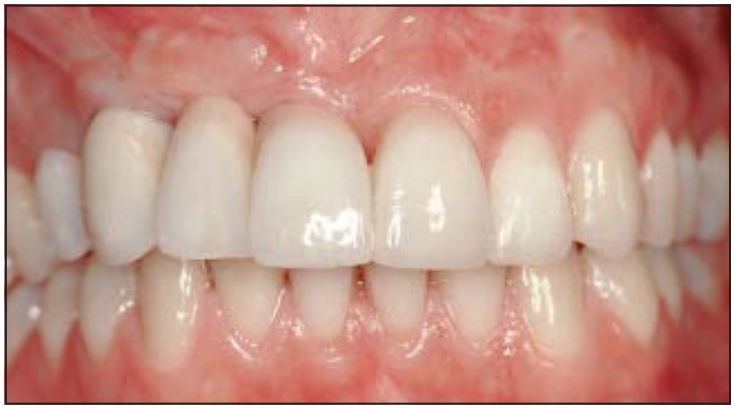


Fig 10 *Clinical photograph showing the final ceramic reconstruction.*

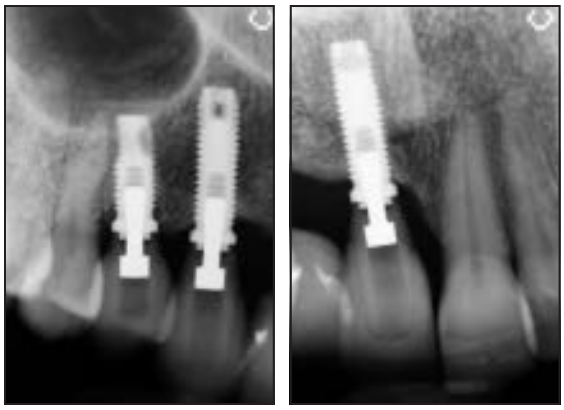


Fig 11 *Periapical radiographs after 16 years of functional load. Stable bone levels and the formation of lamina dura are detectable in all the implant sites and in the pontic area.*

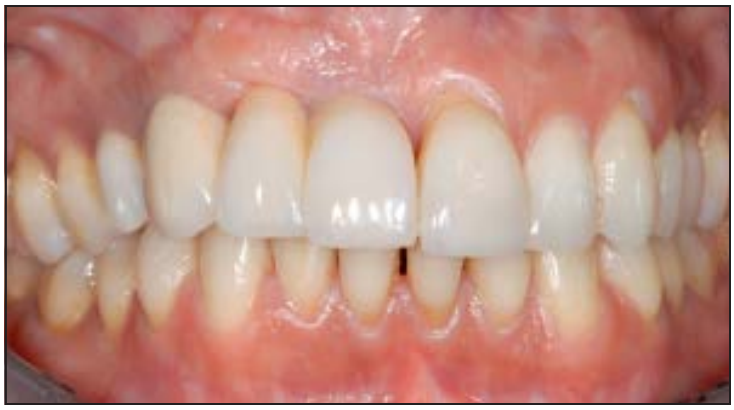


Fig 12 *Clinical photograph after 16 years. The peri-implant mucosa is healthy and no signs of inflammation or recession are evident.*

space was filled with the blood clot only, autogenous bone chips, or a mixture of autogenous bone chips and deproteinized bovine bone mineral (Geistlich).

Depending on the amount of residual bone, a single-stage or a double approach was chosen. The regenerative procedure simultaneous with implant placement was used when the residual bone height was more than 6 mm and primary implant stability was achievable. The healing period after surgery ranged from 6 to 8 months, depending on the bone volume to be augmented. At the time of second-stage surgery, the membrane was removed and the regenerated bone was prepared for the dental implant placement or, in case of single-stage approach, the healing abutment connection was performed.

In the staged approach, after 3 to 4 months of submerged healing implants were uncovered and connected to the healing abutments. After 4 to 6 weeks implants were loaded with a provisional fixed restoration, followed by a porcelain-fused-to-metal final restoration after at least 2 months.

Clinical and radiographic assessment

Two calibrated examiners performed the follow-up visits. Six of the patients were available for follow-up but lived too far from the study center. After calibration and instruction, a referral dentist provided the clinical data, photos, and radiographic images.

