Vertical Ridge Augmentation Using Xenogenic Material Supported by a Configured Titanium Mesh: Clinicohistopathologic and Histochemical Study

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Purpose: *The aim of this study was to evaluate the capability of a configured titanium mesh (CTM) to serve as a mechanical and biologic device for restoring a vertically defected/resorbed alveolar ridge.* ***Materials and Methods:*** *The study comprised 10 severely resorbed sites in 10 patients. Pre- and postoperative ridge measurements were taken with reference to the neighboring teeth and supporting screw head base of the CTM. Bovine bone mineral served as the augmentation filler material. The metal mesh was removed after 9 months. Subsequently, root-form, screw-type implants were placed. During the implant placement phase, cylindric bone samples were retrieved from the augmented area for histopathologic and histochemical examination.* ***Results:*** *Upon soft tissue reflection and before augmentation, defect height, as recorded by a periodontal probe along the main threads exposed on the support screw, was between 5 and 8 mm (average 6.4 mm; SD ± 1.17). At 9 months after augmentation, during the implant placement phase, the defect height was between 0 and 2 mm (average 1.2 mm; SD ± 0.63). Differences were statistically significant ($P < .001$). Bone height gain was between 4 and 6 mm (average 5.2 mm, SD ± 0.79), which gave an average bone fill of 81.2% (SD ± 7.98). Polarizing microscopic examination of sections stained with Picrosirius red showed a gradual increase in new lamellar bone from coronal to apical cuts, reaching the highest area percentage in the deep apical zone.* ***Discussion:*** *At 9 months postaugmentation using the CTM surgical technique, the quality and quantity of the newly established hard tissue appeared to be different in the coronal versus apical areas of the restored alveolar ridge.* ***Conclusion:*** *Although at 9 months postoperatively, the augmented alveolar ridge had different bone content, clinicohistochemical results demonstrated that this surgical technique could be a successful and predictable procedure for rebuilding a resorbed/defected ridge to accommodate endosseous implants.* (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:440–446)

Key words: *alveolar ridge augmentation, bone regeneration, dental implants*

Regeneration of residual ridge bone in the vertical dimension has always been a challenging surgical technique. Rebuilding bone where there is no supportive housing and limited nourishment is difficult to achieve. Onlay block grafts,[1–9] guided bone regeneration (GBR),[10–22] and distraction osteogenesis[23–28] have been proposed for rebuilding bone vertically. However, these procedures involve several considerations: increased morbidity with the autogenous onlay block graft,[29] membrane exposure with the GBR technique,[10,30–32] and frequent visits during the bone distraction phase for the distraction osteogenesis technique. Stabilized soft tissue closure over the augmented area is crucial for success. All are technically sensitive and require a highly skilled surgical team.

The use of a rigid titanium mesh, stabilized as a tent over a resorbed ridge in full/partial restoration of the alveolar process, has been reported.[33–35] Boyne[33] and Shanaman and coworkers[34] used a customized, very stiff titanium mesh with relatively large square holes. Both used at least 50% of autogenous bone mixed with bovine bone mineral. Maiorana and

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associates[35] covered a titanium framework mesh with a GBR membrane of bilayer porcine collagen.

In the present study, an attempt was made to observe the benefit of a configured titanium mesh (CTM) (TRAM; Osteomed, Dallas, TX) as a framework for a filler containing xenograft only. The aim of this study was to examine the outcome of this procedure both clinicohistologically and histochemically.

MATERIALS AND METHODS

Ten sites in 10 patients were selected for this study. All patients (7 women and 3 men aged from 43 to 54 years) were healthy and did not take any medication. Patients were nonsmokers or had quit smoking. All participants gave written informed consent. Each stage of the surgical technique was explained in detail. The Ethics Committee of Tel Aviv University approved the study. Severely 3-dimensionally resorbed ridges were selected for the study. Residual roots and/or hopeless teeth still present at the selected site were removed 4 to 6 weeks before augmentation. The mesiodistal span was that of 3 previously extracted roots, and a ridge restoration of at least 5 mm vertically and 15 to 20 mm mesiodistally was required. As an augmentation housing device, a titanium mesh of various sizes was used to configure the desired ridge convexity. The oval pore size (of the mesh) was 0.3×0.5 mm to avoid any dispersion of the grafted particle/blood aggregation. One main long screw (different lengths according to patient needs) served as a supporting and stabilizing screw and as a reference to measure the height of the required restored vertical bone. When needed, tacking screws were used for additional stabilization of the mesh.

