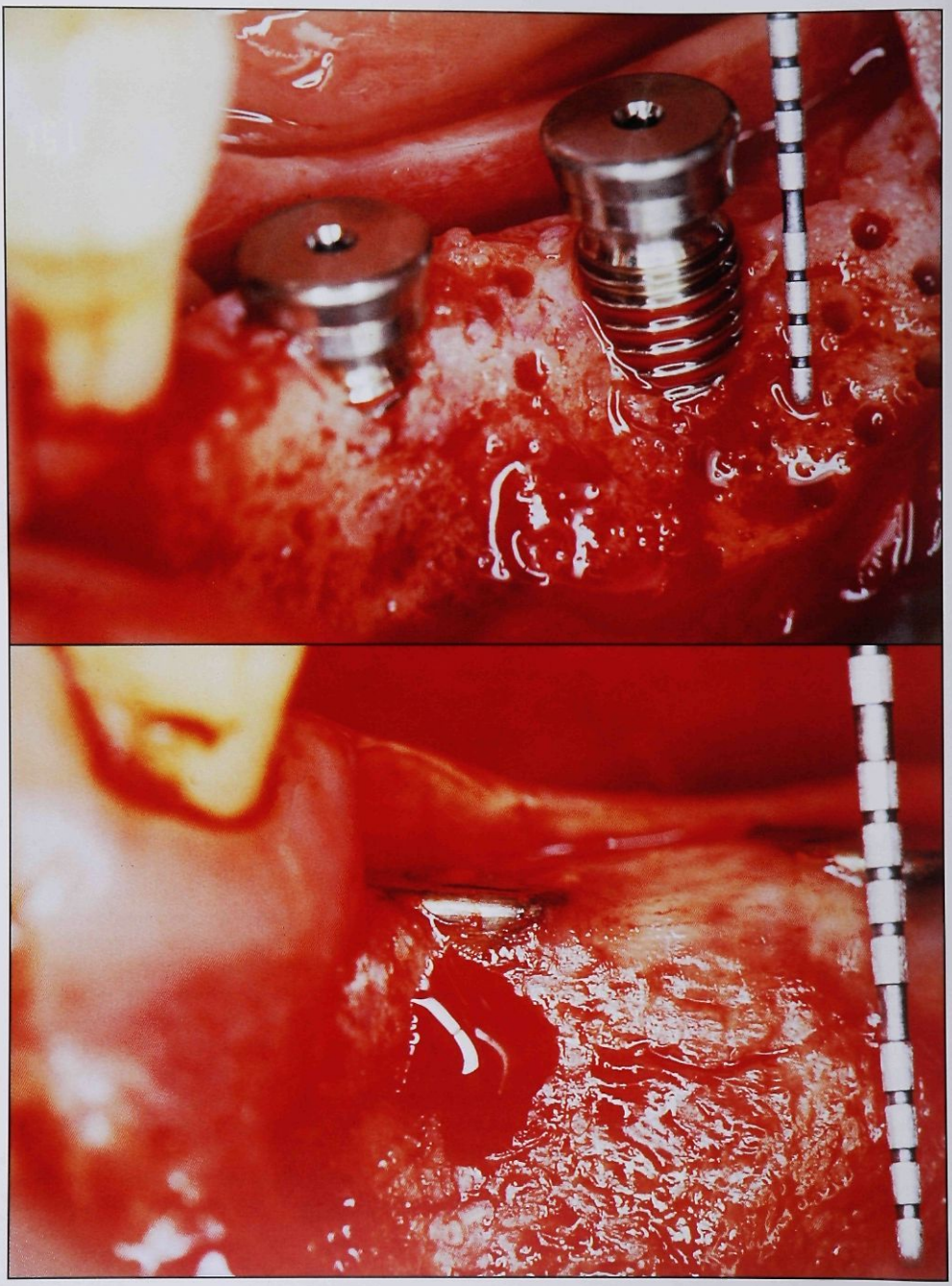

Vertical Ridge Augmentation: What is the Limit?

