Evaluation of Vertical Bone Gain Following Alveolar Distraction Osteogenesis in the Anterior Edentulous Mandible: A Clinical Study

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Abstract

Aim and Objectives To calculate the gain in bony height and volume of the distracted upper segment using an extraosseous unidirectional device to improve the retention of the future prosthesis.

Materials and Methods Ten cases with completely or partially edentulous but severely or considerably resorbed anterior mandibles were managed by vertical alveolar distraction osteogenesis. All the patients were evaluated preoperatively, intraoperatively and post-operatively for various parameters clinically and radiographically i.e. on OPG, lateral cephalogram and on CT scan, at different time intervals. In all cases there was increase in vertical bone height.

Results The study showed mean vertical bone gain (VBG) on OPG as 8.2 mm. The mean VBG on lateral cephalogram was 8.1 mm. The mean VBG on CT scan at right canine was 8.35 mm, at left canine was 8.2 mm and at midline was 8.27 mm.

Conclusion Alveolar distraction osteogenesis is a predictable method for restoring alveolar ridges prior to implant placement or prosthesis. Distraction osteogenesis is ideally suited for recreating missing tissue in the anterior esthetic zone by increasing vertical bone height as well as good width and soft tissue growth.

Keywords Vertical distraction osteogenesis · Alveolar distraction osteogenesis · Atrophic mandible · Alveolar ridge atrophy

Introduction

The techniques traditionally used in patients who present with alveolar ridge atrophy in order to achieve adequate bone height for osseointegrated implant placement are mainly based on the use of autogenous bone grafts [1] as well as alloplastic materials. The high morbidity rate and bone resorption associated with autogenous bone grafting have been widely described in the literature. The use of alloplastic materials does not offer an ideal bed for rehabilitation with osseointegrated implants. In addition, none of these methods render predictable results and they all require a greater waiting time between surgeries to increase the ridge and the placement of the implants.

Alveolar distraction osteogenesis (ADO) is a technique that is based on the principles described by Ilizarov [1, 2] who is credited with having defined and established the biological bases for the clinical use of osteogenic distraction in the management of different bone deformities. Block et al. [3] applied these principles experimentally and were the first to publish studies on the use of ADO in animals in 1996. In the same year, Chin and Toth [4] reported the clinical use of ADO as a treatment in alveolar ridge deficiencies in the upper maxillary. Recently, Uckan et al. [5] and Rachmiel et al. [6] described the use of ADO for the reconstruction of atrophic alveolar ridges. The ADO is a method that allows augmentation of alveolar ridge height with new bone formation as well as obtaining a significant increase in the surrounding soft tissues, offering a predictable result, with low morbidity and infection rates and a significantly shorter waiting period for rehabilitation with implants and prosthesis. Distraction osteogenesis can be achieved by extraosseous [7] or intraosseous [8, 9] devices. Extraosseous devices for vertical distraction of the mandible are usually placed subperiosteally [7].

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We report a study of 10 patients who underwent ADO for vertical alveolar reconstruction in which we determined the real vertical bone gain (VBG) with a specific protocol in which we analyzed the measurement after calculation of magnification factor. The VBG was assessed on the three different levels on CT scan in order to obtain the bone height in the entire width of the anterior mandible.

Materials and Methods

Ten patients (3 women and 7 men; mean age 55 years age range 40–70 years) underwent alveolar reconstruction with distraction osteogenesis. These patients had undergone a vertical alveolar distraction osteogenesis, using an extra-osseous alveolar distraction device (Ortho Max—India) (Fig. 1).

The surgical technique and distraction protocol followed in our study is in line with existing protocol on alveolar distraction. Cano et al. [10] have reviewed the literature on various alveolar distraction procedures and elucidated their indications, applications, procedures and limitations. Suhr and Kreusch [11] studied technical considerations in distraction osteogenesis and described immediate early and late complications. In our study we had followed a similar protocol.

All the patients were evaluated preoperatively, intraoperatively and post-operatively for various parameters clinically and radiographically at different time intervals.

