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A surgical and clinical awareness, guidelines in full joint replacement and orthognathic surgery – A systematic Review

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Abstract

The end stage TMJ (Temporomandibular Joint) disease has a multitude of etiology and pathological processes which diminish the TMJ function and distorts its anatomy. In most of the TMJ anomalies it exists with Dentofacial skeletal abnormality. The optimal management for such end stage TMJ conditions is TJR (Total Joint Replacement) – Alloplastic and concomitant orthognathic surgery which have been conducted in two separate stages. With the new advent technologies, it resulted in adaptation of virtual reality in various surgical fields which has a drastic change in approach and treatment plan. Such improvements had significant impact in the field of Dentofacial deformity or Orthognathic planning which was later adopted to optimize TMJ reconstruction and prosthesis design using virtual design techniques leading to customize Patient Specific Implants (PSI) and surgical guides or templates. Therefore, the multitude of combinations of planning for orthognathic surgery and TMJ replacement facilitated performing the dual procedures concomitantly in one stage. At present, CASS – Computer Assisted Surgical Simulation and 3D printing techniques allows these procedures to be performed virtually in a single surgical step based on fully virtual planning and entirely customizing the surgical procedure. This paper entails on exploring the digital protocol of an end stage TMJ disease with associated Dentofacial deformity, which is managed with customizing all the surgical steps and performed in a single step with patient specific customized surgical guides or templates and Patient

Specific Implants. Thanks to Virtual Surgical Planning (VSP) and Patient fitted osteosynthesis and devices.

Keywords: TMJ, Artherectomy, Condylectomy, Condyloplasty, Surgical Planning, Skeletal Abnormality.

Introduction

TJR - Total Joint Replacement is a clinical procedure for late stage TMJ anomalies and diseases. Certain conventional surgeries for TMJ anomalies such as gap arthroplasty, Artherectomy, high level Condylectomy, Condyloplasty always has a risk of re-ankylosis and recurrence of deformities. In case of esthetic and functional deficit in maxillomandibular region, significantly of the condyle, TJR of the mandible increases the overall quality of life for the patient.

The first TJR procedure was performed in the year 1970 by Christensen R.W., but the procedure was not widely accepted and authorized. In 1990's TMJ replacements with partial alloplastic and silastic compounds led to foreign body reaction and failure of the surgery in Northern America. Later this has led to the use of autogenic grafts for the reconstruction of the temporal fossa and joint components of the TMJ, which showed no signs of reaction and rejection has been in main stream surgery since then.

In 1995, Sonnenburg J and Sonnenburg M modelled a TJR device of titanium condylar component and a polyethylene implant for the temporal fossa. This TJR system of Biomaterials was approved for use in clinical trials by FDA in the same year. In the year 2005, USA officially approved clinical systems for the TJR.

TJR System Component

The conventional FDA approved TMJ TJR system consists of a titanium mandibular condyle component and polyethylene fossa component. This system is a permanent TMJ prosthesis which replaces the total joint and can be designed and customized for any site. TJR prosthesis is of two types – Stock and Custom made. In a recent systematic review and bias adjusted meta-analysis in 2017 on total TJR prosthesis, there is no significant difference noted between stock and custom made TJR systems.

- Stock fit prosthesis
  - Different prefabricated size and shape
  - Modelled over the mean measurement of TMJ
- Custom made: Patient fit (varies with each patient)

Fossa Component: The Fossa component of the TJR system replaces the glenoid fossa and the articular eminence of the joint. The fossa component should have thicker layer to hold and stabilize the condylar component in position and to prevent heterotrophic condylar invasion into the surrounding zone and ectopic positioning. The implant is made up of UHMWPE (Ultra-high molecular-weight polyethylene). The fossa component is fixed using a titanium alloy (Ti-6Al4V) screws of 2mm diameter and emergency screws of 2.3 mm diameter if needed with length variability by segment of 2mm. During Mandibular motion the condylar component slides back and forth on the surface of the implant fossa.

Mandibular component

The Mandibular Component of the TJR system replaces the mandibular condylar process and is made up of Titanium (Ti-6Al-4V). This component is fixed to the ascending ramus of the respective side of the mandible in co-ordination with the glenoid fossa component of the TJR. The component is fixed using screws of 2.5mm diameter and emergency screws of 2.7mm, if needed with length variability by segments of 2mm.