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The aim of this study is to show the possibility of achieving more than a 4-mm new vertical bone apposition on partially edentulous ridges. Six healthy, partially edentulous patients were treated from July 1993 to September 1993. After accurate radiographic investigation, all of the patients were treated using the Brånemark System. After insertion, 14 fixtures were left circumferentially exposed for 37 mm. Autogenous bone graft harvested from a bone filter was placed around the exposed threads and completely covered with titanium-reinforced Gore-Tex augmentation membranes (TR-GTAM). Flaps were coronally displaced to passively cover the regenerative materials. Only one of the six membranes was exposed and it was removed immediately. After a 12-month healing period, the membranes were removed in conjunction with the second-stage surgical procedure. In the five cases where the membranes were kept covered, all of the available space underneath the TR-GTAM was filled with regenerative tissue. In all of the cases a histologic biopsy was performed. In one case all the space was filled with more than 7 mm of bone. In three cases all the space was filled with more than 5 mm of bone. In one case the most coronal part (approximately 1 mm) of the regenerative tissue was represented by connective tissue; the remaining tissue was represented by bone. The measurements demonstrated an average of vertical ridge augmentation of 4.95 mm. In the only case where the membrane underwent exposure and was then removed there was no regenerative tissue present.
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In the last 10 years implant treatment planning proposed by the dentist or requested by the patient has expanded exponentially with the application of osseointegration to the fully or partially endentulous patient. However, many patients presenting for dental implant therapy are not candidates for such treatment because of either an inadequate volume of bone or a bony anatomy that complicates the placement of fixtures, especially in sites where ideal implant positioning is mandatory for optimal esthetics.

To obtain predictable long-term results, the anatomy, quantity of bone, and quality of the jawbone at the site of fixture installation are crucial factors. A minimum of 7 × 4 mm of bone structure is required with use of the shortest standard Brånemark implant[1]; however, to avoid any undesirable complications during the healing process, a minimum buccolingual width of 6 mm is recom-

mended for complete bone coverage of the threaded part of the titanium implant.[2,3]

Bone regeneration procedures can modify, correct, and augment compromised bone sites resulting from an excessive resorption phase following tooth exfoliation because of trauma, deep root fracture, advanced periodontal inflammatory lesions, or maxillofacial trauma.

Prior to the clinical application of the principle of guided tissue regeneration (GTR) to dental implants, extraoral autogenous bone grafting procedures were used to increase the amount of bone tissue. The associated problems with these techniques were the utilization of an extraoral site, hospitalization, and patient morbidity.

In partially edentulous patients, anatomic structures such as the maxillary sinus or the alveolar nerve may limit the bone height available for implant stability and the load-bearing capacity. Different bone graft materials may be utilized for sinus elevation, and alveolar nerve transportation in the mandibular arch may increase the length of the bony tissue to allow the placement of implants of adequate length. However, both techniques are still under clinical evaluation, and the latter presents a consistent risk of temporary or permanent nerve damage. The biologic principles of GTR, reported for the treatment of periodontally involved teeth, have been applied to increase the alveolar ridge width prior to implant placement, to exclude the invasion of nonosteogenic soft tissue cells, and to allow preferential enhancement of new bone tissue around implants placed into sites where there is insufficient bone volume.[4-12] A better understanding of the principles of GBR and innovations in surgical techniques have enhanced new bone formation around implants placed into immediate extraction sockets,[8,13,14] in dehisced or fenestrated implant surfaces,[8,10,12] and in treatment of angular bony defects in a peri-implantitis situation.[2] In addition, GBR has enhanced treatment of other categories of defects using ridge regeneration, and subsequent or simultaneous placement of osseointegrated implants.[4-6,15,16]

The expanded polytetrafluoroethylene (e-PTFE) membrane creates initially secluded space in which the blood clot is protected from mechanical injuries and from the colonization of cells deriving from the gingival tissues. As a result, only cells from the alveolar bone can repopulate the blood clot.

The relationship between space provision and bone regeneration was studied in the 1950s and in the early 1960s. Several studies confirmed this biologic observation in other types of osseous defects. Space provision for bone regeneration is one of the main problems in GTR procedures, as it defines the maximum volume of bone which can be regenerated.[17-20] The creation and maintenance of a sufficient space with an adequate blood clot that does not interfere with stabilization must be established.

