Total reconstruction of mandible by transport distraction after complete resection for benign and malignant tumors

Balaji SM

ABSTRACT

Background: Distraction osteogenesis (DO) is a recognized technique for the bone lengthening and correction of various mandibular deformities. It has an aided advantage of both osteogenesis and histiogenesis in achieving a bone supported mandibular ridge covered with attached gingiva, forming an appropriate vestibule.

Aim: The aim of this study was to present our clinical experience in using transport DO technique (TDO) for treating mandibular bony defects following tumor ablation in both benign and malignant tumor cases.

Materials and Methods: This is a retrospective analysis of patients who underwent mandibular TDO for the correction of mandibular segmental defect at authors’ center from 2000 to 2014 with the inclusion criteria of segmental bony defect in the mandible with moderate soft tissue defect. After the latency period of 10 days, the distraction was initiated at a rate of 0.25–1 mm/day. The distraction period continued until the segment with the transport disc reached the distal base. The total consolidation periods ranged from 6 to 14 weeks.

Results: The study group consists of 9 cases of TDO for reconstruction of segmental defect following tumor resection, of which 5 cases of benign and 4 cases of malignant tumor resection. The mean (standard deviation [SD]) bony defect length was 48 mm (9.8). The mean (SD) distracted bone lengthening was 43 mm (9.7), with a mean (SD) consolidation period of 17.9 (3.4) weeks. The bony defect involved the hemimandibular angle in four patients, hemimandibular body in three patients, with greater involvement of the body, symphysis in two patients, and of the bilateral mandibular body in two patients. Except for two patients who required additional bone grafting to complete union with the residual bone, other seven patients in the distraction zone showed the complete ossification by radiological evaluation. The mean (SD) consolidation period of 13.56 (1.5) weeks ranging from 12-15 weeks with the mean (SD) follow-up years is about 8.7 years (2.95) for the cases. Out of the 9 cases, one case had recurrence in the follow-up period and underwent resection with reconstruction using reconstruction plate in the created bone. The overall success rate of TDO was 88.9% (8 out of 9) in spite of adequate case selection and TDO protocol.

Conclusions: TDO potentially benefits patients with segmental bony defects following tumor ablation in mandible. It is an unswerving tool to achieve sufficient bone in mandible in patients who cannot undergo aggressive surgery or poor general health. Bone resorption remains a critical issue for this reconstruction technique, though blood supply is continuously maintained in TDO.

Key words: Mandibular resection, segmental defect, transport distraction, tumor ablation

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INTRODUCTION

Surgical treatment of extensive hard and soft tissue may leave back segmental mandibular bone defects. Such defects may also be a result of congenital deformities, blast injuries, high-impact trauma, or repeated surgical debridements for the treatment of chronic osteomyelitis of the mandible. Interruption of mandibular continuity results in cosmetic and functional deformity. When form and function are not restored in the reconstructive process, the patient may be left with an undesirable outcome and debilitating condition. The defects resulting from tumor removal often differ from other situations. In other conditions, the concomitant tissues are slowly altered and adapted to the deformity. In post-tumor removal situations, the soft tissue and hard tissues are rapidly mobilized to heal the defect. In addition, in tumor patients, need and exposure for chemotherapy and/or radiotherapy may compromise the local blood supply, thick scars, and repositioned flaps may locally complicate the reconstruction process. These factors play a crucial role in the rate of healing, comfort for patients as well as the success of the reconstruction of surgical defects. Hence, the reconstruction of mandible in three dimensions is necessary to restore the form, function, and cosmesis.

Microvascular free-flaps have been successfully used for the reconstruction of large segmental mandibular defects. However, the patients with increased surgical risks such as uncontrolled hypertension, impaired oxygen saturation, or other systemic illness, which render prolonged anesthesia risky, are not suitable for the microvascular free-flap. The traditional method of reconstruction by the usage of autogenous cancellous cellular bone grafts in conjunction with metal plates and screws often produces adequate hard tissue. Despite the high success of bone grafting, some significant complications have been reported; most importantly, donor-site morbidity, graft resorption, and relapse. These difficulties have led to the exploration of new ways to reconstruct mandibular bone defects.