Distraction Technique

After clinical evaluation alveolar ridge augmentation was carried out in all patients using vertical alveolar distractor. All cases were done under local anesthesia. Mucoperiosteal flap was elevated through a horizontal incision placed on the outer aspect of the alveolar ridge spanning the length of the edentulous area to be augmented, to expose the labial cortex. The dissection avoided elevation of the flap at the crest of the ridge, especially near the periodontal attachment

of the adjacent teeth. The distraction device was first placed on labial aspect of the anterior mandible, properly adopted and placed and fixed by the screws at its predetermined position. Osteotomy lines were drawn as planned and then the device was removed. A 703 bur was used to establish vertical osteotomies through both the labial and lingual cortices 2 mm clear of the adjacent roots from the alveolar crest downwards and towards the basal bone. A third horizontal osteotomy was then placed apically, joining the vertical osteotomies and outlining the transport segment and osteotomized segment. The shape of the transport segment was so planned that it would resemble an inverted trapezoid so that there is no hinderance laterally during its movements (Fig. 2) The osteotomized segment to be distracted was immediately moved by activating the distractor to check the direction of distraction and freedom of movement (Fig. 3). Finally, the osteotomized segment was repositioned at its initial position (Fig. 4) and surgical access was sutured with 3-0 suture (Fig. 5).

Latency period of 7 days was observed in all our cases. Activation of distraction device was done with a rate of 0.5 mm twice a day i.e. 1 mm per day for 10 days was done in all patients. After 3 month of consolidation period, the distractor was removed. At the same time visual and manual assessment of the regenerated bone was made (Fig. 6) and after 1 month rehabilitation was done with denture prosthesis.

Clinical follow-up examinations were performed at 7, 10, 15, 20, 30, 60, and 90 days. The follow-up examination included a search for complications such as infection, tipping of the transport disc, paresthesias, epithelial invagination, and fracture of the transport disc or transport plate. After a consolidation period of 3 months from the last day of distraction, the patients were sent to prosthetic department for rehabilitation.

Clinical Analysis

Preoperatively and post-operatively clinical vertical heights of bone were measured with linear scale from the depth of the sulcus to the uppermost part of the ridge at midline.

Fig. 1 Vertical alveolar distraction device (Ortho Max—India)

Fig. 2 Osteotomy cuts

Fig. 3 Mobility of the transport disc ensured

Fig. 4 Transport disc brought back to normal position

Fig. 5 Incision closed with 3-0 vicryl

Fig. 6 Regenerated bone after removal of distraction device

Radiographic Analysis

Vertical bone gain (VBG) was assessed in three different radiographs i.e. on OPG at midline and on lateral cephalogram after calculation of magnification factor. Only one reference point was taken on OPG and lateral cephalogram because the magnification factor could be calculated at this point only owing to presence of activation rod at this place.

Orthopantomogram

Orthopantomogram radiographies were performed in all patients, one on the day of surgery, one before the beginning

of distraction and one after the consolidation period, 12 weeks post-operatively. The radiographic analysis consisted of obtaining the amount of the VBG in each radiograph. For this, we obtained initially the magnification factor (MF) of each panoramic radiograph by dividing the real size (RS) of the activation rod among the image size (IS) of the activation rod and vertical bone gain was accordingly calculated. After this, to obtain the VBG, we measured initially the length of the distraction pre activation (LD1) which consisted of the distance between the superior portion of the basal plate and the superior portion of the transport plate multiplied by the MF. Then, we measured the length of the distraction post activation (LD2), (Fig. 7) using the same method described earlier, in radiographies performed 12 weeks post-operatively. The VBG was obtained using the following formula: $VBG = LD2 - LD1$. The method used to obtain the MF permitted radiographic analysis to be performed at different radiology departments, making the identification of real bone gain more accurate. This radiographic analysis seems to be an important tool to verify the technique's success as well as in planning the prosthetic rehabilitation [12].

Lateral cephalogram

Lateral cephalometric radiographs were taken preoperatively, immediately after installation of the distractor device, at the end of the active distraction period (1–2 weeks), after a consolidation period of 12 weeks, and before placement of implants. We made measurements using the mandibular plane as a reference, that is, the line drawn at an angle to the posterior portion of the lower border of the mandible, stretching from point gonion to the symphysis curve (point menton). An auxiliary line was constructed perpendicularly, and then another line at an angle to the top of the alveolar process, was drawn in a right angle to the auxiliary line (Fig. 8a, b). All cephalometric radiographs were superimposed using the sella and nasion as references. It was calibrated by using the marks on the forehead positioner that indicated a distance of

Fig. 7 Length of the distraction post activation

10 mm. Subsequently, measurements of bony height were made with a calliper. The angle of the lingual movement of the upper segment was calculated on the day that the distraction device was installed, and compared with the angle that was measured at the end of the distraction period [13].

