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Ihde S.

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Functionally related changes to the vertical peri-implant bone after BOI implant insertion in the mandible

Author:

Dr. med.dent. S.K.A. Ihde

Patients who receive enossally supported bone/implant/restoration systems will experience changes to essential parameters of masticatory function as normal function is restored. Within the jaws, the levels of tension between the affected bone areas will change as well. BOI implants facilitate the enossal transmission of masticatory forces via the baseplates while avoiding the transmission of forces via the vertical aspect of the implant. Consequently, the crestal bone level is able to develop freely to match the masticatory forces, the distribution of functional loads and the tension within the affected jaw. Unlike crestal implants, BOI implants are not associated with any progressive bone loss over time and do not trigger any crater-shaped areas of collapsed bone. In the region of the threaded pin, the bone level can float freely to accommodate the prevailing functional requirements BOI implants were designed to allow these morphological changes. But given that the prosthetic superstructure is the only fixed point of reference within the system, the elevation of the basal disk relative to the mandibular border and masticatory plane requires regular timely subtractive or additive modifications to the fixed restorations in order to protect the system from prosthetic-related overload and damage to the load-transmitting regions. The extent of vertical bone modelling in the mandible will depend on the preoperative vertical bone supply, the differences betweenthe respective bone mass on either side of the jaw and from the presence of absence of a preferred side for mastication.

Key words

Basal osseointegration (BOI), reversal of mandibular atrophy, functional implantology

Summary

Gommiswald Dental Clinic
8737 Gommiswald/SG
Schweiz

Introduction

From a structural point of view, the mandible is essentially a long tubular bone. The chin is an area of maximum flexion in which trajectories from both sides overlap to form a structure of high density. This area is a “safe haven” for implant anchorage, and hence a preferred site for implant placement. The shape of the mandible is derived from a number of factors. Crucial determinants include muscle function (i.e. chewing and mimic muscles) as well as the number, size and position of teeth. When teeth are extracted, the related structure of the alveolar ridge will undergo disuse atrophy, i.e. the vertical bone volume will be reduced in a clinically manifest manner. The delivery of restorations insufficiently supported by residual teeth or enossal anchorage may accelerate bone resorption, , influencing the vertical dimension of occlusion and, hence, , the vertical dimension of the face at large. Similar to the way in which we differentiate between load-bearing and non-load-bearing structures in buildings, we can make an analogous distinction in the jaws. The load-bearing structures of the jaws are those areas that possess a trajectory orientation as a result of masticatory function and are designed to prevent mechanical failure of the jaw as a whole. These structures are resistant to resorption. Bone areas whose principal task is to accommodate the dental roots, by contrast, have no load-bearing function. The distinction is not always clear, however. For example, the basal root segments of lower second molars are frequently located in load-bearing jaw segments – which is good for bone preservation (and thus for the preservation of the teeth), if appropriate functional patterns are present.

There have been very sporadic indications in the literature that BOI-based implant/restoration systems not only arrest the bone loss brought about by periodontal disease but can also generate new bone tissue. Follow-up examinations of implant/restoration systems in heavily resorbed areas of the distal mandible have sometimes revealed considerable new bone formation below and above the load-transmitting disks of BOI implants (Figures 9 and 10). To investigate whether these are coincidental findings or a common reaction on the part of the jawbone, orthopantomographs (OPGs) were used to check vertical bone heights pre- and postoperatively as well as after up to 28 months in situ under full masticatory load. Early vertical bone gain following implant insertion and immediate loading was also found in animal experiments, where there was modelling-type vertical bone growth that originated inthe periosteal tissue. The scope of the bone modelling exceeded the original level that wasreadily discernible on histological sections.

Long-term success can only be achieved if the treatment concept duly considers the functional requirements.

Materials and methods

The target parameter was the vertical bone height around BOI implants inserted at the mandibular first and second molar sites (36/37 and 46/47) placed at our clinic between 1 December 1999 and 1 June 2000 and restored with fixed prosthetic dentures. The place of insertion for the BOI implants varied slightly along the sagittal plane, depending on the prevailing political situation, but was always within the terminal segment of the radiologically documented mandibular linea obliqua.

It was not possible to include implants in the follow-up whose baseline OPG had not been taken digitally by our OPG device (14 affected implants). These OPGs had been taken at other centres and provided to us by the patients themselves. We also excluded those implants that had been inserted in single-tooth gaps for placement of the first molar only (4 affected implants). Three implants had been removed and replaced during the observation period . To the extent that the load-transmitting disks of the replaced (original) implant had remained within the bone at the follow-ups, the measurements were taken at the measuring points of these disks. In the region around one implant, bone growth was so pronounced that the newly formed crestal bone had to be removed by a reductive osteotomy. This implant was not included in the analysis. Overall, 120 BOI implants were available for the follow-up.These 120 implants (57 of the right side, 63 on the left side) had been inserted in 81 patients (29 male, 52 female). Their average age at the time of placement was 61.5 (29–80) years.

The selected interval for this study corresponded to the first 18 months of use of the digital x-ray system that had been instrumental in facilitating a comparative evaluation of the images with sufficient precision and speed in the first place. All implants have been in function for at least 325 days (0.89 years) and at most 1,050 days (2.8 years) – mean: 674 days – between the first and last radiological examination included in the analysis.

The radiographs were taken with a Orthoslice 1000 OPG system (Trophy, Kehl, Germany); the images were processed and measurements were made using the corresponding 4.1K imaging software. This work was performed on a flat-screen monitor (Dell Inspiron 8200), as it had turned out that measurements on a conventional cathode-ray tube showed much greater variation due to variable viewing angles. All measurements were performed by the same operator by clicking on the relevant measurement points

Measuring points (Figures 7 and 8):

• The upper measuring point was the topmost discernible point of the alveolar ridge at the centre of the threaded pin.

• The middle measuring point was the transition from the bar to the thread holder, i.e., at the level of the baseplate.• The lower measuring point was located on a line perpendicular to the lower edge of the mandibular cortical bone.

• If the BOI implants had not been placed at the thinnest (vertical) point of the mandible, the vertical dimensions of these areas were also measured.

• If natural teeth were present on the contralateral side of the implant site, the upper measuring point was the intersection of the mesial root of the second molar (or the distal root of the first molar, as appropriate) with the alveolar ridge. This measurement was taken to determine the contralateral bone height for comparison. The vertical distance to the lower edge of the mandible was determined for these measuring points, too.

• Only single-disk BOI implants were placed.

The average preoperative bone supply at the implant site was 19.3 mm (9.9–30.2 mm) for the right mandible and 18 mm (8.9–30 mm) for the left mandible.

