Repair of segmental bone defects in the maxilla by transport disc distraction osteogenesis: Clinical experience with a new device

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ABSTRACT

The bones of the maxillary complex are vital for normal oro-nasal function and facial cosmetics. Maxillary tumor excision results in large defects that commonly include segments of the alveolar and palatine processes, compromising eating, speech and facial appearance. Unlike the conventional approach to maxillary defect repair by vascularized bone grafting, transport disc distraction osteogenesis (TDDO) stimulates new bone by separating the healing callus, and stimulates growth of surrounding soft tissues as well. Bone formed in this way closely mimics the parent bone in form and internal structure, producing a superior anatomical, functional and cosmetic result. Historically, TDDO has been successfully used to close small horizontal cleft defects in the maxilla, not exceeding 25 mm. Fujioka *et al*. reported in 2012 that "no bone transporter corresponding to the (large) size of the oro-antral fistula is marketed. The authors report the successful treatment of 4 cases involving alveolar defects of between 25 mm and 80 mm in length.

Keywords: Defect, device, maxilla, osteogenesis, transport distraction

INTRODUCTION

This article presents clinical experience of transport disc distraction osteogenesis (TDDO) applied to the repair of segmental defects in the maxilla using a new device, exposing the potential of this technique and promoting further development.

Ablative surgery to the maxillary complex or trauma or congenital defects has profound implications for chewing, swallowing, breathing and speech. This work focuses mainly on defects resulting from tumor excision, in which case large segments of the alveolar process, hard palate, orbits and cheeks are removed,[1] severely compromising oro-nasal function. In the maxilla, the conventional approach to large defect repair has been vascularized bone grafting, which is time-consuming and costly.[2]

Transport disc distraction osteogenesis is a surgical technique used to repair bone defects by means of the gradual, controlled movement of a living bone segment, "bone transport disc" (BTD), across the defect. This procedure begins with surgical osteotomy of the parent bone to create a distinct, yet vital BTD, which is then stabilized to allow a healing callus to form. Subsequent distraction of the BTD stretches the healing callus, stimulating the formation of new bone and surrounding soft tissue in its wake.[3]

In comparison to bone grafting, TDDO has demonstrated a superior anatomical, functional and cosmetic result, with reduced patient trauma, morbidity and faster patient recovery.[2,4,5] Of crucial value in the oral rehabilitation context is the fact that TDDO regenerate mimics the local parent bone in both internal structure and overall form, providing the ideal bony support for dental implants.

The use of TDDO for the repair of large segmental mandibular defects is well documented. However, the literature presents no cases of TDDO applied to defects larger than 20 mm [6-8]. No devices are commercially available to obturate large segmental maxillary defects.[9]

This study presents a new device for closure of large maxillary defects. To our knowledge, this is the first clinical report of such cases.

The practical requirements of maxillary reconstruction by TDDO are indeed demanding, given the complex geometry of the maxilla, and based on clinical experience, the TDDO device should be:

- Installed and activated intra-orally, avoiding any protrusions through the skin
- Easily customisable to match case-specific geometry
- Capable of distracting an unlimited distance within the oral cavity
- Capable of supplying a callus stretching force of at least 60N
- Rigidly anchored directly to the native bone.

The device presented here is the culmination of a 2-year development project, in which three successive versions were produced, clinically evaluated and relatively improved. The device has performed well in clinical practice though the refinement process is ongoing.

MATERIALS AND METHODS

The current version of the device operates on the principle of a worm screw engaged with a toothed rack [Figures 1 and 2]. The worm screw is housed within a mobile component, the bone transport carriage, which translates along the trajectory rail. By rotating the worm screw (activation), the bone transport carriage propels along the toothed rack by a distance of 1 mm per revolution. The trajectory rail can be customized to mimic the natural contours of the maxillary alveolar process by bending and trimming. The current device caters for a distraction length of up to 100 mm and a minimum bend radius of 25 mm. Mini bone screws are used to secure the BTD in a mesh-like cradle.

The device is activated daily through an intraoral approach.

The trajectory rail is rigidly anchored at its ends to the local native bone using bone screws at three distinct locations [Figure 2]:

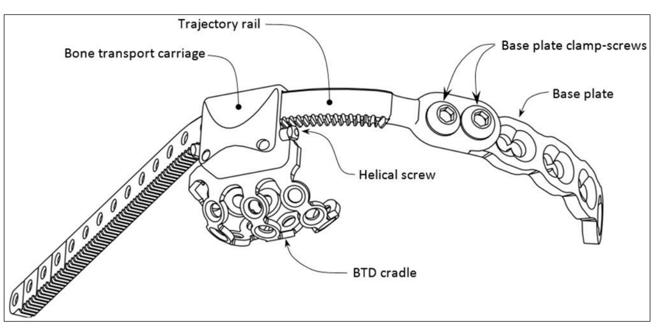

Figure 1: The various components of the transport disc distraction osteogenesis device (University of Cape Town patent number PCT/IB2012/056664)

- Primary anchorage is to the premaxilla using three or four screws
- The zygomatic complex
- The residual alveolar ridge.