The following data related to the patient were collected during the follow-up visit:

- Age
- Smoking habit
- Participation in supportive periodontal therapy (SPT)
- History of periodontal previous treatment

The following clinical measurements were recorded:

- Probing depth (PD) in mm
- Recession in mm
- Bleeding index[13]
- Plaque index[13]
- Presence of keratinized tissue around the implant
- Presence of suppuration

Survival rate and success rate, following Albrektsson criteria,[14] were calculated. At the Estepona Consensus Meeting on Peri-implantits,[15] peri-implantitis was defined as an infection with associated suppuration and clinically significant progressive crestal bone loss after the adaptive phase.

For radiographic implant bone level assessment the following methodology was used: A radiograph taken after the adaptive phase, 1 year after prosthetic loading, was considered the baseline (T_0). Periapical radiographs were made at the final follow-up visit with the paralleling technique and a Rinn positioner and considered T_1. Old and new radiographs were scanned, digitized in JPG format, converted to TIFF files with a 300 dpi resolution, and stored in a personal computer. Peri-implant marginal bone levels were measured using ImageJ software (National Institutes of Health). The software was calibrated for every image using the known implant length. Measurements of the mesial and distal bone crest level adjacent to each implant were made to the nearest 0.1 mm. Reference points for the linear measurements were the coronal margin of the implant shoulder and the most coronal point of bone-to-implant contact.

Data analysis

Data were recorded in Excel (Microsoft) and checked for entry errors. Descriptive statistical analysis included mean and standard deviation for continuous variables, whereas proportions were calculated for categorical variables.

Results

A total of 33 patients (43% of the total) with 91 implants (46% of the total) were available during the recall period for clinical and radiologic examination. The population of the study is described in detail in Table 2. Of these patients, 43 didn't attend the final follow-up visit and therefore 106 implants were not included in the study for the following reasons: no answer (25), refused to come to the visit for health reasons (15), deceased (3). Of the recruited patients, 84% were referred by other dentists.

The mean follow-up time between delivery of the prosthesis and

final reevaluation is 16 years, with a range of 13 to 21 years.

In the 33 patients who attended the follow-up visit, a total of 36 vertical ridge augmentation surgeries were originally performed. Only turned implants were used: 87 Brånemark fixtures (Nobel Biocare) and 4 Ebon fixtures (Nobel Biocare). In 6 of 36 surgical sites, implants were placed simultaneously with the augmentation procedure. A total of 55 implants were placed in the maxilla and 36 in the mandible.

A total of 34 surgical sites in 31 patients healed uneventfully. In 2 patients, membrane exposure occurred after 2 and 6 weeks, respectively. Both surgeries used a single-stage approach. In one case, the small soft tissue dehiscence was carefully cleaned with 0.2% chlorhexidine solution. For 2 weeks, the patient maintained a strict hygiene protocol based on topical application of 1% chlorhexidine gel twice a day. After 2 weeks, the membrane was removed. In the other patient, who showed a larger exposure, the membrane was immediately removed. The periapical radiographs of both patients demonstrated incomplete vertical bone gain and showed two to three implant threads sticking out from the bone crest. Nevertheless, a final restoration was successfully completed for all 91 placed implants.

Clinical and radiographic assessment

Of the 91 implants, 88 were in function at the time of the final follow-up visit, for a survival rate of 97% (Table 2). One implant was lost due to implant fracture, and two implants were removed after 2 years of loading due to progressive bone loss extending over two-thirds of the implant length. The implant success rate was 89%.[14] Of 36 prosthetic rehabilitations, 34 were in funcion at the final follow-up visit, expressing an implant-supported restoration survival rate of 94%.

Table 2 Clinical and Radiographic Outcome Variables

Lost implants, n (%) of patients	3 (6%)
Fractured implants	1 (3%)
Lost due to peri-implantitis	2 (3%)
Survived implant-supported restorations, n (%)	34 (94%)
Survived implants, n (%)	91 (97%)
Survived implants with peri-implantitis	9 (10%)
Successful implants, n (%)	81 (89%)
Clinical outcomes	
Probing depth in mm, mean (SD)	3.25 (1.02)
Soft tissue recession in mm, mean (SD)	0.12 (0.63)
Plaque index[a]	54%
Gingival index[a]	25%
Suppuration[a]	2%
Presence of vestibular keratinized tissue[a]	72%
Radiographic outcomes in terms of marginal bone loss in mm, mean (SD)	
T_0	2.11 (1.17)
T_1	3.16 (1.91)
Loss between T_0 and T_1	−1.02 (1.47)
Mean time between T_0 and T_1 (mo)	181

[a] n = 85.

The average marginal bone level 1 year after prosthetic delivery (T_0) was 2.11 mm. In the years 2013 to 2014, when all patients were reexamined (T_1), the value raised to 3.16 mm. Consequently, the mean marginal bone loss between T_0 and T_1 was 1.02 mm during a time period of 13 to 21 years of function. The frequency distribution of radiographic marginal bone loss, gingival margin, and probing depth is shown in Fig 13.