All radiographs were taken as part of routine follow-up examinations. No additional patient xrays were taken for the purposes of this study.

To evaluate their reproducibility of the x-ray images, vertical measuring pins of a known standard length were placed on the vestibular side of the mandibular arches of 10 patients during the x-ray process. These served to determine the discrepancies between the real length and the measured length in the x-ray image as well as the reproducibility of the measurements. The t test showed the error to be non-significant for 90% of the measurements.
Results.

Vertical bone growth in the right mandible was a mean 0.7 mm (2.8–0.1 mm) (Figure 10, areas A and C) above the implant baseplate and a mean 0.9 mm (4.3–0.1 mm) (Figure 10, area B) below the implant baseplate, i.e. toward the mandibular border.

Vertical bone growth in the left mandible was a mean 0.7 mm (5.4–0.1 mm) (Figure 10, areas A and C) above the implant baseplate and a mean 0.7 mm (4.5–0.1 mm) (Figure 10, area B) below the implant baseplate.

This means that vertical bone growth at the implant site was present in all cases during the postoperative observation period. The mean growth was 1.9 mm (6.2–0.2 mm) (Figure 1).

Differences became evident when the changes in the vertical bone levels at the implant sites are related to the original bone height. The greatest amount of bone apposition was observed where the initial overall bone supply at the implant site was minimal while the vertical bone supply in the distal mandible on the contralateral side was massive (Figure 2)

The findings for two patients were clearly at variance with this overall trend in that the amount of bone apposition by the end of the observation period was even greater than the preoperative vertical bone height on the contralateral side.

Prior to implant insertion, 36 patients had worn removable – in some cases tissue-supported – dentures, while 45 patients had either not worn any restorations or received their implants directly at the time of tooth extraction

. Not surprisingly, the group of patients who had not been wearing restorations exhibited a greater initial total bone height of the implant site. The amount of vertical bone gain was greater for the group that had previously worn dentures.

Taken into account the difference between the implant site and the contralateral side of the mandible, patients with considerably more bone volume on the contralateral side compared to the implant site exhibited greater bone gain in patients whose vertical bone levels tended to be done from both sides of the distal mandible (Figure 6). In other words, the differences in bone volume between the two quadrants are balanced.

The pontic regions of 12 patients exhibited areas of lower vertical bone height than the implant sites themselves. These pontic regions benefited noticeably more in terms of vertical bone gain than the implant sites themselves. The mean vertical bone gain in this region was 6.1 mm (Figure 9).

Discussion

BOI implants are successfully employed to provide enossal anchorage for fixed prosthetic dentures. They have greatly expanded the range of indications for fixed restorations, as they can be inserted even in minimal-height residual bone, on condition that the maximum width of the bone is included.

BOI implants can be used in combination with natural pontics or other implant pontics, but they may also be splinted among themselves by fixed restorations.The vertical component of a BOI implant (i.e. the threaded pin) is smooth and does not show any surface-enlarging features. The surface of the baseplates, however, is usually roughened by sandblasting to maximize the available surface (hybrid design). The masticatory load is transmitted exclusively through these baseplates. While a continuous vertical bone loss has been described for crestal implants in function , blade implants tend to sink into the mandible unless they receive lingual support by the cortical bone. No pertinent results have yet been published for BOI implants.

Bone loss in the region of the threaded pins of BOI implants may be caused by intraosseous infection descending toward the disk or by morphological changes in the jaw caused by atrophic processes. No cases of intraosseous infection were found during the follow-ups in this study. There were only two cases in which the vertical bone gain was so pronounced that a considerable part of the originally intraoral aspect of the threaded pin and of the crown restoration were increasingly covered by bone and overlying because. These regions thus became inaccessible to oral-hygiene efforts, resulting in recurring infection and ultimately requiring re-implantation. In both these cases, the situation during the initial implantation was such that insufficient vertical bone was present at the preferred implant sites (37/47) above the inferior alveolar nerve; the available bone supply was less than 2 mm. This is why areas

further distally on the ascending ramus had to be used instead. After approximately 15 months, reimplantation was possible in the area of the second molars where a sufficientamount of vertical bone had grown on the crestal aspect of the mandibular canal.

Two patients in whom mandibular implants were placed symmetrically on the left and right sides revealed patterns of bone growth that were essentially unilateral. The preferred sides here were those where the vertical dimension had been greater before implantation. The apposition pattern in these patients was the exact opposite of the pattern seen in all other patients studied.

The results on clinical examination confirmed the finding obtained by interviews with these patients, namely that those masticatory patterns were purely unilateral in nature, as TMJ function to the contralateral side was almost completely obstructed. Vertical bone gain was observed mainly on the non-working side.

This apposition behaviour had been described previously by Hylander. It had been attributed to the fact that compressive forces develop on the non-working side of the lower mandibular margin during mastication, whereas tensile forces are predominant in the upper portion of the alveolar ridge. The results that Hylander had obtained in monkeys were later confirmed in more detail in studies on humans performed by Korioth and Hannam.

To compensate for greater chewing forces, the jaw may grow not only vertically but also laterally or medially. However, these dimensional changes were outside the scope of this specific follow-up study.

Likewise, bone is capable of functional adaptation by changing its degree of mineralization. Research in crestal implantology is focused on achieving "osseointegration" and ignores the fact that major solid bodies integrated into bone segments that are subject to natural flexion and whose flexural behaviour is different from that of bone will either not be osseointegrated over their entire surface or the degree of bone mineralization will vary along the interface. The human body lacks true reference points. Enossally anchored (osseointegrated) BOI implants can change their position relative to the radiographically visible boundaries of the jaw as the bone morphology changes due to functional influences. Baseplates inserted in the distal mandible tend to migrate upwards in a cranial direction relative to the lower edge of the mandible. This upward migration is theoretically opposed to the chewing force, whose tendency is to push the disk towards the caudal aspect. It appears that the steady force of trajectorial remodelling is stronger than the periodic influence of mastication. Installing force-transmitting surfaces in the enossal space and immobilizing them relative to each other by prosthetic means will create relative reference points, On the one hand, the mastication surfaces guide the muscles; on the other hand, the muscle function thus modified has an effect on the trajectory architecture of the bone structure and implant bed.

The bone must therefore be given an opportunity to change its morphology to adapt and to re-orient its trajectory. The growth tendencies in the crestal direction must not be thwarted by the presence of pontics. In our experience, increasing contact between the pontics and the mucosa may gradually give rise to pain(frequently at a subconscious level) and avoidance patterns. This in turn may prevent uniform mastication, jeopardizing the integration of implants, or give rise to excessive loading.