Materials and Methods

A male patient of age 30 years with a provisional diagnosis of right condylar hyperplasia of Type 2B i.e., vertical elongation of condyle and neck with horizontal

exophytic growth of the condyle is included in the study. CT findings also concluded facial asymmetry over the affected side and in accordance with Obwegeser classification, patient had a type III hybrid form.

Patient's clinical history of progressive asymmetry of his right side of the face is noted, documented with clinical photography. He had a right class II occlusion with vertical maxillary excess over right side. The patient had no history of preoperative orthodontics procedure. His facial structure with skeletal and dental soft tissue was studied and evaluated by virtual surgical planning (VSP) software using CT scan. And surgical guidance was fabricated based on the CASS virtually. A combined unilateral TJR surgery with orthognathic surgery as a single stage procedure with the help of VSP and its surgical guides and templates was performed which kindled us to make an elaborate explanation about these beautiful and precise surgical guides.

VSP vs Conventional surgical planning in TJR

Conventional Surgical Planning

Conventional surgical planning of TJR is purely based on cephalometric analysis, prediction tracing, clinical evaluation and dental models from which the optimum surgical outcome is structured with relation to functional, esthetics and harmonious occlusion and oropharyngeal dimensions in coordination with the musculoskeletal outline.

Virtual surgical planning

As the name implies it is a computer simulative surgical procedure planned virtually, which shows the post operative outcome in terms of musculoskeletal occlusal harmony pre-operatively utilizing the computer technology – Computer Assisted Surgical Simulation (CASS).

The use of CASS in TJR helps to skip the traditional steps involving the surgeon to manually fix the mandible to its new final position as it could be done using the stereolithic model with improved accuracy in a limited period of time (Fig 1 and 2). And the need for model articulation is eliminated saving the considerable amount of time required for model surgery and splint fabrication, which are accurately done with the help of CASS using VSP software.

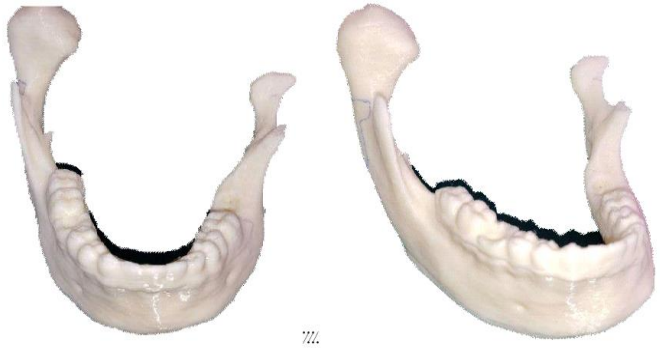

Figure 1: Stereolithic models before CASS procedure in Virtual Surgical Planning

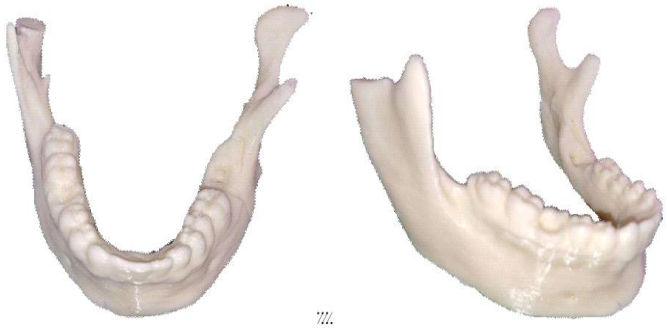

Figure 2: Stereolithic models after CASS procedure in Virtual Surgical Planning

Table 1: Protocol for TJR using VSP

Protocols in traditional TJR	Protocols for TJR using VSP
CT scan	CT scan (1mm overlapping cuts recommended)
Fabrication of stereolithic model	DICOM data processing for CASS projection

Repositioning the models to its final position	CASS aided virtual Dentofacial deformity correction
Condylectomy with recontouring of the fossa and rami if needed	Final positioning with CASS
Model sent for TMJ concepts for prosthetic design, Blue print and wax up	Stereolithic model with final position
Approval for the prosthetic and wax up	Model sent to surgeon for condylectomy and fossa with rami recontouring if needed
Custom fit joint prosthesis construction	Design approved via Internet
Dental Models	Final TMJ prosthesis
Articulation	Maxillary and Mandibular models sent to VSP company
Repositioning and duplication of the changes acquired using stereolithic models	CASS incorporated Intermediate and final splint construction
Intermediate splint fabrication	Models, splints and 3D printout of CASS sent to surgeon

