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Morphofunctional and clinical study on mandibular alveolar distraction osteogenesis

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Abstract: Alveolar Distraction Osteogenesis (ADO) is a process which forms new alveolar bone to correct alveolar deformities in ridge height and width. This work aims (a) to verify the predictability of the augmentation of height of atrophic alveolar ridges using an extra-alveolar distraction device and (b) to study the bone processes in order to optimize implanto-prosthetic rehabilitation. ADO was performed on 10 patients with ridge deformities to obtain the required ridge augmentation. Clinical and radiological (OPT and CT with densitometric assay) evaluations were carried out during the following 12 weeks, before implant insertion. Biopsies at 40, 60 and 88 days were studied after general, specific and histochemical staining of slides; microradiographs were analyzed to evaluate the Trabecular Bone Volume. Forty days after the end of distraction, soft callus indicated the start of ossification. Sixty days after the end of distraction, the soft callus was largely converted into a network of trabecular woven bone; osteogenic activity was high and TBV was about 50%. Eighty-eight days after the end of distraction, the amount of bone appeared reduced, with a more ordered structure; bone formation activity and TBV also diminished, whereas osteoclast erosion was active.
The densitometric assay shows values increasing from the end of distraction, particularly after implant insertion. Histological results show a regression in bone deposition processes 88 days after the end of distraction culminating in a virtual steady-state after a certain time. The results suggest that early implant insertion may be desirable to avoid bone loss due to mechanical unloading.

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Bone ridge atrophy is a frequent occurrence in patients as a consequence of stomatologic diseases, cranio-maxillofacial trauma or following surgery. The regeneration of the alveolar bone is a prerequisite for good prosthetic restoration. Nowadays, bone grafting is the technique most commonly used to increase the ridge (Meffert et al. 1985; Rummelhart et al. 1989; Hislop et al. 1993; Lane 1995; Lovelace et al. 1998; Hall et al. 1999; Kubler et al. 1999). Apart from the type of material used, bone grafting does not always ensure the desired regeneration, in particular in large bone defects. Autologous bone is considered the best grafting material because of its osteogenic properties (Schallhorn 1980; Aichelmann-Reidy & Yukna 1998) but it needs a secondary donor site and suffers from uncontrollable osteoclast resorption.

Osteogenic distraction (OD) can be defined as a biological process which brings about the formation of new bone following a gradual separation of two bone segments previously joined together. The biological process, which follows the application of a distractive force on the callus (formed between the separate bone segments), continues until the completion of distraction. OD was initially performed by Codivilla (1905) in the lengthening of the lower part of the limbs, then it was largely forgotten. At the end of the 1960s, Ilizarov embarked on a systematic study of the biological basis and clinical reliability of OD (Ilizarov 1969; Ilizarov et al. 1986; Ilizarov 1989a, 1989b, 1997). OD was subsequently applied to the craniofacial region in both animals (Snyder et al. 1973; Micheli & Miotti 1977) and, 20 years later, man (McCarthy et al. 1992; Klein & Howaldt 1995; Molina & Monasterio 1995). Following the later studies of Ilizarov (1989a, 1989b), several authors demonstrated clinically and histologically that OD could be achieved by a vector transversally oriented with respect to the principal axis of the bone (Giat et al. 1994; Block et al. 1996; Chin & Toth 1996). The direct consequence was alveolar distraction osteogenesis (ADO).

ADO appears to be extremely promising in the healing of some periodontal defects and the correction of the height and width of alveolar ridge deformities. ADO makes for rapid bone regeneration without the need for a secondary donor site, which involves surgery. Nevertheless, ADO techniques can give the best results only if used in conjunction with rehabilitative implanto-prosthetic techniques.

To improve the distraction protocol, some studies have been performed on the type and quality of bone obtained by ADO (Block et al. 1998; Consolo et al. 1999; Lazar et al. 1999; Urbani et al. 1999a, 1999b). The results are encouraging in that they suggest that reliable tissues can be obtained for implant treatment. Nevertheless, the steps leading to final bone formation have to be carefully studied in order to improve the technique, particularly in the various implant phases, and to achieve the maximum synergy in the correct healing of tissues.

The aim of this work is to find out whether it is possible (a) predictably to augment the height of atrophic alveolar ridges by means of intraoral extra-alveolar distractive devices and (b) to analyze the various stages of bone healing and new bone formation in a dynamic sense. The goal is to identify the most suitable moments at which to intervene in prosthetic rehabilitation to achieve better results.

Material and methods

Ten patients, five male and five female, aged 15–74 years (mean ± SD = 44.57 ± 22.33), five dentulous and five edentulous, healthy but suffering from varying degrees of mandibular alveolar ridge defect (Fig. 1A), underwent surgery by alveolar bone distraction. All the patients gave their informed consent to the procedure. Clinical evaluation was performed throughout all the phases of the treatment, as were radiological examinations (before surgery, at the beginning and at the end of the distraction period (Figs 2 and 3), before removal of the distraction device and before implant insertion). X-ray examinations of the zone to be distracted were performed both by standard projections (such as teleradiography and orthopantomography) and by CT with bone densitometry (expressed as HU units). Densitometry assays of tissue were performed before and after distraction on the sites of the distracted zone, in which no biopsies will be executed or screws inserted.

