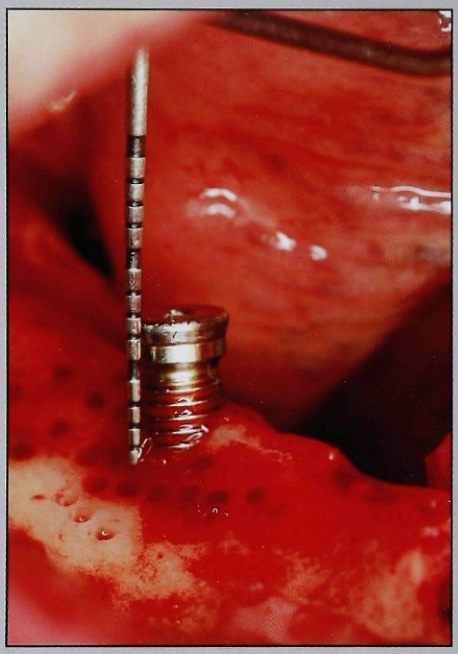

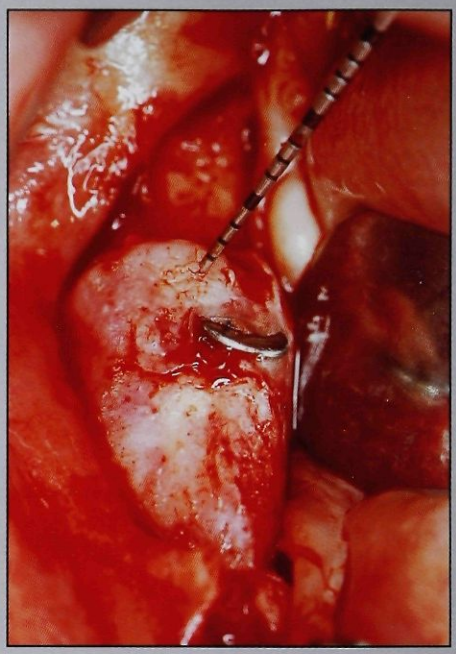

Vertical Ridge Augmentation: Surgical Protocol and Retrospective Evaluation of 48 Consecutively Inserted Implants

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The aim of this retrospective study was to evaluate the predictability of obtaining a vertical ridge augmentation around dental implants, strictly following a surgical protocol. Fourteen partially and four fully edentulous patients were treated between July 1993 and November 1995. Forty-eight consecutive implants were placed so that the circumference of the upper part of the cover screw was exposed from 2 to 7 mm. In addition to bone chips, autogenous bone grafts harvested with a bone-filtering aspirator were placed around the exposed threads and completely covered with a barrier membrane. Flaps were coronally displaced to cover the regenerative materials. Three of the 22 membranes became exposed prematurely and were removed immediately. The remaining 19 membranes stayed in place for a 12-month healing period until the second-stage surgery. In these 19 cases, where the membrane remained completely covered by the soft tissue, all of the available space underneath the membrane was filled with regenerative tissue. In eight cases a histologic biopsy was performed. Histologic analysis demonstrated vital bone with regularly formed bone cells; in three cases the most coronal part (approximately 1 mm) of the regenerative tissue was connective tissue, and the remaining tissue was bone. This retrospective analysis showed that when the clinical protocol was accurately followed, the possibility of clinical complication was reduced and the results for achieving vertical ridge augmentation around implants were predictable. (Int J Periodont Rest Dent 1998;18:435–443.)

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The successful use and the long-term prognosis of osseointegrated implants in the treatment of the fully or partially edentulous patient requires an adequate quantity and quality of jawbone to be available for implant placement.[1–3] When the presurgical evaluation reveals that the width and vertical bone height of the alveolar ridge are insufficient at the desired implant locations, reconstructive bone surgery is required if endosseous implants are to be used. Autogenous bone grafting procedures to increase the volume of bone tissue in the maxillary arch present negative consequences such as the need for an extraoral donor site, and patient hospitalization and morbidity. A common contraindication for implants in the mandibular posterior region is inadequate bone volume above the inferior alveolar nerve. Transposition of the nerve to allow the placement of implants is avoided by

many surgeons because of the risk of temporary or permanent nerve parasthesia.