No autogenous bone graft contribution or biologic GBR barrier was used. The CTM was applied in 10 consecutive severely resorbed ridges in which vertical augmentation of the defect sites was indicated. Inorganic bovine bone (Bio-Oss; Geistlich Biomaterials, Wolhusen, Switzerland) served as the augmentation material. After 9 months, the CTM was removed, and implant placement followed.

Surgical Procedure

Augmentation Phase. Premedication using etodolac 400 mg (Etopan; Taro Pharmaceutical Industries, Haifa Bay, Israel), a non-steroidal anti-inflammatory drug, was administered 1 hour before surgery. Local anesthetic infiltration of lidocaine hydrochloride 3% and 1:80,000 norepinephrine was administered labially and lingually/palatally to the deficient ridge.

One crestal and two buccal releasing incisions were made using a No. 15C blade. The vertical releasing incisions were made at least 3 mm mesially and distally from the planned CTM margins to prevent spontaneous early exposure.

An advanced full-thickness flap was raised when the mental foramen was involved. The mental bundle was carefully exposed to avoid any mechanical pressure by the CTM. All granulation tissue and soft tissue over the exposed ridge were removed. The CTM was trimmed to fit the dimensions of the ridge. The length of the main supporting screw was determined by the extent of the required vertical augmentation, including at least 3 mm for bone anchoring. Therefore, 2 periodontal probes were used to measure the defect (Fig 1a). The supporting screw was then inserted and its stability verified. The distance between the ridge and the base of the screw head was also recorded with the probe (UNC-15; Hu-Friedy, Chicago, IL) (Fig 1b), and the CTM was subsequently snap-fitted onto it. Tacking screws were added when needed, usually to the buccal shelf, to ensure stability of the CTM (Fig 1c). Inorganic bovine bone, 500 to 1,000 μm in size, was used as the filler under the tenting CTM (Fig 1d). The grafted particles were inserted by a grafting syringe until the entire void was gently packed. Soft tissue coverage over the CTM followed to achieve tension-free complete closure (Fig 1e).

Postoperative medication included an analgesic (etodolac 200 mg), antibiotics (amoxicillin 500 mg 3 times daily for 7 days [Moxypen Forte; Teva Pharmaceutical Industries, Petach Tikva, Israel]), and an antiseptic mouthwash (chlorhexidine 0.2%, Tarodent; Taro Pharmaceutical Industries). Sutures (4-0 polyviolene; Look Surgical Specialty, Reading, PA) were removed after 2 weeks. In 2 patients, spontaneous exposure of the metal mesh occurred 4 to 6 weeks postoperatively and increased to a gap of 3 to 4 mm. These were meticulously cleaned twice daily with gauze soaked with 0.2% chlorhexidine digluconate gel (Lacer; S.A. Sardenya, Barcelona, Spain). Close observations revealed no adverse soft tissue effects. Periapical radiographs showed the CTM with its supporting screw harboring the grafted material (Fig 1f).

Implant Placement Phase. The surgical site was exposed after 9 months. The periodontal probe penetrated the metal mesh to record the depth between the supporting screw head base and current crestal augmented area. Then the mesh was removed, along with its tacking and supporting screws. In the 2 patients with exposed CTM, a thin layer of firm connective tissue, approximately 0.5 to 1.0 mm thick, was noted under the metal mesh.

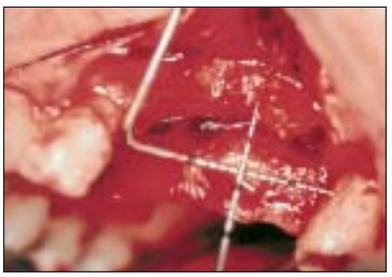

Fig 1a Measurement of the extent of the resorbed ridge using 2 periodontal probes.