The frontal anchorage makes use of a separate base-plate component, to which the trajectory rail can be attached and removed at will, thereby facilitating surgical placement.

Four successive clinical treatment cases have been initiated. In all four cases, the defects were due to surgical removal of maxillary tumors that eliminated the entire posterior segment of the maxilla. The defects ranged in size from 25 mm to 80 mm in length, measured along the outer contour of the alveolar process. The main priority was to regenerate sufficient alveolar bone in order to support dental implants and expand the deficient bony palatal vault. In order to support the neomaxilla posteriorly, an interpositional bone graft is placed between the zygomatic complex and the new bone where indicated.

The basic treatment protocol is not different to the established norms in the literature.

Bone transport disc osteotomy and device installation

The initial surgical procedure involved osteotomy of the BTD and installation of the precustomized device [Figure 2]. The BTD was separated from the parent bone by two osteotomies; one vertical, one horizontal. The vertical cut provided the main osteogenesis site, and the horizontal cut separated the BTD from the remaining maxilla superior to the dental roots. The palatal gingiva was left intact to maintain blood supply to the BTD. The dimensions of the resulting BTD fragment were approximately 15 mm × 15 mm in height and length. The BTD was secured to the bone transport carriage using 5-7 mini bone screws of Ø1.5 mm. This installation procedure was followed by a latent period of 7-10 days.

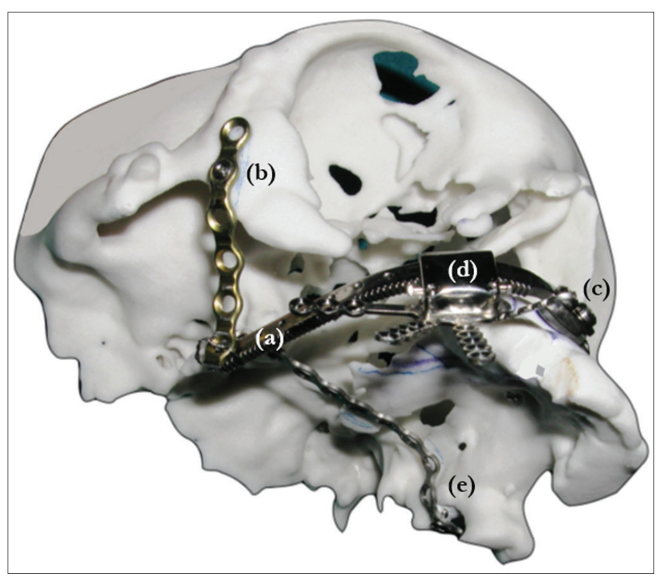

Figure 2: Maxillary transport disc distraction osteogenesis device installed on a preoperative planning model. (a) Trajectory rail, (b) bone transport carriage, (c) premaxillary base plate anchorage, (d) anchorage to zygomatic complex, (e) anchorage to residual alveolar bone

Active distraction and consolidation period

After latency, distraction was carried out at a rate of 1.5 mm per day until the defect had been satisfactorily repaired. Postoperative nasogastric feeding was carried out for all patients until the size of the defect facilitated swallowing without regurgitation. In all four cases, patients returned home within a week of the initial surgery, with daily activation taking place.

Patients were monitored regularly on alternate days. Once distraction had ceased, the new bone was allowed to consolidate for 3-6 months, with the device left in place until the maturation of the regenerate was complete.

In a second surgical procedure, the device was removed, and an interpositional bone graft was placed where necessary.

In the first treatment case, oral function was fully restored, including permanent dental rehabilitation. Four Nobel Active® dental implants (Nobel Biocare® South Africa) were placed into the consolidated regenerate, supporting a hybrid bridge [Figures 3c and 4]. The remaining three cases are currently awaiting consolidation of the regenerate before dental implants can be placed.

RESULTS

Transport disc distraction osteogenesis treatment produced outstanding results, successfully repairing curved segmental alveolar defects as well as associated defects in the adjacent palatine vault. In the first completed case, approximately 45 mm of maxillary alveolar bone was regenerated in a period of approximately 28 days.

Bone transport disc osteotomy and device installation

Installation of the device was straightforward, though some minor adjustments were made to the device intra-operatively to perfect the installation geometry. The premaxillary base plate anchorage provided excellent stability and greatly simplified the installation and osteotomy procedure by allowing the device to be repeatedly installed, removed and adjusted *in situ* without disturbing the bone anchorage.

In all four cases, drilling and deployment of anchorage screws were entirely intra-oral, thus causing no facial lesions. One patient reported pain at the premaxillary anchorage that was attributed to minor loosening and movement of the anchorage screws. Nonetheless, in all cases the device anchorage screws remained stable throughout treatment.