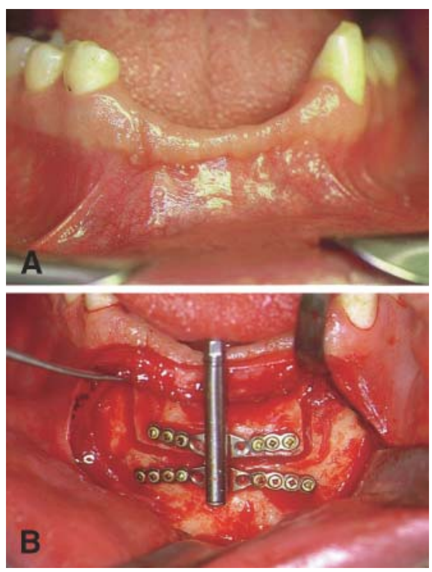

Fig. 1. Dentulous patients with atrophy of the alveolar mandibular ridge (A) and after the application of the distraction device (B). Notice in B the shape of the osteotomized bone segment and the large number of screws used to fix the device rigidly to the bone fragments.

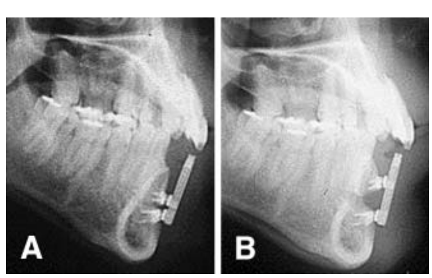

Fig. 2. Maxillary X-ray telegradiographs of the dentulous patient at the beginning (A) and at the end of the distraction period (B). The setting of the distraction vector is virtually unchanged.

The surgical distraction protocol (modified from Hidding et al. 1999) was performed under general anesthesia:

a) opening of a vestibular mucoperiosteal flap to expose the whole surgical intraforamina zone
b) fitting the distraction device (Martin, Tuttlingen, Germany) to the exposed bony surface, and drawing the osteotomy line with a sterile pencil;
c) accommodation of the distraction device plates to execute the correct distraction vector. The plates were bent over to counterbalance the traction exerted by the muscles on the lingual side of the osteotomized segment;
d) osteotomy of the alveolar bone fragment by saw and chisel, without damaging the lingual periosteum;
e) mobilization of the osteotomized alveolar bone fragment and positioning of the distraction device (using a large number of screws) and subsequent device activation (1 mm) (Fig. 1B);
f) 1 week's rest from distraction (1st latency period);
g) distraction device activation (0.5 mm, twice a day) (Figs 2A and 3A). The device must be activated in accordance with the required height of the alveolar ridge

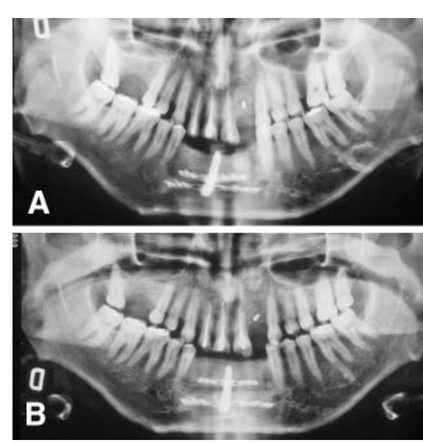

Fig. 3. Orthopantomographs of the dentulous patient at the beginning (A), and at the end of the distraction period (B). Notice the increase in the alveolar ridge.

(up to 15 mm). Clinical and radiological evaluations (teleradiography and orthopantomography) were carried out to see whether the correct height had been reached;

h) 8 weeks' rest from distraction (2nd latency period);
i) radiological check (Figs 2B and 3B) and distraction device removal;
j) 4 weeks' rest from distraction (3rd latency period) (Fig. 4A);
k) radiological check and insertion of submerged implant (3i Osseotite®, Implant System, Implant Innovations, Palm Beach Gdns, FL, USA) (Figs 4B and 5);
l) implant uncovering and prosthetic rehabilitation after 4 months.

The study of the tissue formed after mandibular alveolar distraction was performed on cylindrical biopsies obtained from the zone of distraction callus (by means of a hollow mill operating at 600 r.p.m. under saline jet) 40, 60 and 88 days after the end of distraction.