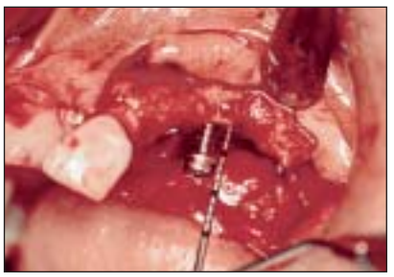

Fig 1b Supporting screw of the CTM was inserted into the resorbed ridge up to 6 mm from its head.

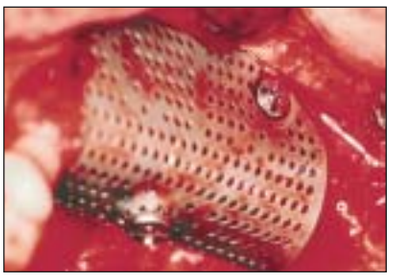

Fig 1c The CTM was snap-fitted onto the main supporting screw and stabilized to the buccal bony shelf with a tacking screw.

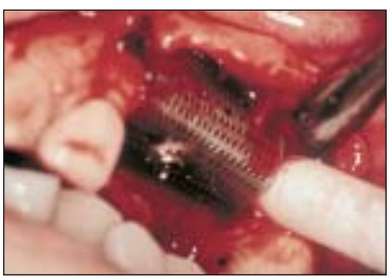

Fig 1d Grafted material was injected between the stabilized CTM and the resorbed ridge.

Fig 1e Complete soft tissue closure over the filled CTM was achieved by an extensive coronally positioned flap.

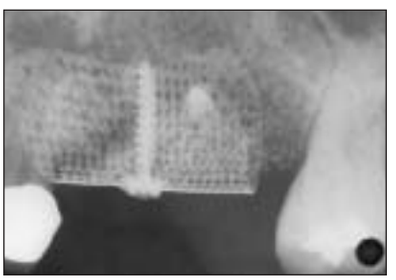

Fig 1f Postoperative radiograph shows the filling material bordered by the CTM with its supporting screw.

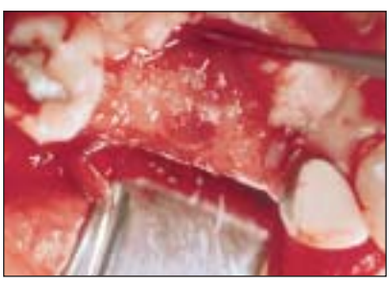

Fig 1g Removal of the CTM exposed the augmented ridge prior to implant placement.

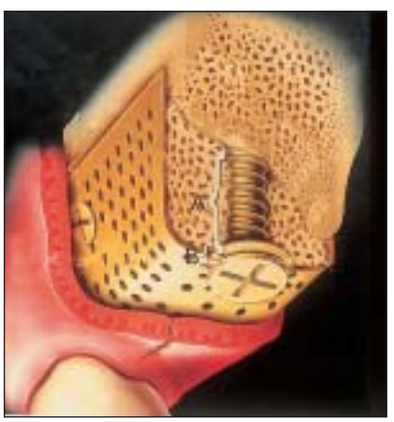

Fig 1h Diagram of the measurements taken prior to grafting (A) and at second-stage surgery (B) to estimate the gain in bone height.

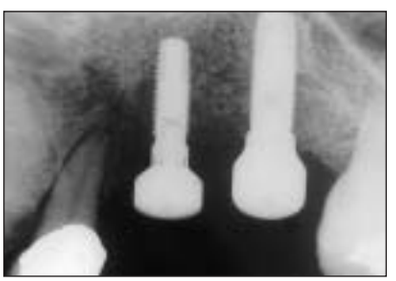

Fig 1i Two implants were placed in the vertically augmented ridge.

This layer was curetted, disclosing the augmented hard tissue ridge (Fig 1g). The gain in bone height was recorded according to the exposed length of the main supporting screw pre- and postoperatively (Fig 1h). Measurement of bone gain was calculated by the difference between preoperative and postoperative height, which was divided by preoperative height and multiplied by 100 to obtain an estimated percentage gain: ([Hpre - Hpost]/Hpre) × 100%.

Two titanium plasma-sprayed, screw-type implants (Steri-Oss; Nobel Biocare, Göteborg, Sweden), 3.25 to 4.5 mm in diameter and 10 to 12 mm in length, were placed in the restored ridge (Fig 1i). The first implant was placed in the vertically augmented site according to a previously prepared surgical template using stepped-up cutting burs. The second implant osteotomy site was prepared using a 2.5-mm internal diameter trephine bur to obtain a hard tissue core for histologic examination.