In addition, contact between pontics and mucosa will keep the bony structure of the jaws from developing their most favourable biomechanical shape. This, too, may cause problems in the implant bed. For example, growth may occur in directions other than the biomechanically favourable crestal direction (e.g. in width). In the worst case, the load-transmitting surfaces may lose their cortical contact. Since morphological changes of this type can never be excluded with certainty, BOI implants should, if possible, tend to project from the cortical bone rather than being located more deeply.

In cases of advanced distal ridge resorption with sufficient bone volume in the anterior segments to retain a fixed restoration, one should consider not inserting the restoration right away but to adopt a wait-and-see strategy following distal implant placement until the upward migration of the implant associated with vertical bone formation has been completed. Bone apposition might be greater if no masticatory forces are present to counteract it. Furthermore, this would theoretically reduce the need for subtractive adjustments to the restoration. The counter argument would be that it is after the restoration of the distal occlusal surfaces (at the centre of the masticatory forces) that a "normal" functional relationship is created in the first place. As proper masticatory function is restored, further substantive modelling forces can be expected to affect the bone. Even the insertion of a new completedenture will change the occlusal situation; similar adaptive processes occur after the delivery of enossally supported restorations.

If the lingual aspect of the residual ridge is very high but narrow preoperatively, the threaded pin can be placed laterally to the ridge. This will create roughly the same spatial relationship as if the ridge were growing in a strictly cranial direction after implant placement (Figure 3). In these situations, our approach is to disrupt the trajectories of the residual ridge from the alveolar crest down to the basal mandibular segment by means of a vertical osteotomy created with a tungsten carbide cutter mesial to the implant site. This increases the functional load on the implant osteotomy, which, in our experience, will accelerate healing, improving the chances of successful implant integration. If this osteotomy is not performed, the risk of integration problems is higher because the bone will lack the functional stimulus to close the lateral osteotomy.

The functionally induced build-up of vertical bone in the mandible has also been discussed in connection with transmandibular implants (TMI). This type of build-up appears to depend on the presence of greater chewing forces acting on the bone from an enossal direction as a result of restored function and on the absence of infection-related bone collapses where the implants penetrate the mucosa. Therefore, the transmucosal vertical implant surfaces must not participate in load transmission; also, they have to be polished to high gloss. Thus, while TMI and BOI implants rely on the same principle for load transmission, the handling of BOI implants is simpler.For several reasons, patients who have previously worn a denture will benefit more from new bone formation than patients who had not previously worn a restoration in the edentulous area. For one thing, the initial situation is less favourable as the disuse atrophy of the edentulous ridge is compounded by denture-induced resorption. Apparently, however, the atrophy is partially reversible. Moreover, chewing forces will decrease in denture patients as they avoid pressure-related pain. The chewing forces can therefore be expected to increase in these patients after a fixed restoration has been inserted. Once the denture is no longer worn, the compressive forces acting on the mucosa – that otherwise cause chronic ischemia of the crestal mucoperiosteal tissue – are reduced. The blood supply through the central mandibular artery is reduced in advanced mandibular resorption.

Atkinson and co-workers demonstrated different regional bone densities in pigs, dogs and humans. Following tooth extraction, bone density in areas exceeding the alveoli would change. In the initial phase, the density would decrease due to a greater degree of porosity. The tunnelling secondary osteons (BMUs) would induce bone remodelling even in the areas surrounding the alveoli. After initial healing, resorption was observed in the area of the extraction socket. Resorption was delayed if crestal implants had been inserted in the area of the alveolus, and bone density was increased; in fact, bone density would sometimes even rise above the baseline level. Nine months after implantation, however, resorption processes adversely affecting the preservation of alveolar bone wereseen in the implant area. On balance, however, the experiments performed by Atkinson and co-workers yielded no evidence of any changes on the lingual side of the mandible following insertion of crestal implants, which is in keeping with our own previous findings with healed but unloaded dental implants in dogs.

Both tooth extraction and the insertion of metal implants will stimulate bone remodelling. Tooth extraction gives rise to disuse atrophy, which the implantation procedure is designed to avoid.

Following the extraction of mandibular molars, the load-transmitting line of the mandible, which usually runs along the vestibular aspect, may be repositioned to the lingual aspect and take a cranial rather than lateral orientation. In dentate patients, the molars prevent the force-transmitting line from establishing its ideal mesiodistal orientation. In patients with deep mandibular periodontitis, the force-transmitting lines become dislocated despite the presence of teeth, which will ultimately cause those teeth to be lost.

Nonetheless, the principal force-transmitting structure of the mandibular bone will remain unchanged if premolars are extracted or replaced by implants.

There are numerous indications in the literature that load-related stress in the mandible (e.g. by muscle attachments and other functional mechanisms) will influence bone growth. Growth is reduced if muscles are removed. By removing them unilaterally, the direction of growth can be modified. Tooth eruption and the sheer presence of teeth will influence boneremodelling and, hence, the structure of the bone. It has long been known that bone fractures healing in a curved position will straighten over the years. , Frost postulated that the reaction of the bone does not result primarily from compressive and tensile forces but from the tendency of the force acting on the bone to change its curvature. In his theory of flexural neutralization, Frost he summarized that increasing concavity promotes bone apposition, whereas increasing convexity promotes bone resorption. This may be one reason for the sharp increase in vertical bone volume observed in the distal mandible once a denture is no longer worn.

Standardized measuring templates are attached to the implants themselves or to the superstructures to perform bone level measurements of crestal implants. Images can be taken using standard dental x-ray systems using identical angles and conditions. For the present study, this procedure could not be used because it does not document the mandibular border used as a reference point. An analysis of CT scan images of the mandible might have yielded more accurate results than the procedure actually used. However, this would have required 4 CT scans per patient (preoperatively, postoperatively and at 6–9 and 12–18 months) to obtain the requisite data. In addition, the angled of the CT layers would have to match exactly, a requirement that would have caused considerable problems. Even custom installations to lock the cranium in a fixed position probably does not facilitate recreation of exactly the same position as previously given the extensive morphological changes(increases the vertical dimension, vertical growth); in addition, caudal apposition is also present, and changes in the angle between the ascending and horizontal mandibular ramus also influenced the result.