Distraction osteogenesis (DO) is one of the recent methods to restore the appearance and the physiology of the affected area. Transport DO (TDO) of the bone is a method of bone defect reconstruction that has been used in the long bones for decades. Using the principles of DO, TDO works by creating an osteotomy by detaching a bone segment (transport disc) from one end of the defect and moving it gradually across the gap to the other end. As the bone segment is moved, bone should form behind it, filling the defect. The new bone should have similar quality and physical dimensions to the original bone.

TDO is considered often as an excellent treatment option for the reconstruction of mandibular defects. TDO allows reconstruction of segmental bony defects with an alveolar height that closely mimics the native mandible. It also provides attached gingiva that resembles the original. This is of utmost importance, as the overlying soft tissue is often too thick following microvascular free-flap reconstruction, leading to unfavorable dental implant placement and maintenance because of the absence of attached gingiva.

In patients having bony defects of the maxillofacial skeleton after tumor ablation, TDO allows regeneration of loosened bone following osteotomy and gradual separation of bony fragments.

English literature has many reports on successful reconstruction in oral cancers and other forms of large facial deformities corrections using TDO. However, to the best of our knowledge, there are very few literatures on comparison of the method and outcomes of segmental correction between post-tumor surgical defects between biologically benign and malignant tumors. The present study intends to report author’s clinical experience using TDO to treat patients having mandibular bony defects following tumor ablation, and the limitations in the distraction of benign and malignant tumor are also analyzed qualitatively.

MATERIALS AND METHODS

This retrospective study was performed from the archival records of the center from January 2000 to December 2014. Only those patients with the mandibular bony defect due to tumor ablation with or without soft tissue defect who underwent TDO were included in the study (bone transport should be used to reconstruct defects in all patients). Those patients with mandibular bony defect due to trauma, osteomyelitis, etc., other than tumor ablation are excluded from the study. Besides patient’s demographic data, tumor type and location, defect length, distracted bone lengthening, consolidation period, type of graft, postoperative complications, quality of bone formed by radiograph, success rate, and follow-up period were noted down. Descriptive results of the study are presented and discussed [Tables 1-4].

Surgical method

All distractor fixation procedures were performed under standard general anesthesia care. Mandibular defect following tumor ablation is reconstructed using a plate-guided distractor (PGD), which was described first by Herford and the two-stage transport disc distraction technique, as described by Whitesides et al. The PGD used consisted of a 27 mm reconstruction plate with two distractors attached to the plate (Herford Transport Distractor, Martin - right and left, 30–50 mm depending on the defect.) The distractors were adapted and secured to the mandible before resection of the tumor intraorally. Osteotomy is performed after reapplying the plate, using the oscillating saw to create a transport segment of varying length depending on the amount of bone required. Care was taken to maintain periosteal blood supply to this transport
Table 1: Details of patient who have undergone TDO

| Age | Sex | Diagnosis                  | Benign/malignant | Defect location                        | Postoperative complication | Follow-up (years) |
|-----|-----|---------------------------|------------------|----------------------------------------|---------------------------|------------------|
| 40  | Male| Ameloblastoma             | Benign           | Right angle                            | Nil                        | 8                |
| 25  | Female| Odontogenic Keratocyst | Benign           | Left angle                             | Nil                        | 10               |
| 35  | Male| Ameloblastoma             | Benign           | Right parasymphysis and left parasymphysis | Nil                       | 12               |
| 32  | Male| Ameloblastoma             | Benign           | Right angle                            | Recurrence                 | 5                |
| 30  | Male| Ameloblastoma             | Benign           | Left retromolar and angle              | Nil                        | 14               |
| 65  | Male| SCC                       | Malignant        | Right canine to molar alveolar bone     | Exposure of plate          | 8                |
| 53  | Male| Mucoepidermoid carcinoma | Malignant        | Left molar – symphysis area            | Nil                        | 10               |
| 48  | Male| SCC                       | Malignant        | Left molar – premolar area             | Nil                        | 5                |
| 49  | Male| SCC                       | Malignant        | Left molar to symphysis                | Infection                  | 6                |