Guided bone regeneration, which is based on the biologic principles of guided tissue regeneration, is used to gain bone regeneration around periodontally compromised teeth. A variety of techniques have been applied to increase the alveolar ridge width by excluding the invasion of non-osteogenic soft tissue cells, and promoting new bone tissue formation around implants placed into sites where there is insufficient bone volume.[4-12] In the last six years, improvement and innovation in surgical techniques have evolved to enhance new bone formation around implants placed into immediate extraction sockets,[8,13,14] in dehisced or fenestrated implants,[8,10,12] and in the treatment of peri-implantitis.[2] Furthermore, the guided bone regeneration technique has been applied to gain bone regeneration and enlargement in edentulous ridges for the subsequent placement of osseointegrated implants.[4,6,15,16]

Recent experimental and clinical results demonstrate vertical ridge augmentation from flat cortical bone surfaces.[17-21] The purpose of this study was to evaluate the possibility of obtaining regenerated bone tissue around implants in vertical ridge defects in consecutive cases when a surgical protocol was meticulously followed.

Method and materials

Patients

Eighteen patients, 14 partially edentulous and 4 fully edentulous, between the ages of 38 and 71 years (mean age 52 years) participated in this clinical study. They had been referred for implant therapy, and they were highly motivated to avoid removable partial dentures. An extensive explanation of the procedures that would be performed was followed by a written consent form. Presurgical evaluation and CT scans revealed insufficient vertical bone height in the alveolar ridge in all cases. A total of 48 Nobel Biocare implants were consecutively placed from July 1993 to November 1995.

Implant defects were selected for treatment and included in the study on the basis of an anatomic residual bone structure that had: *(1)* a bone width and height greater than 5 mm, and *(2)* adequate interarch space for the placement of a fixed prosthesis. Only supracrestal bone deficiencies were included in this retrospective clinical study, and they were all treated at phase 1 surgery according to the surgical protocol described below.

Surgical protocol in the mandible

Local anesthesia (with vasoconstrictor adrenalin 1:100,000) was combined with a sedative premedication (diazepam 5 mg) and administered orally 30 minutes before surgery. A crestal incision within the keratinized tissue was extended intrasulcularly to the mesial line angle of the adjacent teeth, buccally and lingually. Two "hockey stick-shaped" vertical releasing incisions were made on the buccal site; the mesial incision was made at the mesial line angle of the mesial tooth, and the distal incision was made at the mesial line angle of the distal tooth if present, or approximately 7 to 8 mm distal to the most distal extension of the proposed membrane if no distal tooth was present (Fig 1). A buccal mucoperiosteal full-thickness flap was then raised. The intrasulcular lingual incision, which continued the previously executed crestal incision, was extended mesially to include at least three teeth (Fig 2). Mesial and distal vertical releasing incisions that ended no more than 1 mm beyond the mucogingival junction were performed on both sides (Fig 3). A full-thickness lingual flap was then raised, extending beyond the mylohyoid insertion of the omohyoid muscle. By raising the mylohyoid muscle with a full-thickness flap, it is possible to raise the entire

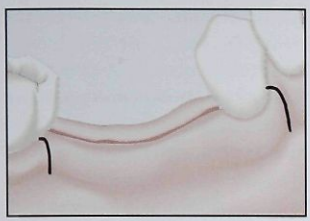


Fig 1 *Buccal flap shows crestal incision within keratinized tissue and the hockey stick-shaped vertical releasing incisions.*

Fig 2 *Lingual flap. Intrasulcular incision, which continues the previously executed crestal incision, is extended mesially to include at least three teeth.*

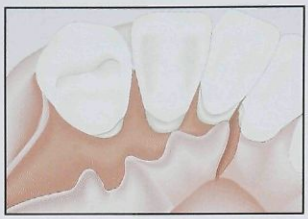


Fig 3 *Lingual flap. Mesial and distal vertical releasing incisions are performed. These incisions must end no more than 1 mm beyond the mucogingival junction.*

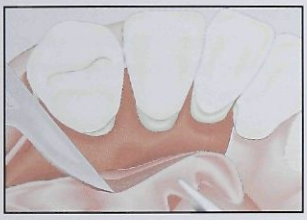


Fig 4 *Lingual flap. Mesiodistal incision releases both the periostium and muscle fibers immediately underneath the periostium layer.*

Fig 5 *Inner aspect of buccal flap. Periosteal incision of full-thickness flap is performed beginning at apical part of distal releasing incision and continuing mesially to mesial releasing incision.*

Fig 6 *Clinical evaluation of simultaneous coronal extension of both flaps.*

floor of the mouth, thereby protecting the important anatomic structures inside the raised muscle, such as the lingual nerve and lingual artery and the sublingual gland. A mesiodistal incision was made to release both the periostium and the muscle fibers immediately underneath the periostium layer. This very superficial incision is extremely important for enhancing elasticity and obtaining a coronal dislodgment of the lingual flap (Fig 4). The coronal dislodgment achieved with the flap must be able to partially cover the occlusal surfaces of the adjacent teeth, and the flap must be tension-free at closure. A periosteal incision of the raised full-thickness flap was then performed, beginning at the apical part of the distal releasing incision and continuing mesially until it reached the apical part of the mesial releasing incision (Fig 5). This incision enhanced the elasticity of the flap and obtained a coronal dislodgment that would allow the flap to reach the occlusal surface of the adjacent teeth.