Exact measurements of the distal mandible cannot be made by CT; in addition, the added cost and radiation exposure levels cannot be justified. The procedure used here is routinely employed for posterior measurements in pre-implantological diagnostics to determine the vertical distance from the inferior alveolar nerve. The measuring balls used in the standard procedure do not indicate any image distortion that may be present. While the measurements in this study were made in millimetres and indicated that such on the pertinent graphs, the fact that x-ray systems have a constant magnification factor must always be taken into account. Discrepancies from the actual height may occur, but this error was identified as systematic while ascertaining the reproducibility of the measurements.

The results of this study underscore the extraordinary importance of a competent follow-up protocol for BOI-based implant/restoration systems. Particularly in the first two years following surgery or prosthetic treatment (initial treatment or re-treatment), the relative migration of the basal disk may give rise to significant premature contacts. For this reason, subtractive occlusal adjustments need to be conducted periodically and in a timely manner. The extent of these subtractive adjustments is greater than dentists less familiar with BOI implants would normally expect based on their experience with natural teeth or crestal implants. It is frequently necessary, for example, to extendsubtractive adjustments down into the metal framework. In patients with occlusal deformities, it is usually necessary to rebuild all masticatory surfaces several times as functional blocks are increasingly resolved over the course of treatment. We use bonded composite for this purpose, since this material can be readily added to ceramic surfaces.

Further investigations are needed to examine the morphological changes of the maxillary bone occurring as a result of increasing functional stimuli. Clinical experience has shown that pontics in the maxilla will routinely call for basal adjustment as well. Lever forces pushing the pontics against the mucosa and ridge may cause implant loss.

If the masticatory surfaces following mandibular implant placement are not adjusted in due course, the mandible will suffer damage if a stable natural dentition is present in the maxilla. By contrast, if BOI-based implant-restoration systems in the maxilla are associated with poor bone quality and quantity, damage will more likely be inflicted in the maxilla in the form of overload osteolysis or implant fractures.

In patients with periodontal disease who originally presented with mobile teeth, BOI implant treatment tends to result in continuously increasing masticatory forces, reconfiguration of the occlusal plane, and extensive bone remodelling. In our experience, these patients therefore require especially close monitoring and even more occlusal adjustments than usual.

Summary and conclusion

The shape of the mandibular ridge may change after BOI implants were inserted, involving vertical bone gain both below and above the load-transmitting baseplate.

The bone generated above the baseplate ends up on the lingual side of the edentulous mandible in accordance with the principal trajectories. The formation of new bone mainly takes place to the lingual of the threaded pin.

The extra bone volume routinely formed below the baseplate is capable of raising the implant and the prosthetic structure relative to the occlusal plane. It is therefore necessary to perform subtractive occlusal adjustment on the occlusal surfaces at regular short intervals for at least two years following implantation. Decompression of the TMJ (e.g. when the denture is no longer used) or a relative elongation of the mandibular ramus may occur as a reaction to the upward migration of the restorative structure.

Since vertical bone apposition is also expected in the areas between the implants, the pontics should always be designed with some clearance. If contact with the crestal mucosa is established as the bridge is worn, the pontics need to be reduced via a caudal approach, as the endpoint of vertical bone growth is not known.

Studies performed on humans and animals have consistently demonstrated that vertical bone formation indeed takes place. . Animal experiments have additionally shown that lingual bone apposition also takes place,possibly as a result of osteotomy-related plastic remodelling of the mandibular ridge for curvature and bone volume compensation.

Since modifications to chewing function must be expected after any changes to the restoration, these changes will also involve morphological adaptations of the bone. This, in turn, may have consequences for the position and loading of BOI implants. BOI-based implant/restoration systems will stabilize within 1 to 3 years. The type and extent of morphological changes during this period will depend on the difference between preoperative and postoperative function and on whether a removable restoration had been worn previously

Since the regular use of the prosthetic structures (stable, symmetrical chewing function) influences bone formation, it is reasonable to assume that prosthetic modifications performed on implants already healed will have far-reaching consequences in terms of bone morphology. Therefore, patients who have received new restorations on existing implants need to be followed up closely by a competent implantologist for another two years.

Generally speaking, a threaded pin of maximum length should be selected for BOI implants, based on the interocclusal dimensions. This will prevent the restoration-bone or restoration-mucosa interface from being overgrown by bone or mucosa even if vertical bone apposition is extensive.

If the vertical bone supply at the site of the second molar is inadequate, an implant is first placed in the lower segment of the ascending ramus, followed by inserting a fixed restoration to stimulate functional bone apposition. The distal implant can later be replaced with a BOI implant located further anteriorly. The load-transmitting disk of the first implant is normally left in place with this strategy.

Thanks to BOI implants, fixed restorations can even be inserted in situations of extreme ridge resorption. However, the surgical and prosthetic measures required for this purpose will interfere substantially with the biomechanics of the masticatory apparatus. Due to the extensive morphological changes in the jawbone, adjustments to the prosthetic restoration need to be made on a regular basis.

Implant/restoration systems based on BOI implants presumably differ from those based on crestal implants with regard to the nature and extent of the required follow-up protocol. Good patient compliance is indispensable if a stable outcome is to be achieved.

Figures

The dotted lines on all graphs indicate a 85% confidence interval.