It has been clinically proven that the fewer the residual bony walls, the more difficult it is to avoid soft tissue and membrane collapse. This is especially true in the presence of gingival recession, dehiscence, or fenestration types of bony defects, where there is no support to the barrier.

Various filling materials have been experimented with and proposed for the creation and maintenance of space and for prevention of a collapse of both the flap and the barrier membrane in non-space-making defects.[21-24]

From clinical experience it is known that empty spaces become rapidly obliterated by a blood clot containing both non-bone-forming and bone-forming cells after the surgical procedure.

Recently, encouraging experimental results have been reported utilizing GBR techniques in vertical ridge augmentation from flat cortical bone surfaces.[25-27]

Many studies have advocated soft tissue pressure and tension to cause membrane collapse in defects, thus limiting the regenerative potential of the bony structures.[25,28]

There are only two studies on jawbone augmentation of the vertical dimension[27,29] in which the authors utilized a new type of e-PTFE membrane reinforced with a pure titanium structure (TR-GTAM, WL Gore) and membrane fixation devices (Memfix system, Straumann). Titanium-reinforced GTAM can be bent and shaped and maintain the desired form because of the titanium structure included in its construction. Thus, the TR-GTAM creates and preserves sufficient space between the membrane and the bony defects, allowing new possibilities for vertical ridge augmentation and regeneration in situations in which the anatomy of the defect is non-space-making.

Jovanovic et al,[27] in a study on five adult beagle dogs, suggested that supracrestal bone regeneration can successfully be enhanced by a submerged membrane technique in the dog model. They also suggested that the TR-GTAM membranes were able to maintain a large protected space without the addition of bone grafts, and that they produced a larger quantity of bone when compared to standard membranes.

Simion et al,[29] in a clinical and histologic study on five patients, suggested that the placement of implants protruding 3 to 4 mm from the top of a resorbed bone surface may result in a vertical bone regeneration gain of 3 to 4 mm in height. Their histologic examination showed that all retrieved miniscrews were in direct contact with the bone, and that the regenerated bone was able to osseointegrate pure titanium implants.

The aim of this clinical study was to demonstrate the possibility of achieving more than 4 mm of new vertical bone apposition on partially edentulous ridges using a membrane technique associated with osseointegrated implants in humans.

Method and materials

Six patients between 40 and 52 years (mean age: 46 years) participated in this clinical study. They were partially edentulous, were initially referred to our dental offices for evaluation for implant therapy, and were highly motivated to undergo this procedure because they wanted to avoid removable partial dentures at all costs. All patients reported in good health and received a comprehensive periodontal evaluation and a complete-mouth radiographic survey.

Computerized tomograms revealed a minimum quantity of residual bone in a coronoapical direction. The bone ridges were carefully examined, and the desired implant location from a prosthetic point of view was determined utilizing a guiding surgical stent.

All patients received an extensive explanation of the procedures that would be performed and signed a written consent form. A total of 14 dental implants (MK II, Nobelpharma) were placed.

Surgical technique (Figs 1a to 1h and 2a to 2e)

All patients were treated following an identical surgical protocol. A crestal incision within the keratinized gingiva was used to elevate a buccal mucoperiosteal full-thickness flap. This incision was extended intrasulcularly and anteriorly to the mesial line angle of the adjacent tooth. Vertical releasing incisions were made at the distal aspect of the crestal incision, approximately 7 to 8 mm distal to the proposed most distal position of the membrane. The lingual flap was raised to full thickness and continued mesially intrasulculary to include three teeth, and a vertical releasing incision of approximately 3 to 4 mm was used on the distal aspect. The periosteum was then released in such a way as to enhance elasticity and to obtain a coronally accentuated dislodgement of the lingual flap.

On the vestibular side the periosteal releasing incision was started from the most apical part of the mesial releasing incision and continued until joining the most apical part of the distal releasing incision. This type of incision left the flap tension-free at closure.