The simultaneous coronal extension of both flaps was clinically evaluated, and implants were placed in a stable position (Fig 6). The cortical bone was then perforated peripherally to

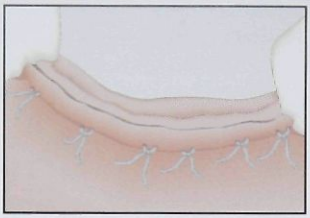


Fig 7 *Horizontal mattress sutures with U stitches provide first line of closure.*

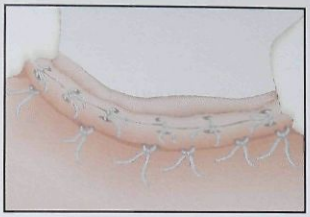


Fig 8 *Simple interrupted sutures provide second line of closure in a more coronal position (compare with Fig 7).*

allow access to the marrow vascular spaces. Autogenous bone particles and/or autogenous bone chips were positioned around the exposed threads to completely cover them. Titanium-reinforced expanded polytetrafluoroethylene membranes (TR-GTAM, 3i) were used in all patients. The titanium-reinforced (TR) membranes were bent with fine tweezers to obtain a close adaption to the underlying bone and to the implants. The lateral portions of the membrane were trimmed with scissors to overlap the edge of the bone beyond the defect margins by approximately 4 mm. The titanium-reinforced membranes were stabilized to the bone with fixation screws. The augmentation material was positioned 3 to 4 mm away from the natural teeth. Horizontal mattress sutures with U stitches (first line of closure) were used to create two contact surfaces at least 3 mm thick; the U stitches were alternated with simple interrupted sutures. The first and second lines of closure are shown in Figs 7 and 8, respectively. No pressure was applied to the surgical area.

The patients were premedicated with an antibiotic (2 g amoxicillin 2 hours prior to surgery), and they received 1 g amoxicillin per day for 1 week postoperative. They were also given appropriate analgesics. Patients were examined at the end of the first week for material exposure, and the sutures were removed after 15 days. Patients were checked monthly thereafter. The use of a removable prosthesis was avoided on the surgical site until stage 2 surgery to prevent any trauma to the augmented site.

Surgical protocol in the maxilla

The procedure in the maxilla only differs in the management of the palatal flap. This flap can be displaced buccally when necessary to offer complete coverage of the membrane.[22] The palatal flap has been managed as described in a previous publication by the authors.[22] The surgery was otherwise identical to that described for the mandible.

This surgical technique, which leaves an implant exposure of 2 to 7 mm—the goal is to cover them completely—has been applied to the maxillary arch when a wide interarch space discrepancy is present. This clinical situation alters the coronal length and form, and the embrasures, and produces a crown-to-root ratio that is unfavorable for the occlusal stress-bearing capability of the implants, thus compromising the function and esthetics of the final prosthesis.

A total of 48 Nobel Biocare implants were inserted according to the standard implant protocol described by Adell et al,[3] except that the implants were intentionally allowed to protrude occlusally 2 to 7 mm from the bone crest with no countersinks. The exposed implant threads were completely covered by a combination of autogenous bone graft particles harvested with a bone-filtering aspirator (Quality Dent) and

autogenous bone chips of approximately 2 mm. All measurements for biometric analysis were taken with a calibrated periodontal probe. The distance from the top of the cover screw to the peri-implant bone crest at the mesial and distal aspects was measured before and after treatment. Autogenous bone was accumulated with a bone-filtering aspirator during the drilling phases of the implant-recipient preparation.