SCC = Squamous cell carcinoma

Table 2: Treatment details and outcomes

| Bone defect length (mm) | Transport disc length (cm) | Distracted length (mm) | Graft type                  | Consolidation period (weeks) | Quality of bone formed by radiograph |
|-------------------------|----------------------------|------------------------|----------------------------|------------------------------|------------------------------------|
| 38                      | 1.8                        | 35                     | Nil                        | 12                           | Good                               |
| 45                      | 2.2                        | 40                     | Nil                        | 14                           | Good                               |
| 50                      | 2.7 (right) and 1.8 (left) | 45                     | Nil                        | 15                           | Good                               |
| 40                      | 2.5                        | 35                     | Nil                        | 12                           | Good                               |
| 37                      | 1.8                        | 35                     | Nil                        | 12                           | Good                               |
| 52                      | 2.2 (right) and 1.5 (left) | 48                     | Nil                        | 15                           | Good                               |
| 55                      | 2.5 (right) and 1.8 (left) | 52                     | Iliac crestal graft        | 15                           | Hour glass defect + re-graft needed |
| 45                      | 2.5                        | 40                     | Nil                        | 12                           | Good                               |
| 70                      | 2.5 (right) and 3.5 (left) | 65                     | Rib graft                  | 15                           | Re-graft needed                     |

Table 3: Demographic data of the study group

| Age (in years) | Values |
|----------------|--------|
| Mean           | 41.9   |
| SD             | 12.12  |
| Range          | 25-65  |
| Female: male ratio | 1:9 |
| Benign: Malignant ratio | 5:4 |

Table 4: Study parameters in the study group

| Bone defect (in mm) | Values |
|---------------------|--------|
| Mean                | 48     |
| SD                  | 9.8    |
| Range               | 37-70  |

| Distracted length (in mm) | Values |
|---------------------------|--------|
| Mean                      | 43.9   |
| SD                        | 9.5    |
| Range                     | 35-65  |

| Consolidation period (weeks) | Values |
|-----------------------------|--------|
| Mean                        | 13.56  |
| SD                          | 1.5    |
| Range                       | 12-15  |

| Follow-up (years) | Values |
|-------------------|--------|
| Mean              | 8.67   |
| SD                | 2.95   |
| Range             | 5-14   |

Bone segment. The distractors were then secured to the transport segment with appropriate screws. This disc would then be distracted along the inner side of the reconstruction bar as it was advanced through the defect. After 5-day latency period, the distractors were activated at a rate of 0.5 mm twice per day until the transport segments had reached the docking site.

In three patients where the defect exceeded 50 mm, trifocal DO is performed; about 8 weeks after the initial distraction, a second mandibular osteotomy was performed to section the transport disc so that the proximal portion would serve as the new transport disc. This proximal portion was secured to the advancing end of the distractor whereas the distal part of the original transport disc was secured to the reconstruction plate with bicortical screws. All patients were subjected to varying periods of latency, rate, and rhythm of the distraction varied based on the clinical situation. After the latency period of 5–10 days, the distractor was activated at a rate of 0.5 mm twice a day till the new transport segment met the opposite site. As the bone disc is transported, new bone is formed behind it to gradually fill the gap, according to the well-established principles of DO. When the transport disc reaches the docking site (at the edge of the other bone segment), the device should be retained in place for a few weeks, depending on the amount of distraction, until the newly formed bone consolidates and is able to sustain chewing forces or carry implants [Figures 1 and 2].

After a 12-15 weeks of consolidation period, surgery was performed once again for the removal of the distractor.
RESULTS

