Transport Distraction Osteogenesis in Reconstruction of Condyle: Use of a 3D Model for Vector Planning

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Abstract

Introduction The temporomandibular joint (TMJ) is a complex joint, and it allows bilateral synchronous rotatory and translatory movements. TMJ reconstruction has evolved as an important step in the management of conditions affecting the TMJ like ankylosis, traumatic injuries and congenital deformities. Distraction osteogenesis (DO) is a biological process of forming new bone and adjacent soft tissues by gradual and controlled traction applied on osteotomized bone segments.

Case report Here is a case report of bilateral TMJ ankylosis which was managed effectively by resection of ankylotic mass and reconstruction of TMJ by transport distraction osteogenesis with preoperative vector planning using a 3D printed model.

Conclusion Distraction osteogenesis can be considered as an effective means of condylar reconstruction for an anatomical and functional TMJ with minimal complications. Use of 3D models can help making such complex TMJ reconstruction procedures simpler.

Keywords TMJ reconstruction · Transport distraction osteogenesis · 3D models · Neocondyle regeneration · Vector planning · Additive manufacturing

Introduction

Condylar reconstruction has become an important procedure to restore the anatomy and function of the temporomandibular joint (TMJ). It would also facilitate to maintain the maxillomandibular relationship and also prevent deformities like facial asymmetry, open bite, etc., resulting due to surgical procedures involving the condyle in cases of ankylosis, congenital deformities, traumatic injuries and tumours involving the TMJ [1]. Among the above problems affecting the condyle, TMJ ankylosis is a frequently encountered condition.

TMJ ankylosis is described as a fibrous or bony adhesion between the articulating components of the joint, i.e. the glenoid fossa and the condyle [2]. Ankylosis of the TMJ is a severe disability that results in restricted mouth opening, masticatory difficulty, cosmetic and psychological issues [3]. Treatment of TMJ ankylosis is one of the greatest challenges to the oral and maxillofacial surgeon. Management of TMJ ankylosis mainly includes gap or interposition arthroplasty, joint reconstruction or replacement [4, 5]. If the joint is not reconstructed, it may result in severe functional and cosmetic impairment. Various autogenous and alloplastic condyle reconstruction options have

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been in use since ages. Distraction osteogenesis (DO) is an emerging newer technique to create new bone without the need for bone grafting, therefore obviating any donor site morbidity.

Reconstruction of a complex anatomical and functional joint like TMJ is a highly challenging task. Distraction vector plays an important role in determining the treatment outcome in transport distraction osteogenesis of condyle. Research on distraction osteogenesis for condylar reconstruction till date is limited with only few published reports. Use of 3D models in the field of medicine and dentistry in the recent years has made a wide array of procedures simpler. 3D models in TMJ reconstruction can be very helpful in assessing the extent of deformity, performing mock surgeries, vector and osteotomy planning for DO, patient education and motivation. This article presents a case of TMJ ankylosis which was managed effectively by resection of ankylotic mass, lining of glenoid fossa with temporalis fascia and reconstruction of the condyle by intra oral transport DO with preoperative vector planning on a 3D model.

Case Report

A 19-year-old male patient has reported to us with limitation in mouth opening since 3 years. Patient gave a history of trauma injuries over the limbs and chin at the age of 14. Clinical examination revealed a 0 mm of mouth opening and loss of upper anterior teeth. Radiographic evaluation suggested bilateral TMJ ankylosis.

Acquisition of CT Data and 3D Model Fabrication

A 3D model of the patient was attained using CT scan data. The CT scan data were stored in the form of digital imaging and communication in medicine (DICOM) images, and density of bone information is captured in the Hounsfield units (HU). In this stage, the 2D DICOM images are collated together for creating a 3D model. With the help of medical software like materialize interactive medical image control system (MIMICS), the data were very conveniently converted to stereo lithography (STL) format, which is the required input data for the AM machine. For the current case study, MakerPi M14 FDM machine is used to build the physical model.

Mock Surgery and Vector Planning for DO

Preoperative planning of the resection of ankylotic mass (Fig. 1), the distraction vector planning and osteotomy planning for transport distraction of condyle was done on the model. With the help of AM model, the extent of

Fig. 1 3D model showing ankylotic mass to be resected

Fig. 2 Vector planning on 3D model

ankylotic mass was identified. Mock surgery was done by resecting the ankylotic mass. A transport distraction segment was identified, and the distraction vector was marked. The osteotomy markings were calibrated and noted to simulate the osteotomy in the intra-operative period using predetermined measurements. Distractors were fixed and activated to see the transport segment moving towards the glenoid fossa (Fig. 2).