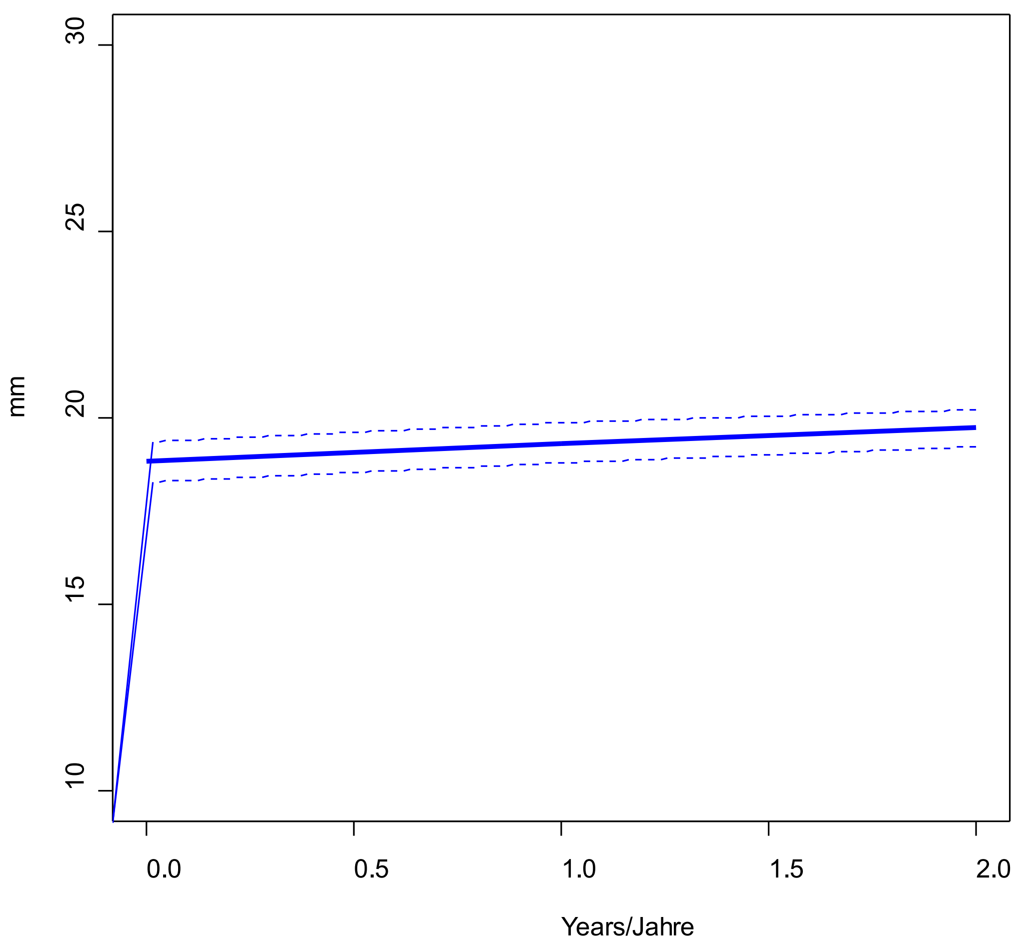

Figure 1
Changes in overall vertical bone height at the implant sites (36/37 and 46/47)

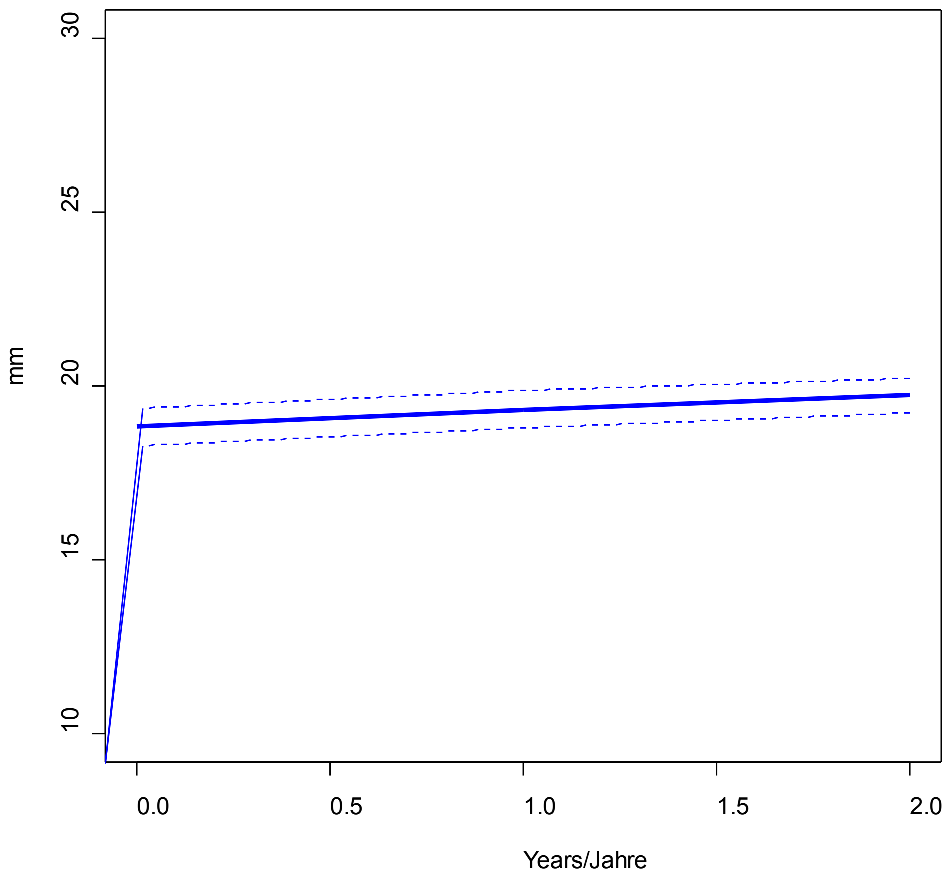

Figure 2

Changes in the overall vertical bone height at the implant sites relative to the initial bone height. For this analysis, each of the original bone height values was assigned to one of four groups: 10–16 mm (blue line; n = 20), 16.1–19 mm (red line; n = 28), 19.1–23 mm (green line; n = 36) and > 23mm (brown line; n = 36)