A total of nine patients with mandibular segmental bone defect treated by TDO fulfilling the inclusion and exclusion criteria were included in the study. The study group consists of five and four cases of benign and malignant mandibular tumors, respectively. Of the nine patients who underwent TDO, except one, rest all the eight patients were males. The mean age of the population ranged from 25 years to 65 years with a mean age of 41 years. The average defect of the mandible was 48 mm ranging from 37 to 70 mm with a standard deviation of 9.8. The average distracted length of the mandible was 43.9 mm ranging from 35 to 65 mm with a standard deviation of 9.5. The bony defect involved the hemimandibular angle in four patients, hemimandibular body in two patients, with greater involvement of the body, symphysis in two patients, and of the bilateral mandibular body in one patient. Except for two patients who required additional bone grafting to complete union with the residual bone (at docking site), other seven patients in the distraction zone showed the complete ossification by radiological evaluation. The mean (SD) consolidation period was 13.56 (1.5) weeks ranging from 12‑15 weeks with a mean (SD) follow up of 8.67 (2.95) ranging from 5 to 14 years. Out of the nine cases, one case had recurrence in the subsequent follow‑up period (diagnosed at 42 months postoperative) and underwent re‑resection along with simultaneous reconstruction using plate in the created bone. The overall success rate of TDO was 88.9% (8 out of 9) in spite of the adequate case selection and TDO protocol.

No complications of TDO were observed. All the patients irrespective of bi-focal or tri-focal TDO had no difficulty in the immediate postoperative phase. The duration of latency period was uneventful. At the beginning of the distraction phase, there was no pain or difficulty during the activation.

Figure 1: (a) Preoperative image (case of ameloblastoma) (b) orthopantomograph showing well-defined multilocular radiolucency in the mandibular body and symphysis (c) intraoperative image showing excision of the tumor (d) surgically excised specimen (e) intraoral bilateral fixation of transport distractor (f-i) series of orthopantomograph showing plate-guided distraction with the formation of newly regenerated bone in successive months follow-up (j) docking of transport segment using harvested rib graft (k and l) implant placement in the newly reconstructed bone (m) postoperative image

Figure 2: (a) Preoperative image (case of squamous cell carcinoma) (b) orthopantomograph showing segmental mandibular defect post-tumor ablation (c and d) reconstruction using transport distraction osteogenesis by plate-guided distraction (e) orthopantomograph showing plate-guided distractor in place (f) implant placement in the newly reconstructed bone (g) postoperative image
The patients were advised to be on soft diet. There was no intraoral gaping or exposure of the transport disc during the distraction phase except for one case where there was an exposure of the plate extraorally. Later, the scar was excised, closure was done, and further distraction was carried out uneventfully.

DISCUSSION

The major primary goals of mandibular reconstruction are restoration of osseous continuity, osseous bulk, alveolar height, arch form, width and alignment, and maintenance of the bone graft/graft durability, acceptable facial form, and appearance.[12]

Over the years, numerous advances have been made, toward achieving these goals of reconstruction. However, the reports[13,14] on mandibular reconstruction revealed that the nonvascularized grafts are best suited for the reconstruction of segmental defects created after ablation of benign tumor lesions. DO has revolutionized the field of reconstructive surgery by the formation of new bone, when existing bone segment is distracted along the long axis of the bone, at a constant rate.[15]

Although DO has been widely used in long bones for several decades, it is only after 1990s this technique became a common method in mandibular lengthening.

TDO has been used successfully for lengthening the extremities for many years. The first application of transport (bifocal) DO for reconstructing segmental mandibular defects was by Costantino et al. in 1990.[16]

DO is a process of new bone formation between two bone segments, when they are gradually separated by incremental traction. This pattern of elongation of bone allows the surrounding soft tissues to adjust to the new skeletal dimensions through the series of adaptive changes called distraction histiogenesis. Active histiogenesis has been shown to occur in various soft tissues including skeletal muscles, nerves, blood vessels, periodontal ligament, and gingiva. The result will be the synthesis of new bone with a cover of periosteum and soft tissues (mucosa, muscles, etc.) as well as new vascular and nerve supply.

Compared to other methods of mandibular reconstruction, including bone grafts, whether vascularized or nonvascularized, allogeneic materials, or guided–bone regeneration, TDO offers the advantage of creating new bone that has the same physical dimensions and tissue properties as the host bone. In addition, TDO eliminates donor-site morbidity and reduces the length of the surgical procedure.[17]

Mandibular reconstruction by primary repair offers significant advantages over secondary repair by preventing the wound from scarring while yielding optimal functional and esthetic results for the patient. Secondary reconstruction of mandibular defects is usually recommended in cases where there is persistent infection in the previously reconstructed tissue (i.e., screw loosening or plate extrusion). It proposes a unique challenge for the surgeons due to the presence of soft tissue scarring and the contracture of the resected end of the mandibular tissue. This often hinders the surgeon’s ability to predict the length and the amount of mucosa required intraorally.