Surgical Procedure

Under general anaesthesia, using Al Kayat and Bramley preauricular incision bilaterally surgical site was exposed. Kaban's protocol was followed, ankylotic mass was resected, and the glenoid fossa was lined with temporalis fascia and temporalis muscle. Interposition of temporalis muscle and fascia helps in acting as a physical barrier to avoid direct bony contact between the skull base and bony segment and also serves as a cushion to reduce pressure on the reconstructed condyle. A 15-mm vertical line, which is about 10 mm away from the posterior border of the ramus, and a 10-mm horizontal line, which is about 15 mm away from the margin of resection, were outlined on the ramus on right side. This “reverse-L”-shaped outline on the

Fig. 3 Intra-operative picture showing placement of distractor

Fig. 4 Post-operative OPG at the end of distraction phase

mandibular ramus was osteotomized using osteotomes. An “L”-shaped osteotomy was performed on the left side in the similar manner. The distraction devices were mounted in the planned position over the mandibular ramus and fixed (Fig. 3). The activation pins were placed emerging from the lateral side of the mandible. After a latency of 5-day distraction was started at the rate of 1 mm/day in 2 increments, and aggressive physiotherapy was initiated in the immediate first post-operative week. Advancement of the osteotomized bone segment provided the formation of the condylar process. Periodic radiographic evaluation was performed to check for the movement of the transporting segment. After a distraction period of 18 days, the activation was stopped and the distractor was left in place for another 60 days from then for consolidation. At the end of the consolidation period, radiographic evaluation for bone formation at the trailing edge of transport disc with bridging of the defect was done and the distractor was removed. Post-operative radiographic examination (Fig. 4) showed the transported segment near the glenoid fossa with mouth opening of 34 mm.

After 38 months of follow-up patient showed a stable mouth opening of 34 mm without any evidence of complications or secondary deformities.

Discussion

Condylar reconstruction has become a significant aspect in treatment of TMJ afflictions like ankylosis, traumatic injuries and tumours involving the joint. Management of TMJ ankylosis poses a significant challenge to the maxillofacial surgeons with respect to the complex joint anatomy and chances of recurrence and difficulty in attaining the natural joint anatomy and function. Ankylosis is one of the common deformities of the temporomandibular joint.

A 7-step protocol for the treatment of TMJ ankylosis proposed by Kaban et al. [6] includes aggressive resection of the ankylotic mass, ipsilateral coronoidectomy, contralateral coronoidectomy when necessary, lining of the joint with temporalis fascia or cartilage, reconstruction of the ramus with a costochondral graft, rigid fixation of the graft and early mobilization along with aggressive physiotherapy. This protocol was later modified to include DO for reconstruction of ramus condyle unit.

Various autogenous grafts and alloplastic materials are available for condylar reconstruction after resection of the ankylotic mass [7]. Autogenous grafts like costochondral, sternoclavicular, fibular, coronoid and metatarsophalangeal have been in use since many years. However, the unpredictable growth pattern of the autogenous grafts has become a significant point of concern [8, 9]. Alloplastic joint reconstruction has evolved to be a successful option in the past few years. Various alloplastic total joint prostheses available are Kent–Vitek total prosthesis [10, 11], Christensen prosthesis [12, 13], Lorenz prosthesis, TMJ Concepts/Techmedica custom-made total joint prosthesis. Alloplastic TMJ prostheses definitely have a key role in TMJ reconstruction today and in the future.

Treatment of TMJ ankylosis should meet the following requirements [14]:

- Ability to restore the vertical, lateral and protrusive movements of the mandible and an adequate mouth opening.
- Ability to restore and maintain the vertical dimension to obtain an adequate dental occlusion.
- Ability to obtain and maintain facial symmetry during and after the period of development of the patient.
- Ability to avoid the re-ankylosis.