Of 91 implants in 33 patients, 81 (89%) demonstrated stable marginal bone levels with marginal bone loss < 3 mm at the last examination (Fig 14). A marginal bone loss > 3 mm was found on 10 implants (11%) in 6 patients. Of these 10 implants, 1 implant did not show any bleeding on probing or suppuration, 6 showed suppuration, and 2 were removed due to bone loss extending over 50% of the total implant length. According to the Estepona Consensus definition,[15] peri-implantitis was diagnosed in 9 implants out of 91 (9.9%), 8 in the mandible and 1 in the maxilla.

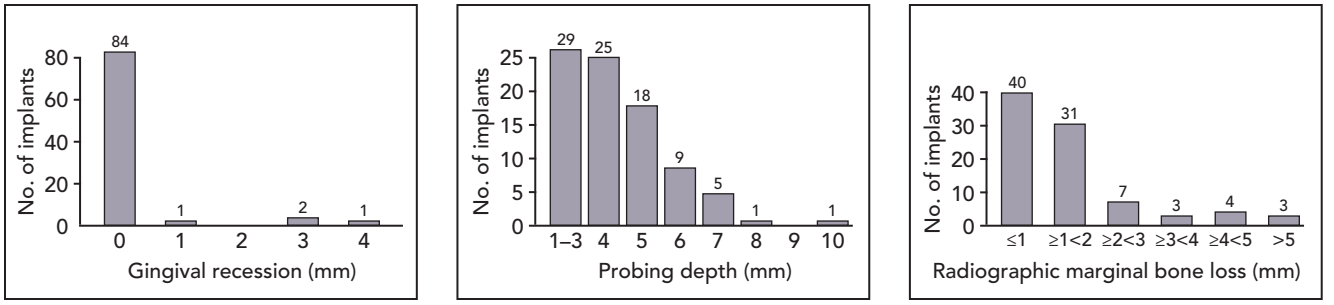


Fig 13 *Frequency distribution of gingival margin position, probing depth around implants, and radiographic marginal bone loss,.*