The prosthetic phase was initiated 3 to 6 months after implant placement.

Pre- and postoperative bone height were recorded and compared for statistical analysis. The paired *t* test was used to identify significant differences ($P < .01$).

Table 1 Vertical Bone Restoration of the 10 Sites

Case no.	Location	Preoperative CTM-to-crest distance*	Postoperative CTM-to-crest distance	Bone height restored vertically	% bone fill in vertical dimension†
1	Max right $PM_{1,2}$,M_1	5 mm	1 mm	4 mm	80.0
2	Max left $PM_{1,2}$,M_1	5 mm	1 mm	4 mm	80.0
3	Mand left $PM_{1,2}$,M_1	8 mm	2 mm	6 mm	75.0
4	Mand right PM_2,M_1	7 mm	1 mm	6 mm	85.0
5	Max left $PM_{1,2}$,M_1	6 mm	1 mm	5 mm	83.3
6	Mand right $M_{1,2}$	7 mm	2 mm	5 mm	71.4
7	Mand right PM_2,M_1	7 mm	1 mm	6 mm	85.0
8	Mand left $PM_{1,2}$,M_1	5 mm	0 mm	5 mm	100.0
9	Mand right $PM_{1,2}$,M_1	6 mm	1 mm	5 mm	83.3
10	Mand left $M_{1,2}$	8 mm	2 mm	6 mm	75.0
Average		6.4 mm‡	1.2 mm‡	5.2 mm	81.2
SD		1.17 mm	0.63 mm	0.79 mm	7.98

$PM_{1,2}$ = first and second premolars; PM_2 = second premolar; M_1 = first molar; M_2 = second molar; $M_{1,2}$ = first and second molars.
*Distance between the bony defect base and the supporting screw head base.
†$\frac{Hpre - Hpost}{Hpre} \times 100\%$
‡$P < .001$.

Histologic and Histochemical Methods

Tissue samples were marked with black ink to identify the coronal and the deeper apical sites. Cylindric specimen cores were fixed in 10% neutral buffered formalin for 7 days and decalcified with 5% formic acid for 2 weeks. Specimens were then embedded in paraffin. Transverse sections, 5 µm in width, were prepared using a microtome. Slides of coronal and apical ends were stained with Mallory trichrome and examined with a light microscope. Other sections from the same sites were stained with Picrosirius red and examined with polarizing microscopy as previously described.[36] Polarization colors of collagen fibers of the same thickness were recorded for thin and thick fibers. Woven bone was characterized when both the thin and thick fibers presented polarization colors, which ranged from green through greenish-yellow to yellow. Organized lamellar bone was characterized by a higher percentage of thick fibers presenting yellow to yellowish-orange polarization colors.[37]

RESULTS

Of the 10 sites, 3 were in the maxilla and 7 were in the mandible. The vertical defect height, ie, the distance between the mesh and the crest preoperatively, as measured along the exposed part of the main supporting screw of the CTM, was between 5 and 8 mm (average 6.4 mm, SD 1.17). At the second surgical phase, the exposed part of the supporting screw was remeasured and found to be between 0 and 2 mm (average 1.2 mm, SD 0.63). This represented a bone height gain of between 4 and 6 mm (average 5.2 mm, SD 0.79) at the 10 sites. The average bone fill was 81.2% (SD ± 7.98) (Table 1). The differences between pre- and postoperative bone height to a fixed reference point (ie, the base of the supporting screw head) were statistically significant ($P < .001$). During the second surgical phase, at the time of CTM removal, a significant amount of hard tissue could be seen in the area that was filled with the grafting particles under the metal mesh. The ridge was almost always restored to near the level of the supporting screw head base.

Buccolingually, the base of the augmentation area maintained ridge dimension and actually followed the mesh configuration. Therefore, screw-type, root-form implants could be placed in all patients. Twenty implants were placed in the vertically augmented sites. All were integrated and prosthetically functional. The prostheses were 2 or 3 units, screw-retained in the premolar/molar positions. Follow-up of at least 2 years showed that all reconstructed sites were in stable functional condition. Since an extensive coronal buccal flap was created in most patients to achieve complete soft tissue closure, a compensatory, apical repositioning surgical technique was applied during exposure of the implant cover screw (third stage) to facilitate adequate masticatory mucosa around the implants and re-form the proper vestibular depth in the augmented site.