The cylindrical biopsies were fixed in 4% paraformaldehyde (reagents of Fluka Chemie AG, Buchs, Switzerland) in 0.1 M phosphate buffer pH 7.2, for 2 h, at room temperature. Specimens were dehydrated through ethanol series at 4 °C, then embedded in methyl methacrylate (PMMA) using a water bath at 4 °C. The PMMA blocks were serially sectioned along the longitudinal axis of the biopsy up to its center using a diamond saw microtome (1600, Leica, Microsystems AG, Wetzlar, Germany). A set of 5-μm-thick sections from the central zone was obtained using a tungsten carbide knife (Profile D) on a bone microtome (Autocut 1150, Reichert-Jung, GmbH, Nussloch, Germany). A thick section (200 μm) from the center of each biopsy was obtained using the diamond saw microtome. Thin sections were stained using the following techniques:

- Toluidine blue;
- Trichrome Gomori Stain;
- von Kossa method;
- Total Alkaline Phosphatase (TAP) histochemical method, a marker of osteogenesis (azo dye = Fast Blue BB);
- Tartrate Resistant Acid Phosphatase (TRAP) histochemical method, to make it easier to distinguish the osteoclasts (azo dye = Fast Red RC).

Thick sections, reduced by grinding to 100 μm and perfectly polished with emery paper and alumina, were X-ray microradiographed (Italstructures, Riva del Garda TN, Italy) at 8 kV and 12.5 mA on Kodak SO 343 film. Microradiographs as well as sections were analyzed and photographed using a microscope (Axiophot, Carl Zeiss Jena GmbH, Jena, Germany) under ordinary light. Trabecular Bone Volume (TBV) of biopsies, as an index of the amount of bone tissue (Parfitt et al. 1987), was evaluated on the microradiographs using a suitable program for image analyzer (VIDAS, Zeiss).

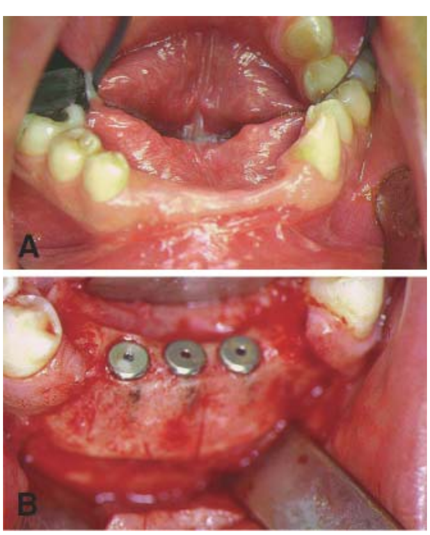

Fig. 4. Alveolar mandibular ridge of the dentulous patient: (A) before implant insertion (4 weeks after the distractive device removal), (B) after the insertion of three 3i Osseotite implants and soft callus biopsy performing. Notice the good squaring of the alveolar ridge allowed by its wide increasing.

Results

The length of osteotomized bone segment ranged between 10 and 60 mm (mean 44.0 $\pm$ standard deviation 1.21) in the 10 patients. The thickness and height of the bone segments proved very difficult to record because of the irregularities in anatomical shape and ridge profile (Fig. 1), and their evaluations were omitted accordingly.

The distraction process produced an alveolar ridge improvement of 10–15 mm (Figs 2 and 3) with a mean of 12 mm ($\pm$ 1.826 standard deviation).

In no cases were any problems (such as infections, dehiscence or alveolar pedicle lesions) observed in the postoperative period. Patients often felt pain during the activation of the distraction device, particularly at the end of the distraction period, when the distractive gap was at its maximum (14 mm). The distraction rate (1 mm/day) was the same in these patients, but the extent of distraction at each activation was reduced (0.25 mm), and the number of daily activation procedures was consequently increased. Two patients experienced pain notwithstanding the reduction in the extent of distraction, thus obliging us to reduce the daily distraction rate (0.5 mm).

The soft tissues displayed good trophism and the alveolar ridges proved suitable for implantation at the end of distraction. The morphology of the buccal vestibule was inadequate in three edentulous patients, owing to soft tissue obliteration caused by the dragging effect of the distraction device. Vestibuloplasty was necessary in all three patients to restore the depth of the buccal vestibule.

The bending of the plates resulted in a correct distraction vector in all but one patient, who underwent lingual reversion of the osteotomized segment beyond the desired extent.

All the patients displayed a good improvement in the alveolar ridge 88 days after the end of distraction. An adequate number of submerged implants were inserted (Figs 4 and 5), on the basis of the individual prosthetic requirements. Four months after the placement of the implants, they were uncovered and prosthetic rehabilitation was carried out. Rehabilitation protocol required prosthetic rehabilitation with implant-supported fixed partial

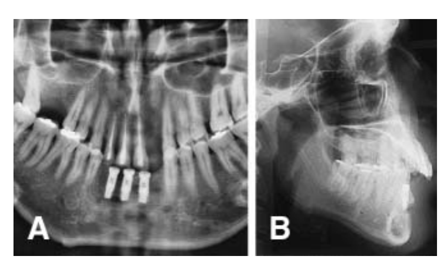

Fig. 5. Orthopantomography (A) and maxillary X-ray telegradiographs (B) of the dentulous patient after implant insertion. A radiotransparent spot, due to the last biopsy performed, is visible between the first and the second implant (from the left to the right of picture A).