Second-stage surgery: Membrane removal

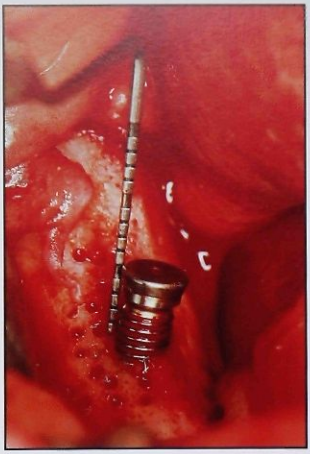
After a 12-month healing period, all TR membranes were removed at the surgery for abutment connection. Three membranes had become exposed during the healing period and were removed prior to second-stage surgery. In all cases a crestal incision was performed in a distomesial direction to raise a flap just beyond the most apical margins of the augmentation material. After removing the fixation screws, the TR membrane was raised with small surgical pliers, beginning at its most apical portion (Fig 9a). Complete photographic documentation and clinical measurements were retaken at the time of membrane removal and abutment connection. All of the space underneath the TR membranes was completely filled with regenerated tissue. The regenerated material appeared as a hard, bonelike structure. A small biopsy specimen of the newly regenerated hard tissue was collected randomly to be processed for histologic examination. These specimens were removed, fixed in 10% neutral buffered formalin for 24 hours, and then dehydrated in an ascending series of alcohol rinses. The sections were stained with hematoxylin-eosin stain.

Results

From July 1993 to November 1995, 48 Nobel Biocare implants were placed in 22 surgical sites and covered with TR-GTAM. During the first surgical implant phase, the experimental implants were positioned so that the circumference of the most coronal part of the cover screw was exposed for 2 to 7 mm (Figs 9b to 10b).

During a 12-month healing period, 3 out of 22 membranes (13.6%) became exposed. In one case the membrane became exposed 15 days postoperative; the membrane was removed and no regeneration was achieved. The second membrane exposure occurred 2 months postoperative because of suppuration; both the implant and membrane were removed. In the third case the membrane became exposed after 5 months. The implant was stable and the space previously created for the regenerated tissue was filled by compact, hard tissue. The histologic specimen from a randomly taken biopsy revealed new immature bone tissue and spongy lamellar bone with osteoblastic lines and osteocyte cells. In the remaining 19 out of 22 cases (86.4%), the membranes remained covered for a 12-month healing period; new tissue formation obliterated the space created but the barrier membrane was found. In three cases a very thin connective tissue layer of approximately 1 mm or less was noted immediately underneath the barrier membrane.

The histologic biopsy specimens, randomly taken in eight cases, demonstrated that the new regenerated tissue had the clinical appearance of healthy, mature bone. In one patient, the TR membrane lost its fixation and was dislodged in a distal direction, leaving only the mesial aspect of the experimental implant uncovered; in only this area was the regenerated tissue represented by fibrous connective tissue. As in all other patients, the regenerated material under the membrane appeared as a hard, bonelike structure.



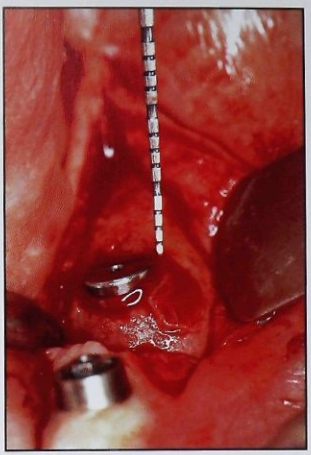
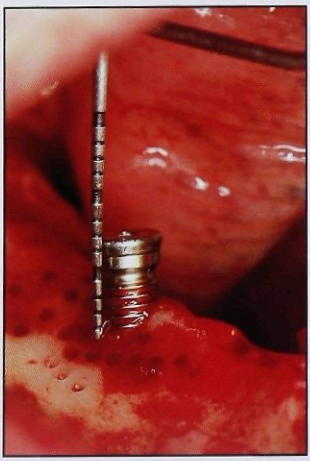


Fig 9a (left) *Experimental implant is positioned so that the circumference of the coronal portion extends outside the bone crest. Distance from residual alveolar crest to top of cover screw is measured. Implant protrudes at least 5 mm from bone crest.*

Fig 9b (right) *Flap elevation and TR membrane removal after a 12-month healing period. Regenerated tissue not only covers the previously exposed threads, but reaches the upper part of the coverscrew.*



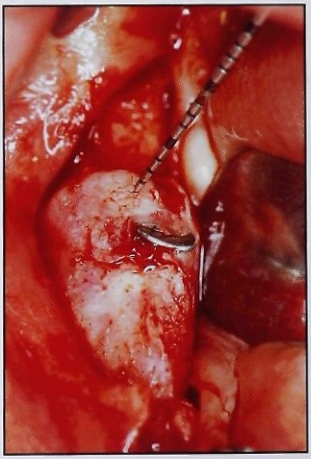


Fig 10a (left) *Nobel Biocare implant protrudes 7 mm circumferentially from bone crest.*