This method enabled us to not only calculate the VBG but also to assess any backward inclination of the transport disc. However none of our cases showed this tendency. This may be due to the correct application of the distractor and its vector.

Computed Tomography

The height of the bone was measured on CT scan from lower border of the mandible to the upper border between the mental foramina at three reference points one at right canine, one at left canine and one at midline. CT scan with axial, coronal and sagittal sections and 3D reconstruction were taken to evaluate the uniformity in regenerated bone height (Fig. 9). Density of the regenerated bone on CT scan was measured in Hounsfield Units (HU). Morphological analysis on CT scan: Regenerative bone thickness on buccolingual view images were evaluated as thicker, almost the same, or thinner than that on the native side in each case.

Results

Clinically the mean VBG was approximately 3.6 mm (Table 1). Clinical evaluation of VBG enabled us to study the feasibility of rehabilitation by denture or implants. The study showed mean VBG on OPG as 8.2 mm (Table 1). On a lateral cephalogram VBG was calculated according the study conducted by Perdijk et al. in 2009 [13], we followed the same technique. The mean VBG on lateral cephalogram was 8.1 mm (Table 1). Three reference points were

Fig. 8 a and b Measurement of the height of the mandibular bone using the mandibular plane as a reference

Fig. 9 Three reference points on CT scan i.e. one at right canine, one at left canine and one at midline

taken to assess the overall VBG as the CT gives accurate calculations without magnification factor. The mean VBG at right canine was 8.35 mm, at left canine was 8.2 mm and at midline was 8.27 mm (Table 1). We found that there is a significant increase in the VBG in all three areas and OPG and lateral cephalogram gave more or less similar results.

Macroscopically the attachment of the gingiva and mucolabial fold were healthy and hardness of the bone was palpated which was hard and firm and equal to native bone. In addition we have also done morphological analysis of the regenerated bone on 3D CT scan and on panoramic radiograph, where the regenerated bone thickness on buccolingual view images was evaluated as Thick.

In case no. 5, there was post-operative infection due to device itself leading to scarring and shrinkage of the soft tissues. Hence, this patient had to be rehabilitated following vestibuloplasty. In our study we observed that there was minimal resorption of the bone following alveolar distraction osteogenesis. About 1 mm of resorption occurred in case no. 3, 5, 7, 9, and 10. The resorption found was minimal and was more or less similar to the study done by Polo [14] who showed a mean resorption of 1 mm for each 10 mm distracted.

Discussion

Vertical alveolar distraction osteogenesis method demonstrates many advantages in treating vertical alveolar bone defects compared with conventional methods from the aspect of bone quality, bone quantity, donor site morbidity, and decreased bone resorption. The main advantage of the vertical alveolar bone distraction is that there is an increase in alveolar bone height with new bone formation beneath the distracted bone. Furthermore, simultaneous lengthening of the surrounding soft tissues is achieved by histiogenesis

Table 1 Vertical bone gain

Pre operative height (mm)												Post-operative height (mm)										
Cases no	1	2	3	4	5	6	7	8	9	10	Mean	1	2	3	4	5	6	7	8	9	10	Mean
Evaluations																						
Clinical	4	2	2	1	2	3	2	2.5	2	1	2.15	8	5.5	5	5	5	7	5	6.5	5.5	5	5.75
OPG	26	16	18	16	18	18	18	20	17	20	18.9	34	23	27	24	27	28	27	29	25	27	27.1
Lateral cephalogram	27	18	19	17	20	16	19	20	18	20	19.4	35	25	27	26	28	24	28	29	26	27	27.5
CT Scan																						
Right canine	27.5	17.6	20.1	17	19.9	21.8	18.9	20.6	18.2	20.6	20.22	35.5	25.5	28.6	26	27.9	30.3	27.9	29.6	26.2	28.1	28.57
Left canine	27.4	17.9	19.2	17.4	20.8	20.9	19	21.7	18	20.9	20.32	35.4	25.4	27.2	25.9	28.8	29.5	28	30.7	26	28.3	28.52
Midline	26.3	16.8	17.8	16	18.1	19.7	18.2	19.9	16.4	18.7	20.29	34.3	24.3	26.3	24.5	26.1	28.3	27.2	28.9	24.4	26.3	28.51
Vertical bone gain (mm)																						
Cases no	1	2	3	4	5	6	7	8	9	10	Mean											
Evaluations																						
Clinical	4	3.5	3	4	3	4	3	4	3.5	4	3.6											
OPG	8	7	9	8	9	8	9	8	8	7	8.2											
Lateral cephalogram	8	7	8	9	8	8	9	9	8	7	8.1											
CT scan																						
Left canine	8	8	8.5	9	8	8.5	9	9	8	7.5	8.35											
Right canine	8	7.5	8	8.5	8	8	9	9	8	7.4	8.2											
Midline	8	7.5	8.5	8.5	8	8.6	9	9	8	7.6	8.22											