Various treatment modalities have been evolving since ages to meet the above criteria in reconstruction of the condyle as a part of management of TMJ ankylosis. Distraction osteogenesis in formation of neocondyle has emerged as a recent effective means of reconstructing the condyle with near features to the natural condyle [15, 16, 18]. Stucki-McCormick for the first time used transport DO for reconstruction of condyle [17]. The

technique involved making a reverse-*L*-shaped osteotomy to create a transport disc of bone from the ramus of the mandible maintaining an intact periosteum and muscle attachments on the medial side to ensure an intact blood supply [19, 20]. After a latency period of 5 days, the osteotomized bone segment is advanced at a rate of 1.0 mm/day in multiple increments (preferably 0.5 mm/increment) until the advancing end of the transport disc makes contact with the glenoid fossa. During the distraction phase, the activation process is followed closely by serial radiographs to evaluate for the amount of distraction gap created. The distraction device is then held in place for a consolidation period of about 5–6 weeks. The leading edge of the transport disc undergoes remodelling to form a neocondyle [3]. Because the neo condyle is a living bony fragment created by DO, this approach avoids donor site morbidity when compared use of autogenous bone grafts [1].

Studies have also shown formation of an intervening fibrous tissue layer between the ascending edge of transport disc and the glenoid fossa which apparently performed as a pseudodisc [17]. But there are confounding results by various authors regarding the formation of pseudodisc. Added to the neocondyle formation and new joint simulation DO also induces modification of the muscle and soft-tissue balance around the TMJ. Distraction for reconstruction of condyle is known to have beneficial effects on the harmony of the craniofacial complex along with the temporomandibular articulation [3].

In the study by Stucki-McCormick, he reported a stable masticatory function during 20 months of follow-up, with increased mouth opening following reconstruction of condyle by DO [17]. In another study by Dean and Alamillos [21] on three children, the authors reported stable mouth opening after 15–25-month follow-up period. In a study of five patients by Cheung and Lo [18], after 1–2 years of follow-up, the authors have concluded that TMJ ankylosis treated by neocondyle regeneration using DO could achieve a long-term stable outcome.

In an animal study by Zhu et al. [1] in goat model, the biomechanical properties of the neocondyle formed by distraction osteogenesis were compared to a normal condyle. The results of this study demonstrated that the neocondyle created was similar and also denser and stiffer than the control side. This indicates that the neocondyle has sufficient strength to withstand TMJ loading.

Recent advances in the field of reconstructive surgery like the use of 3D models in surgical planning and execution have made even the complex TMJ surgical procedures simpler. Since the introduction of 3D printing by Charles Hull in the early 1980s the field of 3D printing has gone through many improvements [22].

While once rarely done due to imaging and software unavailability as well as cost, it is now emerged as a much easier and economic method with widespread availability. 3D models in TMJ reconstructive surgery can be very helpful in three-dimensional assessment of the pathology or the defect, patient education and motivation, planning and executing mock surgery, reduced surgical labour, etc.

DO is a complex and lengthy procedure requiring close and time-to-time monitoring of the patient. Though it has many advantages, the long course of treatment may result in few complications like pin tract soft-tissue infection, bone infection and psychological problems in having the distractors [23]. The complex anatomy of the TMJ poses a challenge in vector and osteotomy planning in transport distraction for condylar reconstruction.

3D models have been in use in the last few years in TMJ reconstruction surgery in various ways. In our case, a 3D model of the patient was attained using CT scan by means of additive manufacturing method of stereolithography (SLA) which is one of several methods used to create 3D-printed objects. It is a process by which a SLA machine converts liquid plastic into solid objects. In this study we could effectively plan the distraction vector and simulate the same intra-operatively making use of the preoperative 3D models. This has helped us in making the surgical procedure simple and straightforward and attaining a desirable treatment outcome with planned approach towards the problem.

Conclusion

The wide variety of available TMJ reconstructive options reflects that it remains an evolving field. Although there is no gold standard in condylar reconstruction, various techniques have been described in the literature with each having their own merits and demerits. Keeping in view of the ultimate aims in reconstructing a condyle, distraction osteogenesis can be considered as an effective means of condylar reconstruction for an anatomical and functional TMJ with minimal complications. Use of 3D models can help making the complex TMJ reconstruction procedures like transport distraction osteogenesis of condyle simpler and more commonly chosen approach. Ultimately, it is the choice of the surgeon to choose the most suitable treatment plan considering the underlying pathology and the needs of the individual patient.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

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