On the maxillary arch, a crestal incision and two vertical buccal releasing incisions were used at a reasonable distance from the anticipated edge of the membrane and were connected by a mesiodistal incision at the base of the flap to enhance flap elasticity by releasing the periosteum. On the palatal side, a coronally positioned palatal sliding flap was performed as described by Tinti and Parma-Benfenati.[30]

After positioning the surgical stent made by the prosthodontists, a total of 14 MK II Nobelpharma fixtures were inserted. Standard implant protocol as described by Adell et al[3] was followed, except that implants were placed in an ideal position for restoration, and were intentionally allowed to protrude 3 to 7 mm from the bone crest. Countersinks were not used. All the measurements for biometric analysis were taken with a calibrated periodontal probe from the top of the cover screw to the periimplant bone crest at the mesial and distal aspects before and after treatment.

During the drilling phase for the preparation of the fixture-recipient sites the physiologic solution was suctioned with the interposition of the bone filter (Quality Aspirators, Quality Dent) for the purpose of saving the bone. Before implant placement a round small-diameter bur was used to perforate the cortical bone to allow a larger number of medullary cavities to favor bleeding. Fourteen fixtures were positioned in six surgical sites, and the bone particles taken for the bone filters were positioned all around the fixtures.

Titanium-reinforced e-PTFE membrane (TR-GTAM, WL Gore) was used in all patients (Fig 1c). Titanium-reinforced membranes were bent with fine tweezers to obtain the desired shape for a close adaption to the underlying bone and to the implants. The lateral portions were trimmed with scissors in such a way that the outer portion overlapped the edge of the bone beyond the defect margins by approximately 4 mm. All the titanium-reinforced membranes were additionally stabilized to the bone with Memfix fixation screws (Fig 1c). When the augmentation material was close to natural teeth, attention was given to prevent interference with the healing process of the periodontal structures. Every effort was made to achieve primary closure of the flaps and passive adaption at closure. Horizontal mattress sutures with U stitches were used to create two contact surfaces at least 3 mm thick and were alternated with simple interrupted sutures.

The patients were premedicated with an antibiotic (2g of amoxicillin 2 hours prior to surgery), and were prescribed 1 g of amoxicillin per day for 1 week postoperatively. The patients were given appropriate analgesics. They were examined at the end of the first week for material exposure,

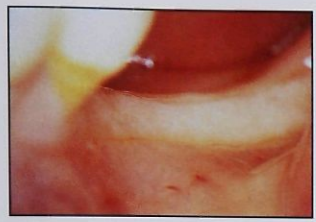

Fig 1a *Edentulous space in the left mandibular region of a 48-year-old woman. First and second mandibular molars were lost several years previously. There is insufficient bone height to allow traditional implant placement.*

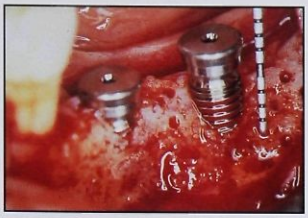

Fig 1b *Two 10-mm self-tapping implants placed in ideal prosthetic position. The distal fixture protrudes 6 to 7 mm from the bone crest. The mesial fixture is not included on the study.*

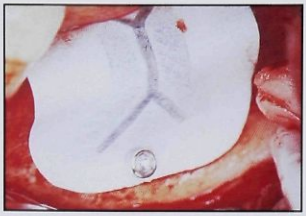

Fig 1c *Titanium-reinforced GTAM is positioned over the bone defect and the protruded implants and fixed to the bone with one Memfix fixation screw. The titanium frame gives rigidity to the membrane to maintain space.*

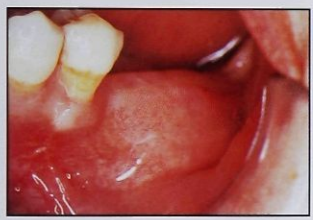

Fig 1d *Clinical appearance prior to stage 2 surgery after 12 months of uneventful healing.*

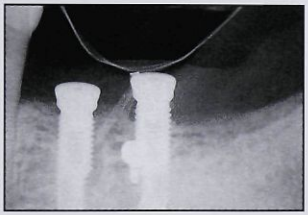

Fig 1e *Periapical radiograph immediately after positioning the two implants.*

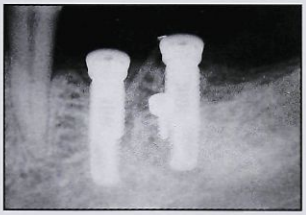

Fig 1f *Periapical radiograph 1 year postoperative. Newly regenerated calcified tissue can be seen.*