[15, 16]. Compared with other techniques of regeneration, the ADO permits less treatment time because the distraction segments are well formed in 12 weeks.

There are various types of distractors in the market that are classified mainly as intraosseous and extraosseous; both have their own advantages and disadvantages. Extraosseous devices for vertical distraction of the mandible are usually placed subperiosteally.

With good width and soft tissue growth, the rehabilitation of the patient with prosthetic appliances was made easy. There was increase in retention of the dentures in these patients. Further there was no need for any secondary procedures such as vestibuloplasty which was necessary in other techniques of the bone augmentation like bone grafts or alloplastic augmentations, etc. In our study only one patient needed vestibuloplasty. In case no. 5, there was post-operative infection due to device itself leading to scarring and shrinkage of the soft tissues. Hence, this patient had to be rehabilitated following vestibuloplasty.

Although alveolar distraction has proven to be successful for treating alveolar ridge deficiency, it has some intraoperative and post-operative complications [15, 17–20]. During the distraction process, complications include resorption of the transport segment, difficulty in completing the osteotomy on the lingual side, excessive length of the threaded rod and device failure. Post-operative complications include incorrect direction of distraction (tipping of transport segment), perforation of the mucosa by the transport segment, and inadequate length of distraction.

Complications were categorized into two groups: minor complications [15], i.e. those that did not affect the final result but required immediate attention; and major complications, i.e. those that lead to failure of the technique. Minor complications included tipping of the bone transport segment, dehiscence, infection, lack of patient collaboration and perforation of the mucosa by the transport segment. Major complications included resorption of the bone transport segment, device failure, fracture of the mandible, non-union, dysesthesia of the mental nerve, and inadequate length of distraction.

It was concluded in a clinical study that ADO is an effective technique to treat vertical alveolar ridge deficiencies. Most complications related to surgery can be avoided with adequate treatment planning. We have not observed serious complications, such as fracture of the mandible, fracture of the transport segment, or breakage of the distraction device in our study. Among the minor complications, in one patient post-operative infection was developed due to which the gingiva was not healthy and present with multiple sinuses. This complication however disappeared after the removal of distractor device. Otherwise there was neither clinically observed infection nor resorption of the superior aspect of the alveolar ridge.

Although there are many studies done previously on alveolar ridge augmentation this study is unique in the sense that we have shown the new protocol of calculating the VBG on OPG, lateral cephalogram and CT scan. We have shown the VBG on three reference points on CT scan covering the entire span of the anterior mandible, thereby showing uniform increase in the vertical height of the alveolar bone along the whole width of the mandible.

Alveolar distraction osteogenesis (ADO) is an effective technique to treat vertical alveolar ridge deficiencies. Although complications are frequent, they are usually easy to resolve. Very close follow-up is required.

Conclusion

Alveolar distraction osteogenesis is a predictable method for restoring alveolar ridge height prior to implant placement or prosthesis. Distraction osteogenesis is ideally suited for recreating missing tissue in the anterior esthetic zone.

Despite the limited number of patients, the following conclusions can be drawn: Alveolar vertical distraction osteogenesis has proven to be reliable and predictable technique, as demonstrated by this study and others. Vertical bone gain may reach more than 10 mm using distraction osteogenesis without the use of bone transplantation; thus, morbidity is reduced with this technique. The bone gain reached at the end of distraction appears to be lasting. The quality of the bone regenerate is equivalent or close to the native bone and compatible with implant placement. The risk of infection of the surgical site was extremely limited.

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