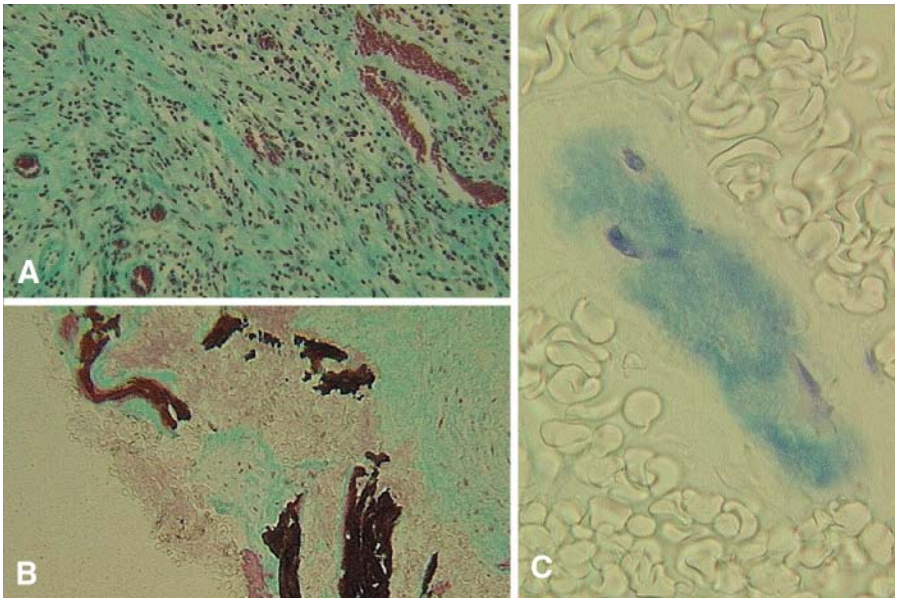

Fig. 6. Histology of the soft callus 40 days after the end of distraction. Trichrome Gomori staining highlights the blood cells (red) contained in the several newly formed vessels of the soft callus (A). Scattered bone trabeculae (black-brown) surrounded by blood vessels are highlighted after von Kossa histochemical staining (B). Trabeculae contain irregular osteocytes and do not show osteoblasts laid down on their surfaces (C, toluidine blue stain). Field width A, B = 575 μm; C = 100 μm.

denture (or with Toronto bridge) where individual factors, such as the distraction mode and the patient's general health and hygiene, allowed it. Implant-supported overdentures were used in all cases of permanent fixture.

In all patients, biopsy was performed twice: six patients underwent biopsies at 60 and 88 days, one patient at 40 and 60 days and two patients at 40 and 88 days. Only one patient underwent the first biopsy at 60 days, the second biopsy being performed at implant insertion time (i.e. 200 days after the end of distraction) for causes not dependent on our treatment.

Forty days after the end of distraction, the biopsies showed a distraction callus formed by a soft tissue rich in collagen fibers and fibroblasts. This tissue usually showed only a few small vessels; several large blood vessels (angiogenic processes preceding bone formation) were present but only in restricted zones (Fig. 6A). In this peculiarly vascularized tissue, some newly formed bone structures (ossification centers) appeared (Fig. 6B). Isolated and randomized, small bony trabeculae form such centers of ossification. The trabeculae were of woven structure with characteristic globe-shaped osteocytes, surrounded by several vessels; osteoblasts covering the trabecular surface were not observed (Fig. 6C).

Twenty days later, however, i.e. 60 days after the end of distraction, the surfaces of the bony trabeculae of the biopsies were covered by layered cuboidal osteoblasts (Fig. 7A), i.e. very active bone-forming cells, which completely transformed the soft callus into a network of bony trabeculae (Figs 7 and 9A). Almost all the bony trabeculae displayed a woven structure containing the characteristic globe-shaped osteocytes (Fig. 7A). Total alkaline phosphatase (TAP) expression was high (Fig. 7B) in the tissue of the medullary spaces, except for the blood vessels (Fig. 7), and was very high not only on the plasma membrane of osteoblasts, but also in the tissue behind the osteoblasts (Fig. 7). No erosive activity by osteoclasts was observed at this time, but some mononucleated cells (probably preosteoclasts) were revealed by tartrate resistant acid phosphatase (TRAP) in a few medullary spaces. The mean value of Trabecular Bone Volume (TBV) in 6 biopsies was about 50% 60days after the end of distraction (Fig. 10).

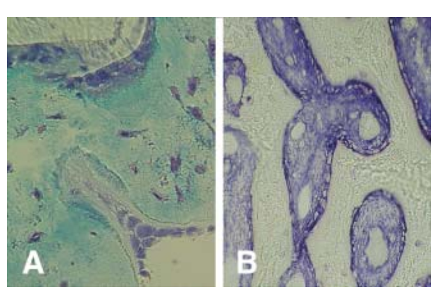

Fig. 7. Morphology (A, toluidine blue stain) and histochemistry (B, Total Alkaline Phosphatase – TAP) of the hard callus 60 days after the end of distraction. Layered cuboidal osteoblasts (A) cover the bony surface containing the globe-shaped osteocytes, typical of woven bone. All medullary spaces (B), except for blood vessels in their center, show TAP (blue) highly expressed. Field width A = 190 μm; B = 630 μm.