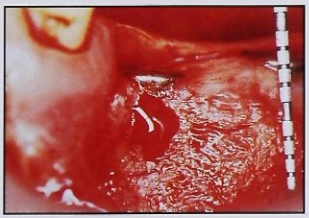

Fig 1g *Membrane removal demonstrates a newly regenerated ridge and that the peri-implant bone defects are filled with new osseous tissue.*

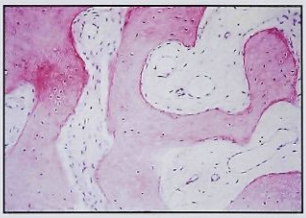

Fig 1h *Histologic findings from the biopsy specimen. New regenerated bone (lamellar) with osteoblastic lines and osteocite cells are present.*

Table 1 Result of GBR treatment in vertical ridge augmentation around implants in six patients

Patient	Healing	Tooth no.	Stage 1 surgery	Stage 2 surgery	Gain in ridge height (mm)
1	U	15	4	0	4
	U	14	5	0	5
	U	13	7	0	7
2	U	47	5	+2	7
3	U	37	7	1	6
4	U	35	4.5	0	4.5
	U	36	4	0	4
	U	37	4	0	4
5	MD	24	4	4	0
	MD	25	4	4	0
6	U	21	5.5	0	5.5
	U	22	4	0	4
	U	23	4	0	4
	U	24	4.5	0	4.5

U = Uneventful; MD = membrane dehiscence.

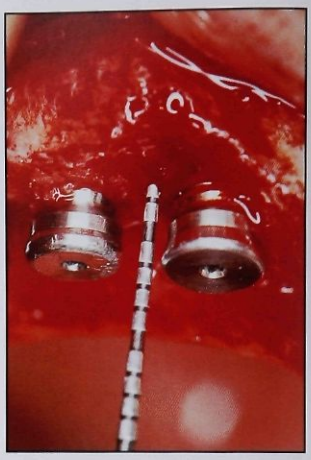

Fig 2a *Three MK II Nobelpharma implants placed in ideal prosthetic position with coronal implant surface extending outside the bone crest. Measurements were taken from the residual alveolar crest to the top of the cover screw.*

and the sutures were removed in 15 days.

The patients were checked monthly, and the use of a removable prosthesis was avoided on the surgical site until stage 2 surgery to prevent any trauma to the augmented site.

One TR membrane became exposed after 11 days and was immediately removed.

Second-stage surgery—Membrane removal

After a 12-month healing period, all TR membranes were removed except for the one that became exposed at the surgery for abutment connection. In all cases a crestal incision in a distomesial direction was performed to raise a flap just beyond the most apical margins of the augmentation material.

After removing the Memfix fixation screws, the TR membrane was raised with small surgical pliers from its most apical portion.

Complete photographic documentation and clinical measurements were retaken at the time of membrane removal and abutment connection.

All the space underneath the TR membranes was completely filled with regenerated tissue (Figs 1e to 1h and 2a to 2d). In one patient the most coronal part, approximately 1 mm, contained fibrous connective tissue. The regenerated material in the remaining space, as well as all the space in the other patients, appeared as a hard, bone-like structure. A small biopsy specimen of newly regenerated hard tissue was collected from each patient to be processed for histologic examination (Figs 1h and 2e). 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.

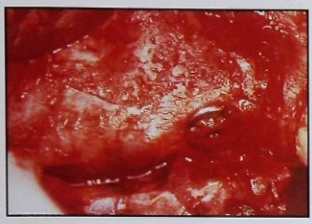

Fig 2b *Clinical view after flap elevation and TR membrane removal. Previous ridge loss is completely regenerated with newly formed bone.*