Histologically, new bone formation was observed in all specimens. The osseous tissue demonstrated numerous osteocytes and different stages of remodeling and maturation. The grafted particles were in

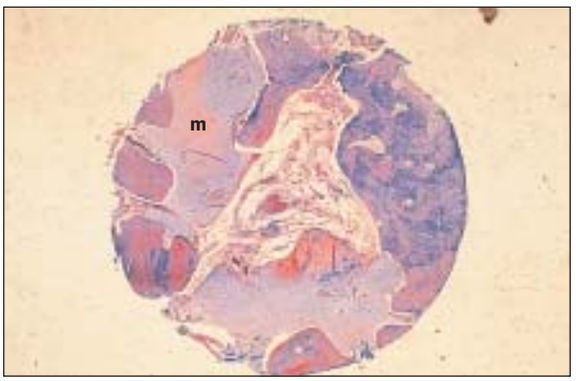

Fig 2a Coronal area section cut from a cylindric specimen sample at 9 months. The tissue area fraction is dominated by the grafted material (m) and connective tissue (Mallory trichrome; magnification ×20).

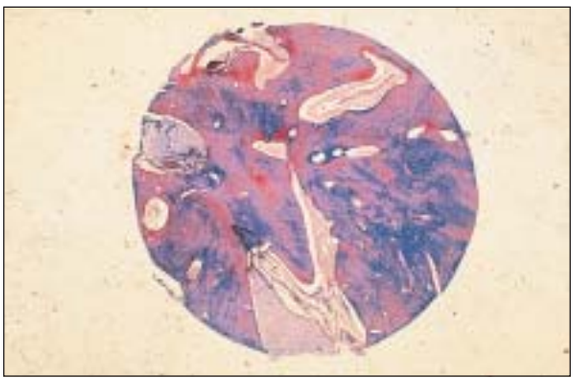

Fig 2b Apical area section from the same specimen core shown in Fig 2a. Most of the tissue area fraction is occupied by newly formed bone (Mallory trichrome; magnification ×20).

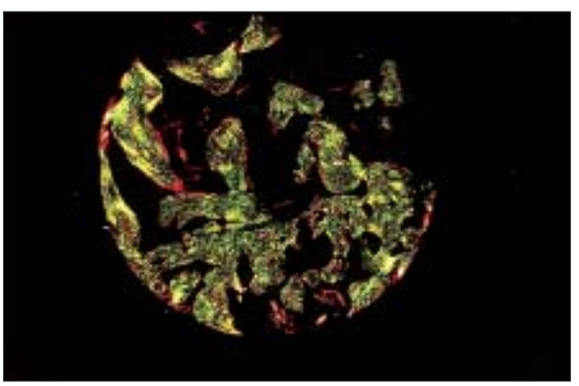

Fig 2c Photomicrograph of coronal section showing mainly woven bone containing both unorganized thin and thick collagen fibers with polarization colors of green to greenish-yellow (Picrosirius red with polarizing microscopy; magnification ×20).

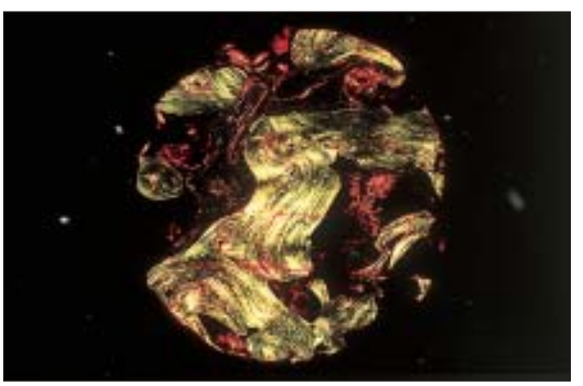

Fig 2d Apical section presenting a higher percentage of lamellar bone at 9 months, consisting mainly of fibers with greenish-yellow and yellow polarization colors (Picrosirius red with polarizing microscopy; magnification ×20).

direct contact with the newly formed bone as well as with connective tissue. When the coronal section and the apical deep cuts of the specimens were examined, the newly formed bone occupied a much greater area in the apical augmented zone, compared to the coronal zone in close proximity to the CTM (Figs 2a and 2b).