In biopsies performed 88 days from the end of distraction, several bony trabeculae displayed a more ordered structure (Figs 8A and 9B). The osteoblasts formed parallel fibered or lamellar bone in apposition to the pre-existing woven bone (Fig. 8A). TAP expression was lower than that observed after 60 days from the end of distraction. Most parts of the tissue of the medullary spaces failed to display any TAP positivity, while only about one third (or less) of the trabecular surfaces displayed TAP positivity around the osteoblasts. Analysis of the biopsies reveals a great reduction in the number and the size of trabeculae (Fig. 9B). The microradiographs of the biopsies clearly show newly formed trabeculae with a woven-fibered structure as well as trabeculae with a more ordered structure (Fig. 9B). The TRAP reaction highlights the presence of several active osteoclasts on the trabecular surface (Fig. 8B). The mean TBV value reduced to about 37% after 88 days (Fig. 10).

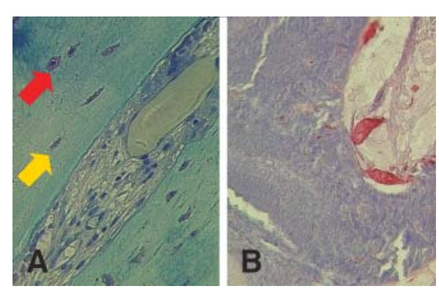

Fig. 8. Morphology (A, toluidine blue stain) and histochemistry (B, Tartrate Resistant Acid Phosphatase – TRAP) of the hard callus 88 days after the end of distraction. More ordered bone, which contains the typical ellipsoid-shaped osteocytes (yellow arrow), is formed in apposition to the woven bone, which contains globe-shaped osteocytes (red arrow). Several osteoclasts (B) are active on the surfaces of bone trabeculae. Field width A = 180 μm; B = 160 μm.

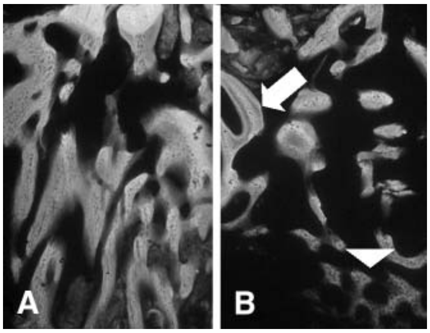

Fig. 9. Microradiographs of biopsies of the same patient at 60 (A) and 88 (B) days after the end of distraction. Notice the different amount of bone between A and B. The arrow indicates a bone trabecula with the core of woven bone covered by more ordered bone. The arrowhead indicates a group of woven bone trabeculae. Field width A, B = 1.9 mm.

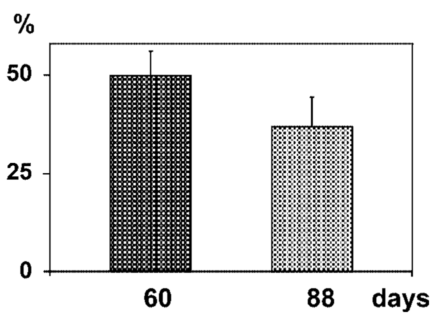

Fig. 10. Trabecular Bone Volume (mean ± standard deviation) evaluated in the microradiographs of the biopsies of six patients at 60 and 88 days after the end of distraction.

In the biopsy performed 200 days after the end of distraction, the amount of bone did not seem to differ from that performed after 88 days. Several osteoid seams were observed inside the biopsy. They were very thick (up to 25 μm) and covered by a discontinuous layer of flattened cells. Hardly any trabecular surfaces displayed TAP positivity. The very few osteoid seams of the biopsy displaying TAP positivity (Fig. 11B) were laid down by flat osteoblasts arranged in a continuous layer (Fig. 11A). TRAP activity, i.e. the presence of active osteoclasts was virtually absent.

Densitometry performed on six patients clearly showed the initial decrease in Hounsfield values (Hounsfield 1980) after surgery and a subsequent increase in due course (Fig. 12). The slope of the curve differs with age: the younger the patients, the steeper the curves.

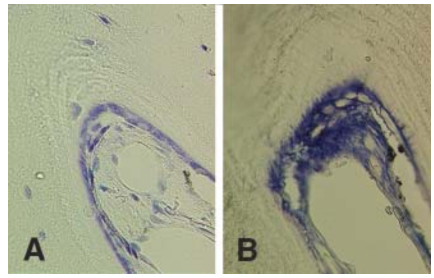

Fig. 11. Morphology (A, toluidine blue stain) and histochemistry (B, Total alkaline phosphatase – TAP) of the hard callus 200 days after the end of the distraction. The bone of the whole biopsy is lamellar in structure and without osteoblasts. The picture shows the only bony surface of the biopsy covered by osteoblasts (A). The layered flat osteoblasts (B) display positive TAP expression. Field width A = 120 μm; B = 190 μm.