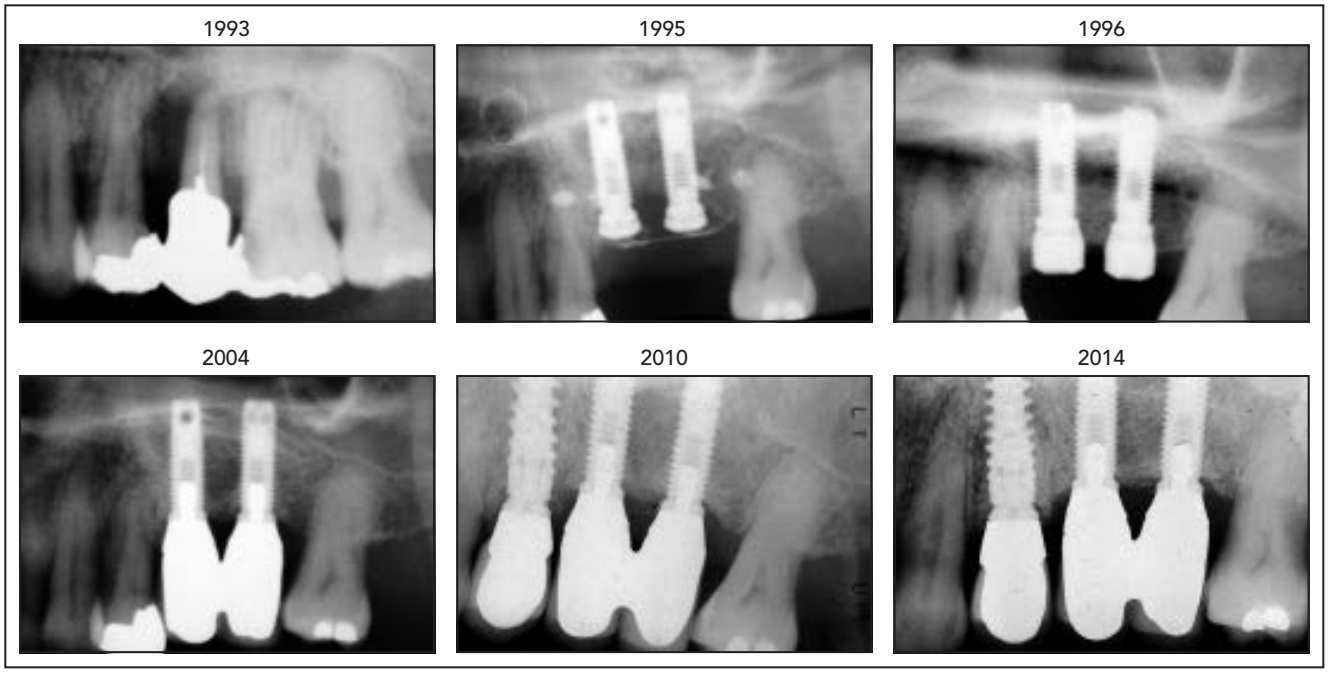


Fig 14 *Sequence of periapical radiographs from 1993 to 2014 of a patient treated with vertical ridge augmentation at the level of the maxillary right premolar and first molar. Bone stability over 18 years is evident. The adjacent first premolar was lost due to periodontal disease and substituted with an implant in 2009.*

Mean probing depth and the other clinical and radiographic variables evaluated during the final follow-up visit on the survived implants are shown in Table 2.

Of the implants considered in this study, 95% showed no mucosal recession, with a mean value of 0.12 mm. The mean probing depth was 3.25 mm. The presence of an adequate quantity of keratinized tissue (3 mm) surrounding the implant was reported in 76% of the cases. Bleeding on probing was seen in 25% of the implants, and 54% presented plaque.

Discussion

The present retrospective clinical study provides the first available results on implants placed in jaw bones in association with GBR vertical ridge augmentation techniques with 13 to 21 years' follow-up.

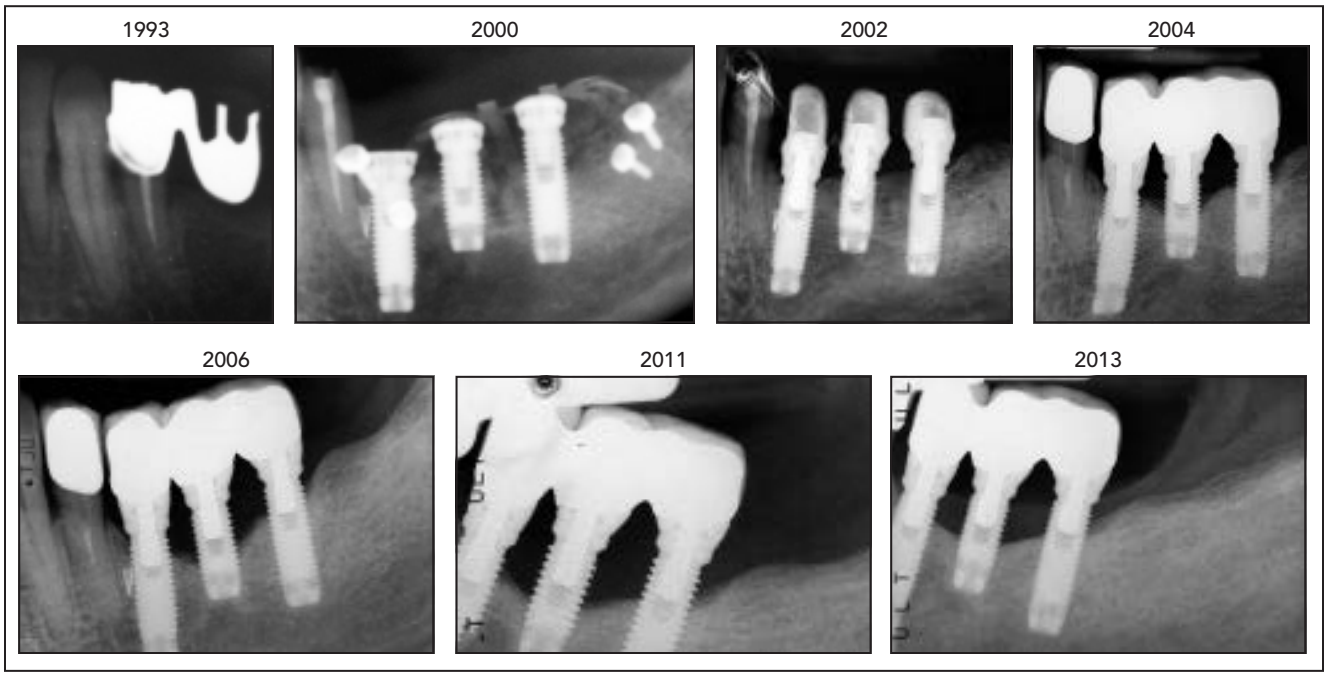


Fig 15 *Sequence of periapical radiographs from 1999 to 2013 of a patient treated with vertical ridge augmentation in sites 35 to 37 demonstrating progressive bone loss over more than 10 years. The bone resorption is progressing very slowly and the lamina dura is still present in the peri-implant bone.*

Patients examined in this study were treated between 1993 and 2000 and were followed for an extremely long period. Obviously, clinical follow-up over long periods is difficult; some patients disappeared and others were ill or deceased, thus data from some of them were impossible to recover. For these reasons, it is not surprising that only 33 of 76 patients from the treated group were available for analysis.