Examination of the coronal area sections presented larger areas of woven bone characterized by thin and thick collagen fibers possessing polarization colors of green and greenish-yellow (Fig 2c). However, the apical area sections stained with Picrosirius red and examined with a polarized microscope revealed greenish to yellow polarization colors for thin fibers and more yellow to orange colors for thick fibers in a higher percentage. This represented a higher percentage of lamellar bone at this site (Fig 2d). The black areas in the sections represented grafted particles and only minimal areas of loose connective tissue.

DISCUSSION

Restoration of a 3-dimensionally resorbed ridge can be achieved using CTM. The procedure is technically sensitive. The void under the mesh should be maintained and stabilized,[38,39] which is achievable only by using a meticulous surgical technique. In the first 3 to 4 weeks after CTM placement, during cell differentiation and tissue identification, prevention of spontaneous exposure of the CTM is essential. It is important to establish a tension-free complete soft tissue closure. However, at 4 weeks after CTM placement, a spontaneous exposure occurred in 2 patients. This late exposure was probably a result of constant labial muscle tension and function in the forcibly shallowed vestibule that had been established. Furthermore, subsiding of the edema and diminished blood vessel nourishment to the area could also have contributed to this undesired exposure. However, it appears that this exposure did

not substantially affect the clinical outcome in the augmentation site. The thin soft tissue zone that was identified under the CTM has also been reported in other vertical GBR cases.[11] This soft tissue could have been a result of the micromovement and pressure over the site[39] during the remodeling phase.

Clinically and histologically, no substantial difference was observed between the 3 maxillary and the 7 mandibular cases. Nevertheless, while soft tissue closure was achieved by lingual and buccal coronally positioned flaps in the mandible, the rigidity and inflexibility of the masticatory palatal tissue made necessary an extensive coronal positioning of the buccal flap, which nearly eliminates the vestibular depth space. However, reduction of the labial vestibule did not cause any inconvenience to the patients, and the vestibule was eventually re-deepened at the time of implant cover screw exposure. The patients with spontaneously exposed CTM reported a metal taste that disappeared after the device was removed.

Histologically, new bone formation and presence of the grafted particles at 9 to 42 months were evident.[40–45] Most of these reports involved inlay augmentation procedures. Generally, there was a gradual increase in newly formed bone from the coronal to the apical cuts. Lamellar bone was more pronounced in the deep apical area, whereas woven bone dominated the coronal zone. This was repeatedly emphasized with the Picrosirius red staining and polarizing microscopy. The reason for this is that the apical section cuts are closer to the recipient bed, which is well nourished, whereas the coronal zone is nourished primarily by the overlying flap and the relatively distant osseous recipient area. Consequently, the quality and quantity of the newly established hard tissue are affected in different zones of the restored ridge. Similar data have been reported in extraction sites and sinus augmentation procedures.[37,44]

CONCLUSION

The CTM surgical technique to rebuild a resorbed ridge proved to be a clinically successful procedure. Its predictability depends on a meticulous surgical protocol. Implants can be placed at a later stage. The restored ridge was proven clinically and histologically to accommodate endosseous implants and subsequent fixed prosthesis rehabilitation. The application of inorganic bovine bone as the filler material resulted in new bone formation at various stages of remodeling and maturation.