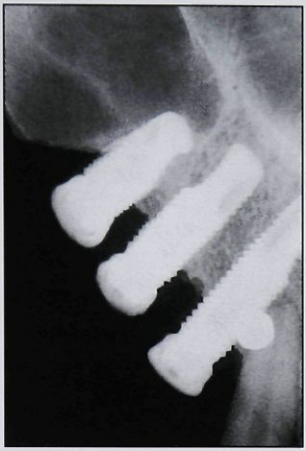

Fig 2c *Radiograph immediately after fixture positioning.*

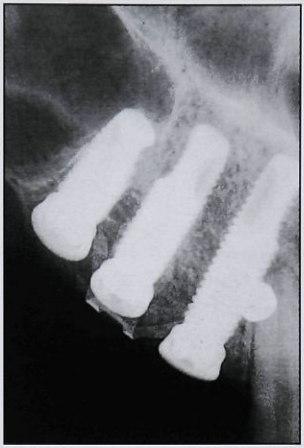

Fig 2d *Radiograph 1 year postoperative.*

Results

The results of the present study are summarized in Table 1. All patients recovered well, and no signs of infection were noted at the surgical site. Only one patient reported a membrane dehiscence after 11 days of healing. The membrane was removed immediately. This patient did not show any bone formation at the implant site. In the remaining five patients (12 fixtures), no exposure of the membrane occurred during the entire healing period. The membranes remained stable as they were placed. There were no signs of inflammation.

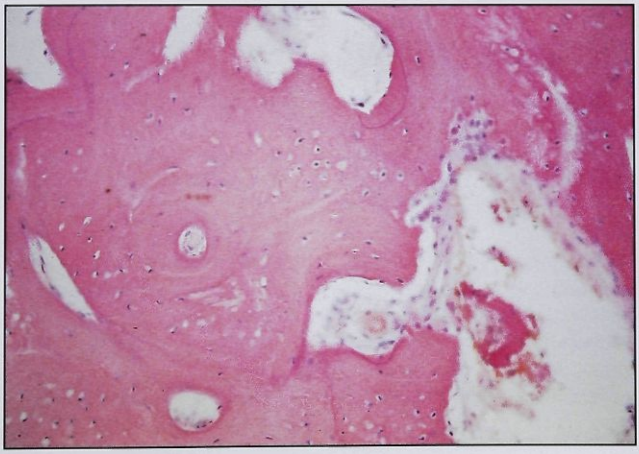

Fig 2e *Histologic findings. New bone tissue-spongeous lamellar bone with osteoblastic lines and osteocite cells.*

During the second-stage surgical phase at membrane removal the fixation screws were removed and the membranes were gently dissected from the underlying newly regenerated tissue.

An approximately 1-mm-thick layer of connective tissue was present after removal of the membrane in the most coronal part in only one case. This tissue was removed, leaving only bone around the implant. Connective tissue was not found around the implants in any of the other cases.

Measurements were carried out mesially and distally from the highest part of the cover screw to the top of the newly formed ridge. The measurements demonstrated an average circumferential bone formation in vertical regeneration of the ridge of 4.95 mm, and in one case the regeneration was over 7 mm.

The histologic examination of the regenerated tissue unequivocally demonstrated that it was healthy, vital bone with mature and regularly formed bone cells (see Figs 1h and 2e). The histologic examination of the soft tissue demonstrated that it was connective tissue with no inflammatory reaction, no macrophages, few cells, and scarce blood vessels.

Discussion

This study confirmed the capacity of the GTR technique to vertically augment bone from flat cortical bone surfaces, as was previously demonstrated in experiments with both animals[25–27] and humans.[29] Simion et al[29] found a 4-mm limit of vertical regeneration of the ridge. In this study, five of six cases showed a vertical bone regeneration of approximately 5 mm, and in one case of more than 7 mm. The space below the membrane in all cases presented had been filled almost exclusively with tissue which both clinically and histologically was shown to be bone. The discrepancy in the results shown in the present article and that of Simion may be caused by *(1)* the amount of time between stage 1 and stage 2 surgery; and *(2)* the use of autogenous bone graft from the filter.

Conclusion

The aim of this study was to demonstrate the possibility of supracrestal bone regeneration of over 4 mm. This goal appeared possible when:

1. The flap completely covered the membrane and was placed without tension.
2. The membrane was covered for 1 year.
3. The membrane was stabilized.
4. Autogenous bone was used.
5. There were abundant perforations of the cortical bone.
6. Horizontal mattress sutures with U stitches were used to create two contact surfaces at least 3 mm thick.

Further research is needed to evaluate the load-bearing capability and long-term results of the newly formed tissue.

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