Some of the patients considered were also included in the previous study by Simion et al showing stable bone crest levels with a mean bone loss ranging from 1.35 mm to 1.87 mm after 18 to 69 months of functional load.[12] The results from the present study confirm the high long-term predictability of GBR techniques used for vertical ridge augmentation in association with turned titanium dental implants. This is also in agreement with other studies considering shorter follow-up periods.[9,16]

Due to the very long follow-up, it is difficult to compare the data of the present study with the literature. In fact, only studies on implants placed in native bone are available with such a long period of observation, whereas long-term studies on implants in vertically augmented bone are lacking.

The implant survival rate (97%) presented in this article is in accordance with other long-term follow-up studies on turned implants placed in native bone. Astrand et al reported a survival rate of 99.2% after 20 years of function for 123 turned implants placed in 21 fully edentulous patients.[17] Simion et al found a cumulative survival rate of 93.2% in 59 turned implants placed in the posterior maxillae of 29 partially edentulous patients followed for 12 years.[18] Similar data were reported by Jemt and Johannson,[19] Lekholm et al,[20] and Lindquist et al[21] for turned implants placed in native bone.

The mean marginal bone loss of 1.02 mm during a period of 13 to 21 years of function demonstrates high dimensional stability of the vertical augmented bone with turned implants on a long-term basis. Ten implants out of 91 (11%) in 6 patients showed a marginal bone loss > 3 mm. These data are in line with results by Astrand et al[17] on native

bone that reported 11% of implants with bone loss > 3 after 20 years, but superior to those reported by Simion et al[18] demonstrating only 10% of implants with bone loss between 2 and 3 mm and no implants with more than 3 mm.

The observations from the present study demonstrated a slightly higher prevalence of progressive bone resorption due to peri-implantitis (9.9%) in implants placed in vertical augmented bone as compared with native bone. Astrand et al reported 2.5% after 20 years[17] and Simion et al 0% after 12 years in native bone.[18] However, the progression of bone resorption due to peri-implantitis with turned implants seems to be quite slow (Fig 15) since only 2 implants were lost after 13 to 21 years .

According to the data from the present study, the prevalence of peri-implantitis in implants placed in vertically augmented bone seems to be higher in the mandible (22%) compared with the maxilla (1.8%).

In a recent study, Fontana et al retrospectively evaluated 75 implants inserted in vertically augmented ridges in the posterior mandible of 21 patients after 1 to 6 years of prosthetic loading.[8] The results demonstrated progressive bone resorption at 27.9% of the implant sites. This high percentage of peri-implant bone resorption in a short period may be due to implant location exclusively in the posterior mandible and to the more roughened implant surfaces.

The presence of keratinized tissue in the peri-implant mucosa is advocated to be a positive factor that could reduce the prevalence of marginal inflammation and progressive bone loss around implants.[8,22] In our study, most of the implants (72%) showed > 3 mm width of keratinized tissue, in agreement with this hypothesis.

Only 30% of the patients participated in regular periodontal maintenance in the authors' office with the dental hygienist. This seems to indicate low compliance, but it must be considered that 84% of the patients were referred by other dentists and about 70% of them returned to the original practice after the implant surgery for regular maintenance.

The biometric evaluation of the present study should be considered with caution as bone levels were measured by means of a regular paralleling periapical x-ray technique with the standard Rinn positioners, since no individual standardization of the radiographic technique was used at the T_0 examination. Therefore, minor measurement errors could have occurred at the follow-up visit.

Conclusions

Within the limitations of this retrospective study, it can be stated that after a mean follow-up of 13 to 21 years the vertically augmented bone demonstrated stability in a high percentage of cases, and after implant placement behaved like native bone. It must be taken into consideration that turned implants with a traditional submerged approach were used. The prevalence of peri-implantitis was quite low but slightly higher than seen with turned implants placed in native bone. Keratinized tissue and periodontal maintenance could probably help achieve predictable long-term results.

Acknowledgments

The authors reported no conflicts of interest related to this study.

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