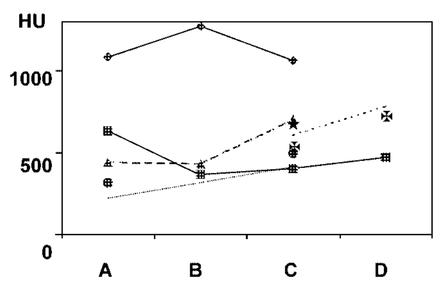

Fig. 12. CT densitometry (expressed as Hounsfied Unit – HU) in six patients at: A, before surgery; B, device removal, C, implant insertion; D, implant uncovering. Notice the substantial increase in the densitometric values from surgery to implant uncovering.

Discussion

Clinical, radiological and histological results highlight the reliability of this surgical preprosthetic technique applied with a view to increasing the volume of alveolar bone ridges. The method used allows the alveolar ridge height to be rapidly increased, without any grafting and with more predictable results, particularly as regards bone resorption. It also makes for even more rapid prosthetic rehabilitation, compared with more traditional two-stage (Hell et al. 1997; Lundgren et al. 1997; Keller et al. 1999) or even one-stage (Astrand et al. 1996; Kondell et al. 1996; Verhoeven et al. 1997) bone grafting techniques. The extra-alveolar distraction technique allows an implant insertion about 3 months after the end of distraction, providing the best 'grafting material', i.e. autologous bone Schliephake et al. 1991), without any donor site.

Our results agree with those obtained by Hidding et al. (1999, 2000) who used almost the same type of distraction and protocol. However, their two pilot studies depended mainly on clinical observation, whereas our study includes some more morphofunctional and radiological analyses. The alveolar ridge increase we obtained is greater than those obtained by Urbani et al. (1999a,1999b) and Gaggl et al. (1999, 2000) who used intra-alveolar devices. These devices allow distraction with more conservative surgery and may avoid removal of the device (Gaggl et al. 1999). Nevertheless, with such devices control of the distraction vector is problematical; great care needs to be taken in positioning the distractor and prosthetic rehabilitation is hard to harmonize with implant insertion.

The extra-alveolar device used in our study allows good control of the distraction vector in almost all cases at the time of its positioning and also distraction of up to 15 mm to be achieved. It is advisable to use many screws to ensure that the device is rigidly fixed to the bone so that the initial setting of the distraction vector remains unchanged. An angular overcorrection of the device in the vestibular direction is needed to obtain a correct distraction vector, depending on the site of distraction, the sex and age of the patient, and the mechanical capability of the patient's soft tissues. Nevertheless a dragging effect on soft tissues (particularly produced by older types of distraction device with three load-bearing columns) is recorded in edentulous patients with a very high degree of bone atrophy and who have been wearing removable dentures for long time. These patients exhibit a markedly reduced vestibular sulcus and presence of mucosal dense fibrous tissue. Probably, the greater the density of the connective tissue, the stronger its adhesion to the distraction device is likely to be, which enhances its dragging effect. Moreover, these patients undergo the greatest ridge increase, thus further exacerbating the dragging effect. Vestibuloplasty is required in these cases to restore anatomical functionality to the prosthetic rehabilitation.

Corrective effects are readily demonstrated by radiographic analyses of the region. However, radiographs can only highlight fine bone growth after a long time. Densitometry affords reliable information about bone mineralization, but only if performed in the same site, which must be different from the sites where screws and implants are applied or from where biopsies are taken. The number of subjects forming our densitometric sample is restricted, for economic reasons, but the results indicate the bone growth trend. All subjects (except for one) show an increase from 60 to 88 days and a further increase at the implant uncovering. This finding is apparently inconsistent with the morphofunctional analyses of the biopsies.

Histology indicates that bone histogenesis not only starts at the point where the bone is cut (Ilizarov 1989a, 1989b; Schenk & Gächter 1994), but also in the central part of soft callus, though to a lesser extent. Osteoprogenitors produce a bone matrix at this site that subsequently mineralizes and engulfs the cells, which are transformed into osteocytes – that is, a static osteogenesis occurs (Marotti et al. 1999). This early osteogenesis will be later followed by a dynamic osteogenesis (Marotti et al. 1999), which will connect the bone to that formed in apposition to the cut bone endings.