Fig 10b (right) *Newly regenerated tissue almost completely covers cover screw; tissue extends several millimeters above cover screw on distal aspect. Implant is stable and regenerated tissue cannot be probed periodontally or detached with a periostium elevator. Regenerated tissue appears as hard, bonelike structure.*

Discussion

This retrospective analysis demonstrated that this vertical bone augmentation technique is predictable only when the surgical protocol is followed and the clinician pays attention to all the details (Figs 9 and 10). It is the authors' opinion that the predictability of this new technique is strictly related to respecting the clinical protocol and is highly technique-sensitive. A very important step is to obtain tension-free flaps at the barrier membrane, so that the regenerative material can be kept completely covered for a 12-month healing period. The buccal and lingual periostium must be released in such a way that elasticity is greatly enhanced and a coronal dislodgment of both flaps is achieved. For the buccal flap the major precaution is to stay as far away as possible from the mental foramen. For the lingual aspect it is extremely important that the full-thickness flap is raised beyond the insertion of the mylohyoid muscle; the muscle must be raised to protect important anatomic structures, including the lingual nerve, lingual artery, and sublingual gland.

Out of the 19 cases in which the membranes were kept completely covered, the regenerative tissue completely filled the space available for bone regeneration in nine cases. The space created and mantained with the TR-GTAM was related to the individual regenerative needs of each case. In the early cases the regenerative needs were limited to less difficult situations (those requiring less than 3 mm of vertical ridge augmentation), and only autogenous bone particles taken from the bone-filtering aspirator were positioned around the exposed threads of the implants. With more experience, more complicated cases (those requiring more than 3 mm of vertical ridge augmentation) were treated using autogenous bone chips in addition to the bone particles. In all of the 19 cases analyzed, the available space below the membrane was filled almost exclusively with newly regenerated tissue, which both clinical and histologic analysis showed to be bone. These results are in agreement with previous clinical and histologic studies on vertical ridge augmentation.[17-21]

Advanced atrophy represents a great problem for esthetic and prosthetic rehabilitation in the edentulous jaw. From a surgical point of view, the insertion of implants is not possible without onlay bone grafts in combination with vestibuloplasties or other surgical techniques. Discouraging results caused by the rapid resorption of the graft or a sensory disturbance in the mental nerve region called the necessity of bone grafting into question.[23] One of the major advantages of such a surgical procedure is that it spares the patient considerable biologic cost. Other advantages are that this procedure can be performed in an office setting without hospitalization when a standard surgical protocol is followed, and patient morbidity is the same as that associated with one-phase implant insertion. Furthermore, the autogenous bone graft is collected from the same surgical site, eliminating the need for either an intraoral or extraoral donor site. Because guided bone regeneration is a simultaneous approach, it is implemented at the same time as dental implant placement. This simultaneous approach is an advantageous alternative to a staged approach, avoiding the trouble of an additional surgery for the patient.

The major disadvantage to this procedure seems to be the need to strictly follow a clinical protocol, rendering the procedure technique-sensitive. Another disadvantage is the possibility of early membrane exposure and/or an infected implant surface, but lost implants can most likely be replaced later.

This surgical technique is indicated *(1)* for the primary stability of an implant that is associated with a highly resorbed alveolar ridge, or *(2)* for the placement of a dental implant in an appropriate position from a functional and prosthetic point of view. The major contraindication in a private office setting is severe alveolar bone resorption that is manageable only by a maxillofacial approach. The frequent lack of interocclusal space in edentulous posterior areas must also be considered an anatomic contraindication. Vertical ridge augmentation in the posterior sextants could result in the loss of interocclusal space, which often impairs the clinician's ability to make a proper restoration. A longer healing period was used in this clinical situation than in a staged approach because these defects are "nonspace-making"; bone formation and bone maturation take more time in these larger defects treated with a simultaneous approach.

Conclusion

After an unavoidable clinical learning experience and a development period for this procedure, the guided bone regeneration technique described can be considered predictable in every case where the surgical protocol has been respected.

This guided bone regeneration approach is only recommended for vertical ridge augmentation in partially edentulous patients with reduced alveolar ridges. As previously mentioned, this technique has limitations imposed by the available residual alveolar ridge for the placement of an implant with primary stability. In fully edentulous patients with severe bone atrophy, the use of autogenous bone grafts from the iliac crest following the biologic principles of guided bone regeneration is the treatment of choice if osseointegrated implants are to be inserted. Further research is needed to evaluate the load-bearing capacity of the newly formed tissue and the long-term results of this procedure.

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