DO has the unique ability to correct osseous and soft tissue deficiencies simultaneously. Mandibular deformities following tumor ablation involve a combination of osseous and soft tissue deficiencies, hence the satisfactory reconstruction with conventional methods is difficult or may be sometimes impossible. The amount of soft tissue available in benign cases is more when compared to the malignant cases, which is one of the major limitations for the movement of the distractor device. The tissue tension is comparatively less in benign cases, as observed in our patients helping in docking the transport segment distally.

After resection of malignant tumors, more soft tissue reconstruction is often necessary. This may include the floor of the mouth, the tongue, the cheek, and the chin, in addition to adequate soft tissue covering of the major vessels of the neck following neck dissection. This has always been a challenging task. In spite of the wide variety of reconstruction methods, none of them is completely satisfactory.

Inherently, the biological aggressiveness of tumor determines the extent of the surgical deformity. Often, aggressive tumors lead to larger defects as the need for marginal clearance is larger. Benign lesions and those that spread locally, such as ameloblastoma, require less marginal clearance and thus, the defect size is relatively smaller. However, this concept cannot be generalized as most of the tumors in the head and neck region can have diverse presentation. A small innocuous lesion may behave aggressively while a large, space-occupying lesion may have an indolent growth pattern. Furthermore, at any point of time, the tumor may turn aggressive. In this study, it is observed that the biologically benign lesions were able to regrow the mandible faster than the malignant counterpart. However, as there are numerous confounders that could be causing the phenomenon, in this small sample, this observation need to be tested with a larger sample size.

The distraction device can be uni-directional or multi-vector; extraoral or intraoral. However, in our present study, we used only the intraoral device which has an added advantage in eliminating patient discomfort in social life and cutaneous scar. In addition to the technical problems associated with device assembly and application, the distraction devices had a completely independent function to the reconstruction
plate. While the reconstruction plate takes the curved shape of the original mandible, the distraction device carries the transport segment toward the docking site guided by the linear vector of the distraction device irrelevant to the course of the reconstruction plate. In other words, the fixative function of the reconstruction plate was separated from the new bone formation, even when the two device components were physically connected. In addition, the length range of the regenerate is limited by the length of the device, which makes it unable to reconstruct large mandibular defect, especially those crossing the midline. Determination and selection of the optimal device depends on the clinical patients’ defect characteristics to accomplish most of the bone distraction requirements. The devices should follow the initial vector plan, with an activation system that allows distraction without patient intervention and either bifocal or multifocal distraction abilities to restore the curvilinear continuity of the newly formed bone when reconstructing the facial contour.

Hence, in our study, only two cases with defect crossing midline have bilateral devices distracted simultaneously docked toward the midline, creating the anterior mandibular curve. The transport unit can be disassembled and removed after the end of distraction, while the plate itself can be retained in place for as long as desired.

For the success of these techniques, it is very important that the transport disc maintains an adequate blood supply. This is important for bone union at the docking site and for a more rapid consolidation. In addition, the transport disc must remain stable and attached to the transport unit, and must have adequate apposition with the distal native bone stump. The distraction device must also have the mechanical properties to hold the transport segment firmly at the docking site, and preferably must be able to apply sustained compression at after docking.

It is important to maintain rigidity of the distracted tissues during the ossification phase. The distraction device typically provides this support for the regenerate. If a period of immobilization is not accomplished, the regenerate will fail to ossify and fibrous tissue will result.

The study was undertaken as an attempt to evaluate the technique of DO and the efficacy of TDO in the reconstruction of mandibular defects following benign and malignant tumors.

The transport disc develops a fibrous or cartilage cap as it is transported. Costantino and Fried-man recommend cleaning the soft tissue by passing an oscillating saw at the docking site to prevent a nonunion and “freshen” the bony surfaces. In our patients, a bone graft was placed at the time of distractor removal in two patients. The grafts were much smaller than would have been required if DO had not been accomplished first. If a bone graft is required after the transport segment has been “docked,” a much smaller quantity of the bone is required. A second reason for distraction is that the soft tissue is expanded before bone grafting, creating a well-defined pocket. This can eliminate the need for adjunctive soft tissue procedures later.