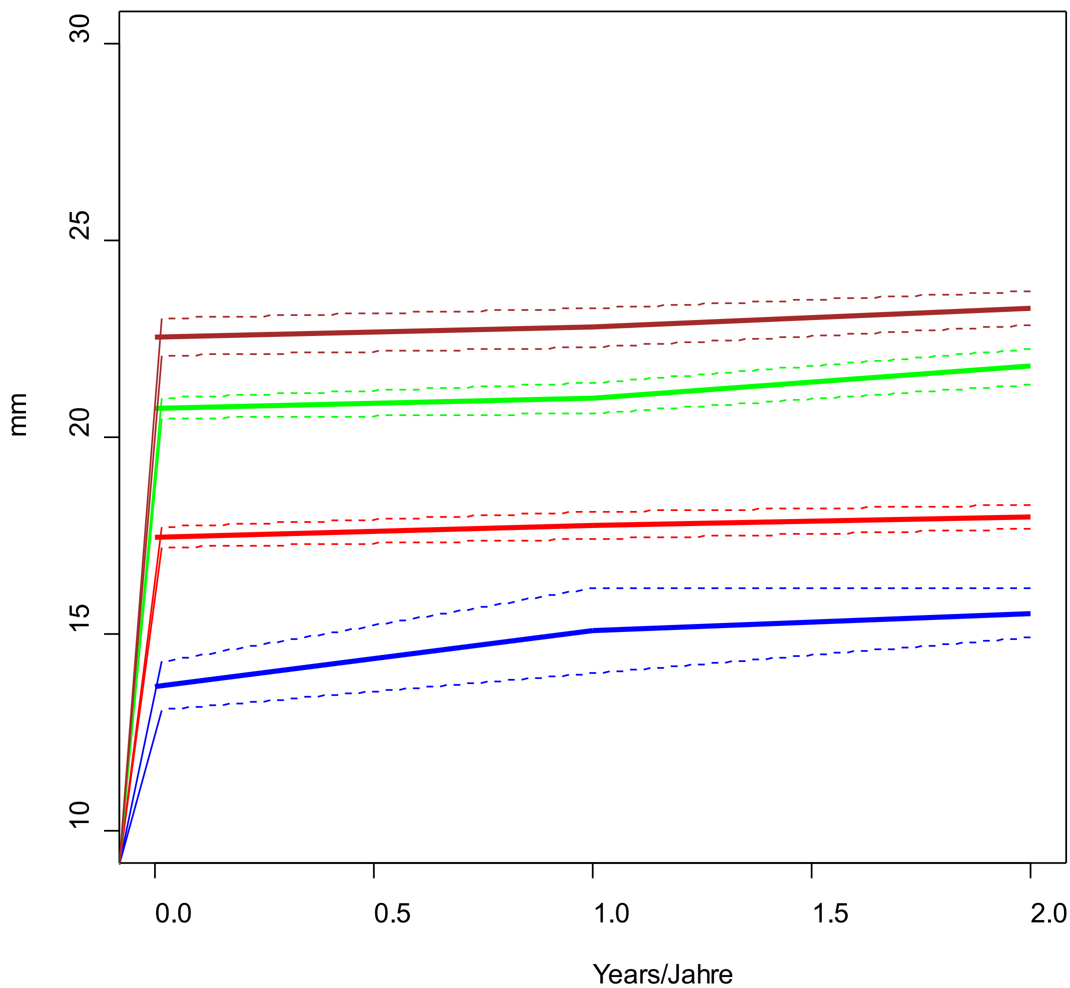

Figure 3
Insertion of a BOI implant at site 47: With BOI implants, the load-transmitting baseplates are inserted in broad basal areas of the mandible; the threaded pin may, if necessary, be positioned to the lateral of any residual thin remnants of the alveolar ridge. These remnants are loads-transmitting trajectories that should be interrupted to the mesial of the implant site (light-blue dot/dash line) to improve the chances of healing of the implant osteotomy.

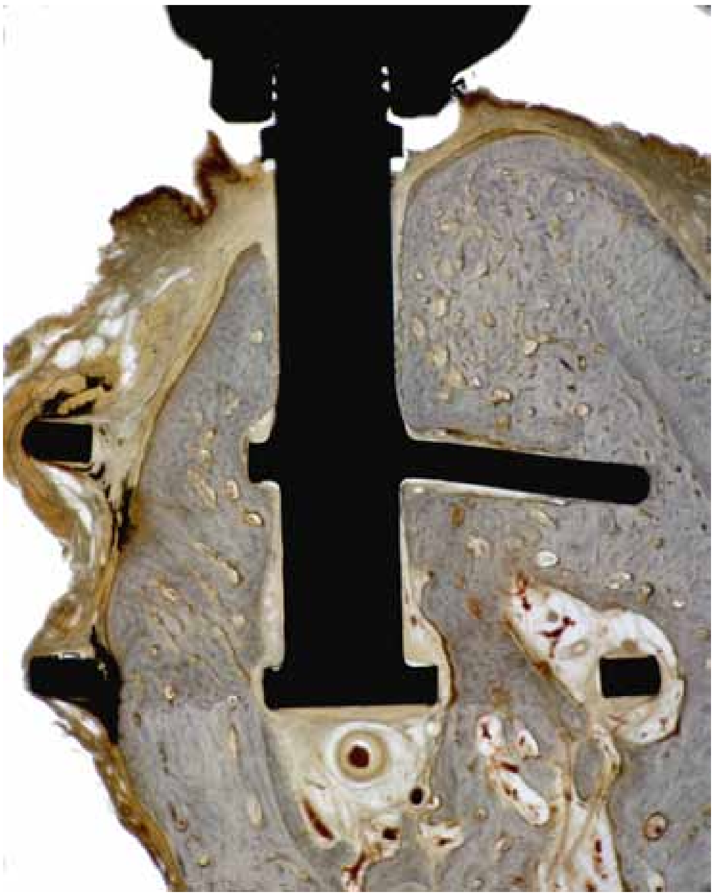

Figure 4
Double BOI implant with a splinted crown restoration: The old cortical bone line is clearly visible. Lingually, there is new formation of lamellar bone. The connective tissue in the shaft area extends below the crown, and there is no epithelial growth in a caudal direction. The soft-tissue structures around BOI implants do not seem to have a layered structure (biological width) like the one described with crestal implants. The implant has been sandblasted for a smooth uniform surface.