Active distraction and consolidation period

In general, TDDO treatment stimulated healthy callus formation, with a height and width comparable to that of the native alveolar bone and consistent along its length. The callus retained its shape throughout the active distraction and consolidation phases. In the first fully-consolidated case, the X-ray-inferred bone density of the alveolar regenerate achieved D3 status according to Misch's classification, indicative of normal maxillary bone.[10]

Transport disc distraction osteogenesis has been used successfully to treat a variety of maxillectomy defects. Due to its predictability and anatomical accuracy, TDDO techniques have replaced bone grafting in the repair of segmental mandibular defects. However, in the maxilla the TDDO technique has been limited to small defects (<20 mm). It is suggested that this is largely due to the complex anatomical constraints of the adult maxilla and the absence of a suitable bone transporter.[9]

DISCUSSION

The clinical experience presented here demonstrates that, given the appropriate hardware, TDDO is a feasible method of segmental maxillary alveolar defect repair. In addition to alveolar defects, TDDO simultaneously repairs associated defects in the hard palate. At the time of writing, the first clinical case, involving a defect in excess of 40 mm, had culminated in full functional and cosmetic rehabilitation, including implant-borne crown and bridgework.

At the time of writing, the remaining two cases were due to receive implants.

These cases are the first known of their kind and some difficulties were encountered, most of which related to the practicalities of the initial surgical BTD osteotomy and installation procedure. Many of these difficulties have been resolved subsequently through minor design modifications and amendments to the surgical protocol. It is anticipated that further clinical experience

Figure 3: Results of transport disc distraction osteogenesis (TDDO) treatment: (a) Defect due to tumor excision, before treatment, (b) after treatment by TDDO and minor secondary grafting, (c) after dental implant placement

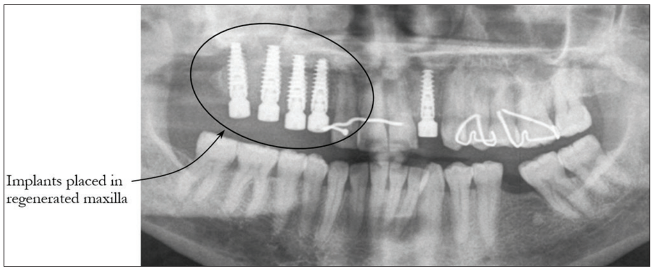

Figure 4: X-ray image of fully rehabilitated maxillary alveolus, with four dental implants placed in the maxillary alveolar regenerate

will prompt similar improvements to the treatment protocol and the supporting hardware.

In order to obviate early ossification of the regenerate, it is crucial that the rhythm of 1.5 mm per day is carefully monitored and maintained throughout the distraction phase.

In addition, careful patient selection is paramount to success in these cases. As patients are initially dependent upon naso-gastric feeding, their full co-operation is germane to the successful completion of this modality of treatment.

The device is supported by a patent held by the University of Cape Town [Figure 1] and shared by the authors.

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Explicit patient consent has been obtained to publish their likeness in all forms.

REFERENCES

1. Brown JS, Rogers SN, McNally DN, Boyle M. A modified classification for the maxillectomy defect. Head Neck 2000;22:17-26.
2. Wang JJ, Chen J, Ping FY, Yan Fg. Double-step transport distraction osteogenesis in the reconstruction of unilateral large mandibular defects after tumour resection using internal distraction devices. Int J Oral Maxillofac Surg 2012;41:587-95.
3. Saunders MM, Lee JS. The influence of mechanical environment on bone healing and distraction osteogenesis. Atlas Oral Maxillofac Surg Clin North Am 2008;16:147-58.
4. Akay MC. Distraction Osteogenesis of the Maxillofacial Skeleton: Clinical and Radiological Evaluation. [Book auth.] Subburaj K. CT Scanning – Techniques and Applications. ISBN: 978-953-307-943-1: sl. InTech; 2011. p. 121-46.
5. Zapata U, Elsalanty ME, Dechow PC, Opperman LA. Biomechanical configurations of mandibular transport distraction osteogenesis devices. Tissue Eng Part B Rev 2010;16:273-83.
6. Mitsugi M, Ito O, Alcalde RE. Maxillary bone transportation in alveolar cleft-transport distraction osteogenesis for treatment of alveolar cleft repair. Br J Plast Surg 2005;58:619-25.
7. Liou EJ, Chen PK, Huang CS, Chen YR. Interdental distraction osteogenesis and rapid orthodontic tooth movement: A novel approach to approximate a wide alveolar cleft or bony defect. Plast Reconstr Surg 2000;105:1262-72.
8. Tibesar RJ, Moore EJ, Bite U. Distraction osteogenesis for cleft palate closure in a canine model. Arch Facial Plast Surg 2005;7:398-404.
9. Fujioka M, Kanno T, Mitsugi M, Sukegawa S, Furuki Y. Oral rehabilitation of a maxillectomy defect using bone transport distraction and dental implants. J Oral Maxillofac Surg 2010;68:2278-82.
10. Misch CE. Density of bone: Effect on treatment plans, surgical approach, healing, and progressive boen loading. Int J Oral Implantol 1990;6:23-31.

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