The osteogenic activities lead to a consistent formation of new bone, which characterizes the biopsies taken 60 days after the end of distraction. Thereafter, the amount of bone reduces, as is recorded by TBV at 88 days. This may be caused by: (a) the physiological decrease in bone processes; (b) the absence of loads; (c) bone modeling and remodeling. After the first phase of soft tissue reorganization (angiogenesis), bone cell differentiation from precursors begins and gradually increases. The active osteoblasts produce a very high amount of bone tissue, apart from the actual load skeletal requirements. A subsequent reduction occurs in the bone mass, which may be particularly marked if the skeletal segment is unloaded. The remodeling of the bone trabeculae may have an enhancing effect on this reduction in the bone mass. At 60 days, the bone is almost completely of woven structure, i.e. with a very disordered structure of collagen fibers and a very high cellularity of large osteocytes (Ferretti et al. 1999), even though highly mineralized. This kind of bone is mechanically barely adequate and will eventually be replaced by more ordered bone (Marotti 1996). The parallel fibered and lamellar bone has an ordered structure of collagen fibers, three-axis ellipsoid osteocytes and low cellularity (Ferretti et al. 1999) and has a relative large amount of mineralized matrix. It forms thin trabeculae surrounding large medullary spaces thanks to its higher mechanical properties. The apparent contradiction between the decreased TBV and the increased CT densitometric values at 88 days may be explained by the fact that CT densitometry depends on the total amount of mineralized material in a site, i.e. the mineralized matrix, which is higher in the more ordered bone. The eventual further increase in CT densitometry values is probably due to the complete substitution of woven bone by lamellar bone, as was observed in the biopsy at 200 days.

Implant insertion could play a fundamental role in bone remodeling both for iatrogenic and for mechanical reasons. Prosthetic surgery certainly produces traumatic effects on the tissue of the skeletal segment, but can also have a stimulating effect on bone activities. Implants have a small loading effect on the bone, although they are uncharged. In the biopsy taken 200 days after the end of distraction (without implant insertion) the bone activities were almost quiescent, i.e. a 'steady state' seemed to have been definitely reached that would appear to involve some of the biopsies taken at 88 days. The authors therefore suggest that earlier implant insertion and prosthetic loading (with load degree modulated) might prevent the reduction in TBV. Earlier implant insertion could also have a positive effect on the structure of the newly formed bone. Remodeled tissue formed after 60 days is structurally arranged to withstand loads acting on the bone before implant insertion. The arrangement of the bone structure is certainly not consistent with that required by prosthetic loading. So it may be that new bone formation concurrent with a suitable structure arrangement could go some way to improving prosthetic rehabilitation. This is consistent with the aim of the alveolar distraction technique in performing a prosthetic rehabilitation which fastens permanently to the implants by means of an implant-fixed prosthesis.

In conclusion, our results provide firm evidence of the efficacy of alveolar distraction osteogenesis in the bone improvement of skeletal segments for prosthetic rehabilitation. Since the findings relate to a rather limited number of patients, further studies with a larger number of patients may be necessary to confirm our results. As regards the eventual fate of the distracted segment, long-term studies have also to be carried out.

Résume

L'ostéogenèse de distraction alvéolaire (ADO) est un processus qui forme du nouvel os alvéolaire dans le but de corriger les inégalités alvéolaires de hauteur et de largeur. L'objectif de cette étude a été de vérifier la prévision de l'épaississement de la hauteur des crêtes alvéolaires atrophiées en utilisant un système de distraction extra-alvéolaire et d'étudier les processus osseux ayant pour intention d'améliorer la réhabilitation implanto-prothétique. L'ADO a été effectuée chez dix patients ayant des déformations de la crête afin d'obtenir un épaississement de cette dernière. Des évaluations cliniques et radiologiques (OPT et CT avec essais densitométriques) ont été effectuées durant les douze semaines suivantes, avant le placement des implants. Des biopsies aux jours 40, 60 et 88 ont été étudiées après coloration générale spécifique et histochimique des coupes; des microradiographies ont été analysées à l'aide du volume osseux trabéculaire (TBV). Quarante jours après la fin de la distraction, le caillot mou a signalé le début de l'ossification. Soixante jours après la fin de la distraction le caillot mou était transformé en un réseau d'os trabéculaire lâche; l'activité ostéogénique était importante et TBV était d'environ 50%. Quatre-vingt-huit jours après la fin de la distraction, la quantité d'os se révélait réduite avec une structure plus ordonnée; l'activité de la formation osseuse et du TBV diminuait aussi tandis que l'érosion ostéoclastique restait active. L'essai densitométrique enregistrait des valeurs en augmentation depuis la fin de la distraction, particulièrement après l'insertion implantaire. Les résultats histologiques ont indiqué une régression des processus de dépôts osseux 88 jours après la fin de la distraction culminant à un stade quasi constant après un certain temps. Les résultats suggèrent qu'une insertion implantaire précoce peut être préférable pour éviter une perte osseuse dûe à la charge mécanique.