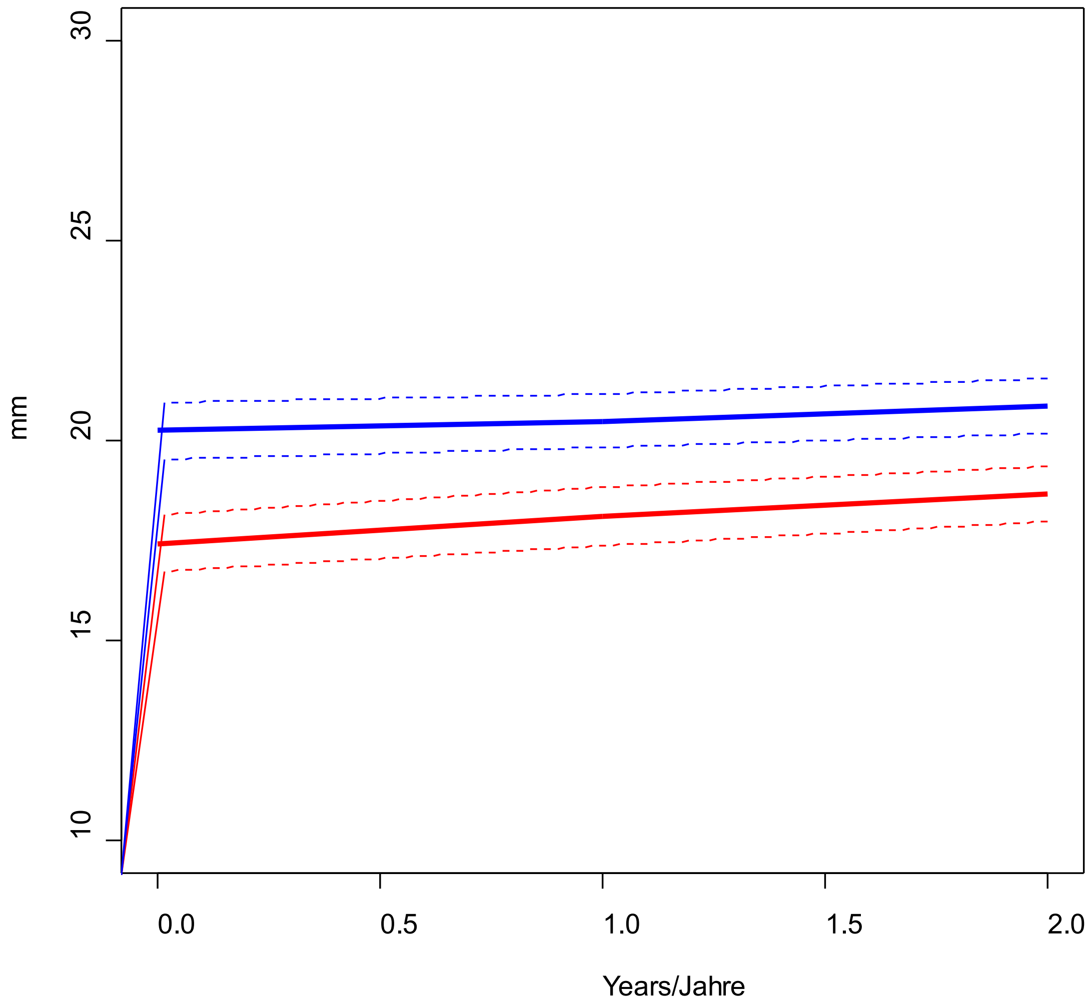

Figure 5
Patients who had been wearing removable dentures prior to BOI implant insertion (red line; n = 36) exhibited more vertical bone gain than patients who had not been wearing removable dentures in the area of the implant site (blue line; n = 45).

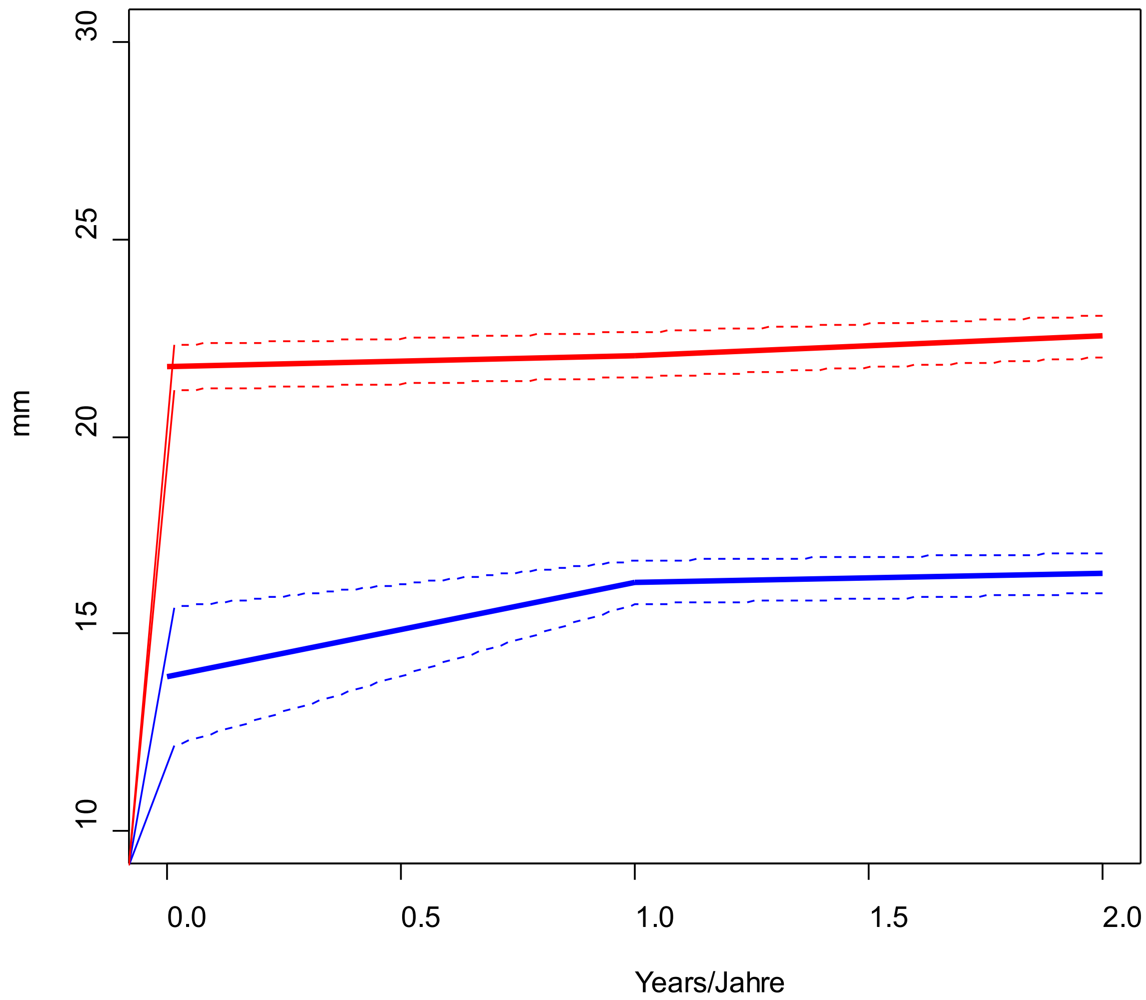

Figure 6
If only minimal vertical bone is present at the implant site that baseline (10–19 mm) and a substantial amount of bone is present on the contralateral side of the distal mandible (> 22 mm), there is more vertical bone gain (blue line; n = 7). If the bone has approximately the same vertical height as the contralateral side of the distal mandible (> 20 mm total bone height on both sides), the amount of vertical bone gain will be less (red line; n = 62).

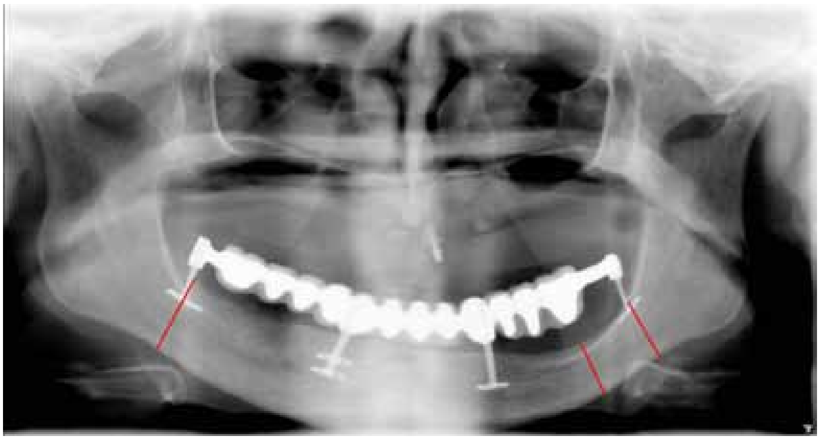

Figure 7
OPG taken after insertion of mandibular BOI implants and delivery of a cemented bridge. This patient had previously been wearing a mandibular complete denture retained only by three ball attachments on the right side. The atrophy of the left posterior mandible had been caused by the denture it had to support.