ACKNOWLEDGMENT

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REFERENCES

1. Leake DL. Contouring split ribs for correction of severe mandibular atrophy. J Oral Surg 1976;34:940–941.
2. Frost DE, Gregg JM, Terry BC, Fonseca RJ. Mandibular interpositional and onlay bone grafting for treatment of mandibular bony deficiency in the edentulous patient. J Oral Maxillofac Surg 1982;40:353–360.
3. Adell R, Lekholm U, Grondahl K, Brånemark P-I, Lindstrom J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. Int J Oral Maxillofac Implants 1990;5:233–246.
4. Isaksson S, Alberius P. Maxillary alveolar ridge augmentation with onlay bone-grafts and immediate endosseous implants. J Craniomaxillofac Surg 1992;20:2–7.
5. Misch CE, Dietsh F. Endosteal implants and iliac crest grafts to restore severely resorbed totally edentulous maxillae: A retrospective study. J Oral Implantol 1994;20:100–110.
6. Astrand P, Nord PG, Brånemark P-I. Titanium implants and onlay bone graft to the atrophic edentulous maxilla: A 3-year longitudinal study. Int J Oral Maxillofac Surg 1996;25:25–29.
7. Nystrom E, Ahlqvist J, Kahnberg KE, Rosenquist JB. Autogenous onlay bone grafts fixed with screw implants for the treatment of severely resorbed maxillae. Radiographic evaluation of preoperative bone dimensions, post-operative bone loss, and changes in soft-tissue profile. Int J Oral Maxillofac Surg 1996;25:351–359.
8. van Steenberghe D, Naert I, Bossuyt M, et al. The rehabilitation of the severely resorbed maxilla by simultaneous placement of autogenous bone grafts and implants: A 10-year evaluation. Clin Oral Invest 1997;1:102–108.
9. Keller EE, Tolman DE, Eckert S. Surgical-prosthodontic reconstruction of advanced maxillary bone compromise with autogenous onlay block bone grafts and osseointegrated endosseous implants: A 12-year study of 32 consecutive patients. Int J Oral Maxillofac Implants 1999;14:197–209.
10. Simion M, Baldoni M, Rossi P, Zaffe D. A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. Int J Periodontics Restorative Dent 1994;14:166–180.
11. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. Int J Periodontics Restorative Dent 1994;14:497–511.
12. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. Int J Periodontics Restorative Dent 1998;18:9–23.
13. Simion M, Jovanovic SA, Tinti C, Benfenati SP. Long-term evaluation of osseointegrated implants inserted at the time or after vertical ridge augmentation. A retrospective study on 123 implants with 1-5 year follow-up. Clin Oral Implants Res 2001;12:35–45.
14. Jensen OT, Greer RO Jr, Johnson L, Kassebaum D. Vertical guided bone-graft augmentation in a new canine mandibular model. Int J Oral Maxillofac Implants 1995;10:335–344.