The overall force required for bone transport segment consists of several different load components. All adherent structures of the transporting bone segment such as tendons, fasciae, and muscles generate a force due to the distraction of the soft tissues. Another component of the overall traction force is directly related to the callus and the new forming bone tissue of the regenerate. The tissue reproduction in callus distraction is stimulated by traction, and the process is known as DO.

We also found improved alveolar bone height and attached tissue with distraction in benign tumor compared to the malignant cases, which could be explained due to the availability of soft tissue and less tissue tension.

In patients who are not candidates for more aggressive surgery or prolonged surgical time because of poor general health, TDO is an appropriate primary surgical treatment.

The most challenging aspect of TDO remains to be the achievement of union at the docking site. Various techniques to achieve union at the docking site includes sustained compression, alternate compression-distraction, bone grafting, and adjunctive therapies such as electromagnetic stimulation, low intensity ultrasound, and bone-inducing factors.

Two of the total nine patients required additional bone grafting to fill the gap between the distracted bone and the distal stump. Nonunion was evident in two patients where the additional grafting is done using iliac crest/rib graft. In fact, the distraction device should apply compression forces at the docking sites to achieve fusion with the residual distal skeleton stump, although this is not always possible. The added advantage of TDO is that the needed additional small bone graft is often much smaller than the one required if TDO is not used. Moreover, soft tissue is accordingly expanded. In those two patients, bone grafting material was harvested from the rib or anterioiliac crest, which is a safe and easy donor site. In about seven patients, bone grafting was unnecessary, and direct union between bone poles was achieved.

Overall, TDO success with adequate bone formation was observed in 8 out of 9 patients in our series. Good bone quality was radiographically observed which was taken in series throughout the distraction phase. The most frequent complaint was discomfort by the patients. This was not secondary to pain during distraction; discomfort was reported by patients with an intraoral activator placed in
the mandibular body. This represents interference with the normal surrounding soft tissue such as the cheeks or lips.

Radiographically, hour glass bone deformity was formed in one case, which is the frequent complication of the distraction which is corrected using bone graft.

Some of the reported factors that increase the chances of postoperative infections include immediate reconstruction, reconstruction in an irradiated recipient site, and reconstruction via the intr‑oral route.[30,32] Only one patient had secondary infection secondary to distraction which could be attributed to reduced immune status secondary to aging or immediate reconstruction via the intra‑oral approach with intra‑operative wound contamination by salivary organisms and substrates.

Only one out of the nine cases had recurrence (benign ameloblastoma case) in the follow‑up period, which was corrected by surgical excision and bone grafting. Out of the nine patients, only one patient had plate exposure, which was reconstructed using the local soft tissue flap.

Success of the procedure was adjudged as maintenance of bone continuity and complete consolidation, with the absence of any evidence of infection both on clinical and radiographic examinations. Failure was regarded as loss of the whole graft or part of it which necessitated another reconstructive surgery. The overall success rate of TDO was 88.9% (8 of 9 patients), and surgeons must expect a potential of 10% failure rate in spite of rigorous patient selection and sufficient TDO protocol.

All of our patients either received osseo‑integrated dental implants or will have them placed in the near future. These titanium root‑form implants are important for prosthetic rehabilitation and to maintain the bulk of regenerated tissue and decrease the rate of bone resorption.

CONCLUSION

TDO is of potential benefit for patients with bony defects following tumor ablation at various locations in the mandible. It is useful for treating patients who are unsuitable for more aggressive surgery or prolonged surgical time because of poor general health or for patients in whom primary treatment using a vascularized free‑osseous flap has failed. TDO is a reliable tool to gain sufficient bone following tumor ablation. The ease of distraction and the formation of effective bone is superior in case of benign tumor compared to the malignant tumor, which could be explained mainly because of loss of more soft tissue and tissue tension during distraction. Further, large studies are necessary to conclude the same taking into account of other factors too.

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Conflicts of interest
There are no conflicts of interest.

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