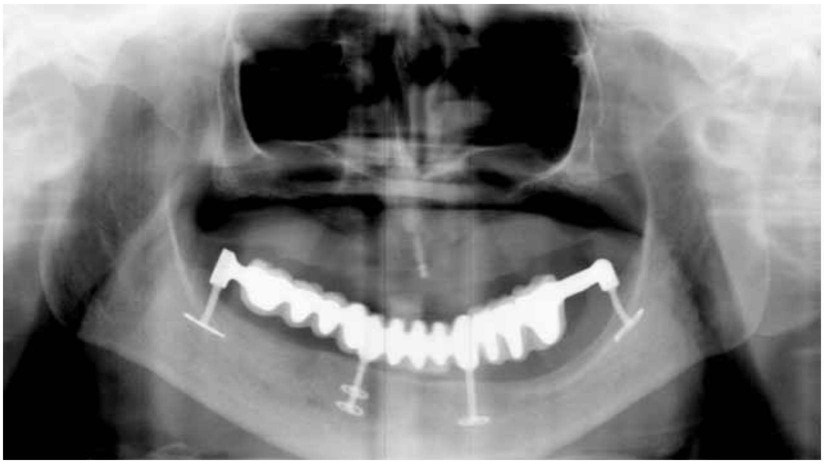

Figure 8
This OPG shows the same patient as in Figure 7, approximately 18 months later. There has been equilibration of bone volume on in the left and right posterior mandible, with a vertical bone gain on the left side of 2 mm. The bone elevations around the extraction sockets still visible in Figure 7 have been levelled. The distance between the ridge and the pontic has been greatly diminished

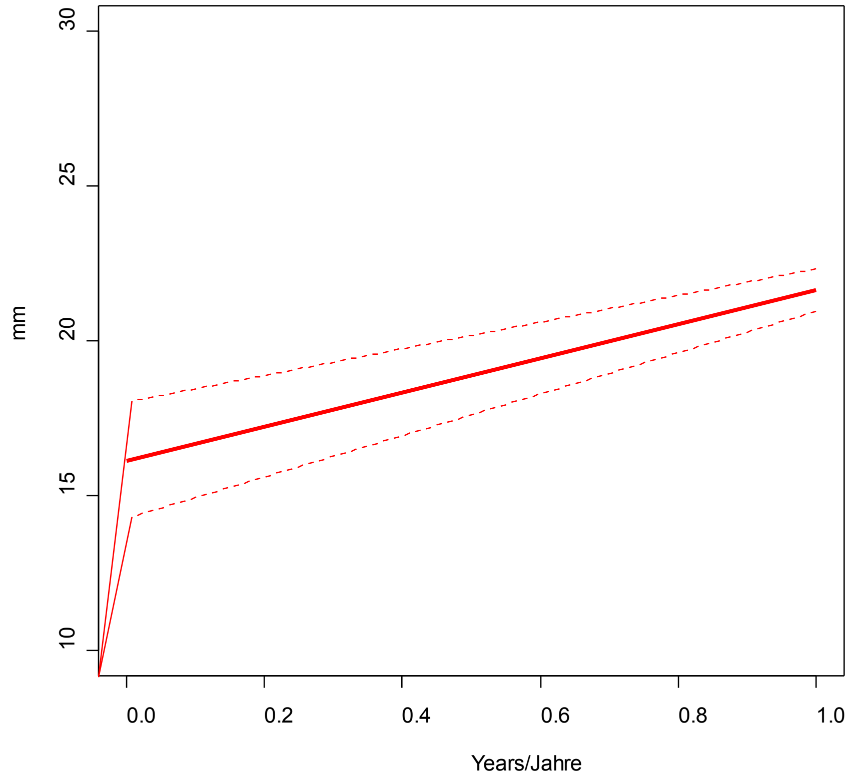

Figure 9

Changes in total vertical bone height at the lowest points (pontic regions) of the treated mandibles (n = 12).

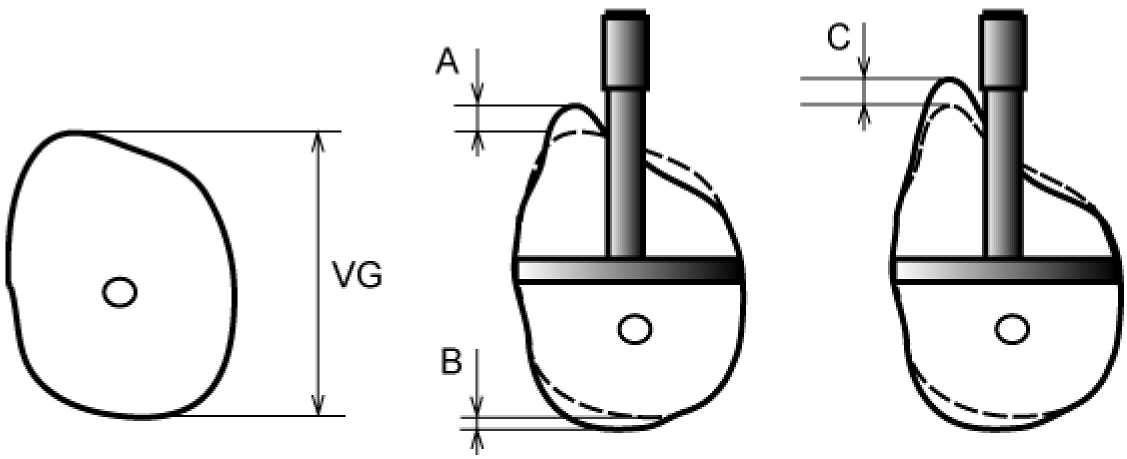

Figure 10

Outline of bone remodelling around a BOI implant in the distal mandible. Left – initial shape of the resorbed mandible. Centre – situation at 12 months after BOI insertion. Right – situation at 24 months. Each dotted line indicates the shape in the adjacent drawing to the left.

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