Zusammenfassung

Die Distraktionsosteogenese am Alveolarfortsatz (ADO) stellt ein Verfahren dar, mit welchem neuer Alveolarknochen zur Korrektur von Deformitäten des Kammes in Höhe und Breite gebildet werden kann. Die Ziele dieser Arbeit waren a) die Voraussagbarkeit der Augmentation von atrophischen Alveolarkämmen in der Höhe mittels eines extra-alveolären Distraktionsgeräts zu verifizieren und b) den Verknöcherungsprozess zu studieren, um die implantatprothetische Rehabilitation zu optimieren. ADO wurde bei 10 Patienten mit Kammdeformitäten durchgeführt, um die nötige Kammaugmentation zu erhalten. Klinische und radiologische (OPT und CT mit densitometrischer Auswertung) Untersuchungen wurden während der folgenden 12 Wochen noch vor der Eingliederung der Implantate durchgeführt. Biopsien, gewonnen nach 40, 60 und 88 Tagen, wurden nach genereller, spezifischer und histochemischer Färbung der Schnitte untersucht. Mikroradiographien wurden analysiert, um das trabekuläre Knochenvolumen zu untersuchen. Vierzig Tage nach Ende der Distraktion zeigte ein weicher Kallus den Beginn der Ossifikation. Sechzig Tage nach Ende der Distraktion war der Kallus grösstenteils in ein Netzwerk von trabekulärem Knochen umgeformt worden. Die osteogene Aktivität war hoch und das TBV betrug ca. 50%. Achtundachzig Tage nach Ende der Distraktion schien die Menge des Knochens reduziert zu sein, zeigte aber mehr geordnete Strukturen. Die Aktivität der Knochenformation und das TBV nahmen ebenfalls ab, jedoch war die osteoklastische Erosion aktiv. Die densitometrischen Analysen zeigten ab dem Ende der Distraktion ansteigende Werte, im speziellen nach dem Einsetzen der Implantate. Die histologischen Resultate zeigten eine Abnahme der Knochendeposition 88 Tage nach dem Ende der Distraktion, welche nach einer bestimmten Zeit in einem virtuellen Gleichgewicht gipfelte. Die Resultate lassen vermuten, dass eine frühe Implantatplazierung wünschenswert sein könnte, um Knochenverlust wegen fehlender mechanischer Belastung zu vermeiden.

Resumen

La Osteogénesis de distracción alveolar (ADO) es un proceso que forma un Nuevo hueso alveolar para corregir deformidades alveolares en la altura y anchura de la cresta. Este trabajo pretende a) verificar la predictibilidad del aumento de la altura de crestas alveolares usando un dispositivo extraalveolar de distracción y b) estudiar los procesos óseos en orden a optimizar la rehabilitación implanto-prostética.

Se llevó a cabo el ADO en 10 pacientes con deformidades de la cresta para obtener el aumento crestal requerido. Se llevaron a cabo evaluaciones clínicas y radiológicas (OPT y CT con valoración densitométrica) durante las siguientes 12 semanas antes de la inserción de los implantes. Se estudiaron las biopsias a los 40, 60 y 88 días tras tinción general, específica e histoquímica de los cortes; se analizaron microrradiografías se analizaron para evaluar el Volumen de Hueso Trabecular.

Cuarenta días tras el final de la distracción, un callo blando indicó el comienzo de la osificación. Sesenta días tras el final de la distracción, el callo blando se convirtió largamente en una red de hueso trabecular entretejido; la actividad osteogénica fue alta y el TBV fue alrededor del 50%. Ochenta y ocho días tras el final de la distracción, la cantidad de hueso pareció reducirse, con una estructura mas ordenada; la actividad de formación ósea y el TBV también disminuyeron, mientras que la erosión osteoclástica estaba activa. Los ensayos densitométricos mostraron valores incrementándose desde el final de la distracción, particularmente tras la inserción de los implantes.

Los resultados histológicos mostraron una regresión en el proceso de deposición ósea tras 88 días del fin de la distracción culminando en una situación virtualmente estable tras un cierto tiempo. Los resultados sugieren que una inserción temprana puede ser deseable para evitar perdidas óseas debido a descarga mecánica.

要旨

歯槽骨延長再生術（ADO）は、顎堤の高径と幅径に変形をきたした歯槽骨を是正するために歯槽骨を新生させる過程である。本研究は、ａ）骨延長装置による萎縮した歯槽堤高径の増多術の予知性を証明し、ｂ）インプラント補綴によるリハビリテーションを至適化するために骨の再生過程を調べることを目的に行った。

ＡＤＯは顎堤が変形した１０名の患者において、顎堤増多を図るために行った。術後に臨床的評価およびレントゲン像による評価（ＯＰＴ及び CT と骨密度アッセイ）を、インプラント埋入前１２週間の期間に行った。組織切片の全般的、特異的及び組織化学的染色を行った後、４０日、６０日及び８８日後に生検を行った、顕微鏡像を解析して骨梁量（TBV）を評価した。

延長術終了４０日後に柔らかい仮骨の骨化が始まっていた。延長術終了６０日後に柔らかい仮骨の大半は骨梁網状骨のネットワークに変換していた；骨形成活性は高く、ＴＢＶは約５０％であった。延長術終了８８日後には、骨量は減少しているようであったが、より秩序だった構造になっていた。骨形成活性とＴＢＶも減少していたが、一方破骨細胞の侵食は活発であった。骨密度アッセイでは延長術終了後、特にインプラント埋入後から値が増加した。

組織学検査の結果は、骨添加の過程は延長術終了後８８日で退行し、特定の時間が過ぎると実質上 steady-state の状態になることを示した。本研究の結果は、機械的荷重により骨の喪失を避けるために、インプラントの早期埋入が望ましいことを示唆している。

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