15. Piattelli M, Scarano A, Piattelli A. Vertical ridge augmentation using a resorbable membrane: A case report. J Periodontol 1996;67:158–161.
16. Tinti C, Parma-Benfenati S, Polizzi G. Vertical ridge augmentation: What is the limit? Int J Periodontics Restorative Dent 1996;16:220–229.
17. Schliephake H, Kracht D. Vertical ridge augmentation using polylactic membranes in conjunction with immediate implants in periodontally compromised extraction sites: An experimental study in dogs. Int J Oral Maxillofac Implants 1997;12:325–334.
18. Tinti C, Parma-Benfenati S. Vertical ridge augmentation: Surgical protocol and retrospective evaluation of 48 consecutively inserted implants. Int J Periodontics Restorative Dent 1998;18:434–443.
19. Tinti C, Parma-Benfenati S. Treatment of peri-implant defects with the vertical ridge augmentation procedure: A patient report. Int J Oral Maxillofac Implants 2001;16:572–577.
20. Parma-Benfenati S, Tinti C, Albrektsson T, Johansson C. Histologic evaluation of guided vertical ridge augmentation around implants in humans. Int J Periodontics Restorative Dent 1999;19:424–437.
21. Artzi Z. Coronal ridge augmentation in the absence of bilateral bony plates around a pathologically denuded implant surface. Int J Periodontics Restorative Dent 2000;20:191–197.
22. Cornelini R, Cangini F, Covani U, Andreana S. Simultaneous implant placement and vertical ridge augmentation with a titanium-reinforced membrane: A case report. Int J Oral Maxillofac Implants 2000;15:883–888.
23. Chin M, Toth BA. Distraction osteogenesis in maxillofacial surgery using internal devices: Review of five cases. J Oral Maxillofac Surg 1996;54:45–53.
24. Chin M. The role of distraction osteogenesis in oral and maxillofacial surgery. J Oral Maxillofac Surg 1998;56:805–806.
25. Gaggl A, Schultes G, Karcher H. Vertical alveolar ridge distraction with prosthetic treatable distractors: A clinical investigation. Int J Oral Maxillofac Implants 2000;15:701–710.
26. Raghoebar GM, Heydenrijk K, Vissink A. Vertical distraction of the severely resorbed mandible. The Groningen distraction device. Int J Oral Maxillofac Surg 2000;29:416–420.
27. Cho BC, Seo MS, Baik BS. Distraction osteogenesis after membranous bone onlay grafting in a dog model. J Oral Maxillofac Surg 2001;59:1025–1033.
28. Henkel KO, Ma L, Lenz JH, Jones L, Gundlach KK. Closure of vertical alveolar bone defects with guided horizontal distraction osteogenesis: An experimental study in pigs and first clinical results. J Craniomaxillofac Surg 2001;29:249–253.
29. Younger EM, Chapman MW. Morbidity at bone graft donor sites. J Orthop Trauma 1989;3:192–195.
30. Murphy KG. Postoperative healing complications associated with Gore-Tex periodontal material. Part I. Incidence and characterization. Int J Periodontics Restorative Dent 1995; 15:363–375.
31. Murphy KG. Postoperative healing complications associated with Gore-Tex periodontal material. Part II. Effect of complications on regeneration. Int J Periodontics Restorative Dent 1995;15:548–561.
32. Nowzari H, Matian F, Slots J. Periodontal pathogens on polytetrafluoroethylene membrane for guided tissue regeneration inhibit healing. J Clin Periodontol 1995;22:469–474.
33. Boyne PJ. Surgical reconstruction using titanium mesh in combination with bone grafts. In: Evensen L (ed). Osseous Reconstruction of the Maxilla and the Mandible. Chicago: Quintessence, 1997:27–52.
34. Shanaman R, Filstein MR, Danesh-Meyer MJ. Localized ridge augmentation using GBR and platelet-rich plasma: Case reports. Int J Periodontics Restorative Dent 2001;21: 345–355.
35. Maiorana C, Santoro F, Rabagliati M, Salina S. Evaluation of the use of iliac cancellous bone and anorganic bovine bone in the reconstruction of the atrophic maxilla with titanium mesh: A clinical and histological investigation. Int J Oral Maxillofac Implants 2001;16:427–432.
36. Dayan D, Hiss Y, Hirshberg A, Bubis JJ, Wolman M. Are the polarization colors of picrosirius red-stained collagen determined only by the diameter of the fibers? Histochemistry 1989;93:27–29.
37. Artzi Z, Tal H, Dayan D. Porous bovine bone mineral in healing of human extraction sockets. Part 2. Histochemical observations at 9 months. J Periodontol 2001;72:152–159.
38. Wikesjo UM, Nilveus R. Periodontal repair in dogs: Effect of wound stabilization on healing. J Periodontol 1990;61: 719–724.
39. Haney JM, Nilveus RE, McMillan PJ, Wikesjo UM. Periodontal repair in dogs: Expanded polytetrafluoroethylene barrier membranes support wound stabilization and enhance bone regeneration. J Periodontol 1993;64:883–890.
40. Berglundh T, Lindhe J. Healing around implants placed in bone defects treated with Bio-Oss. An experiment study in the dog. Clini Oral Implants Res 1997;8:117–124.
41. Skoglund A, Hising P, Young C. A clinical and histologic examination in humans of the osseous response to implanted natural bone mineral. Int J Oral Maxillofac Implants 1997; 12:194–199.
42. Artzi Z, Nemcovsky CE. The application of deproteinized bovine bone mineral for ridge preservation prior to implantation. Clinical and histological observations in a case report. J Periodontol 1998;69:1062–1067.
43. Hämmerle CH, Chiantaella GC, Karring T, Lang NP. The effect of a deproteinized bovine bone mineral on bone regeneration around titanium dental implants. Clin Oral Implants Res 1998;9:151–162.
44. Artzi Z, Tal H, Dayan D. Porous bovine bone mineral in healing of human extraction sockets. Part 1. Histomorphometric evaluation at 9 months. J Periodontol 2000;71:1015–1023.
45. Zitzmann NU, Scharer P, Marinello CP, Schupbach P, Berglundh T. Alveolar ridge augmentation with Bio-Oss: A histologic study in humans. Int J Periodontics Restorative Dent 2001;21:288–295.