Role of VSP Surgical aids in TJR

CASS of VSP marks its landmark by its high precision in the surgical simulation such as complicated Osteotomies and reconstruction. With computed aided thorough examination of bony and soft tissue architecture, intra operative complications of the neurovascular injuries, skeletal vascular dimensional distortions are assessed and correlated to the surgical procedures making the surgery easy & minimizing the complications. VSP is most preferably used in the planning of orthognathic surgery for its precision. But there's been relatively less evidence for its use in planning condylectomy and TJR. In 2018 Han et al operated a case of hemi mandibular hyperplasia performing condylectomy with orthognathic surgery aided by VSP guides and due to extreme skeletal distortion of the skull base in hyperplasia of the condyle as such, there is a high probability of screw mal-angulation and mal-alignment which may lead to Intracranial mal-positioning and inner-ear damage.

Surgical guides and templates

On the advent of CASS various surgical aids have been developed by the surgeons and applied in variety of fields such as cardiology, neurosurgery, maxillofacial surgeries. Although the uses of CASS in TJR have been reported few, intra operatively it had shown promising and precise results. Pre-operatively the efficacy of these aids were also been assessed by cutting and drilling in stereolithographic models. So the post-surgical outcome is more or less been predicted pre surgically. Hence digital templates and surgical guides designed with VSP allows precise joint positioning in TJR.

Templates and guides for TJR in Condylar Hyperplasia

1. Condylectomy - Ramus template for condylar resection – osteotomy plane of condylar neck
2. Osteotomy plane for Inferior border of Mandible
3. Osteotomy plane for differential maxillary osteotomy
4. Intermediate occlusal Splint
5. Final occlusal Splint
6. Stereolithic pre-operative model
7. Fossa drill guide

Clinical guide

After Virtually assessing the ramus and the condylar anatomic distortion, a template was designed and developed to be adapted to the ascending ramus with fixation screws for the stability of the surgical guide. It was designed in such a way that the bony structures with the guides could be resected without any irregularities and a precise level of osteotomy can be performed. The Condylectomy Ramus template are designed with template fixing holes and orientation holes in co-ordination with the final prosthesis screw holes, and the orientation of the holes are designed in a way to avoid inferior alveolar canal preventing neurovascular injury intraoperatively. (Fig 3)

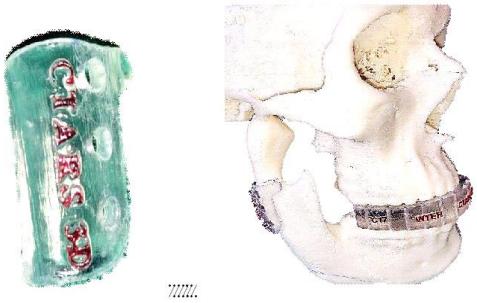

Figure 3: Template for Condylectomy

Osteotomy plane for Inferior border of Mandible / peripheral mandibular osteotomy template

This template is designed in a way so as to be used in co-ordination with maxillary osteotomy template (secondary surgery) for a single stage occlusal correction. It is designed to aid in resecting the abnormal excessive growth of the mandibular lower border in accordance with inferior alveolar canal, hence prevents injury to inferior alveolar nerve and mental nerve canal. It comes with 2 stabilizing screws and 2 maxillary osteotomy splint locking stumps. The level of osteotomy is assessed and developed in a proportional symmetry with the contralateral side with precision to correct the facial asymmetry in terms of hard and soft tissues. The osteotomy plane with the template may sometime differ with patients, either superior or inferior based on their anatomy and esthetic needs. After the orientation of the template, the mandibular border osteotomy is done using No. 703 bur in a linear fashion with not much of anatomic compliances and mimicking the contralateral side. (Fig 4)

Figure 4: Template for Peripheral Mandibular Osteotomy

Maxillary Lefort I osteotomy splint and Surgical Guide

As mentioned before this template is designed to be used in combination with the peripheral mandibular osteotomy templates. The template is designed in accordance with the occlusion in mind. Hence serves as an occlusal splint during osteotomy, the need for fixation of the template is through occlusal orientation of the surgical guide.

It has 3 parts:(Fig 5)

- Occlusal plane
- Two connectors
- Two symmetrical / differential osteotomy planes

Occlusal Plane: It helps in securing the template and surgical plate in position during osteotomy. It consists of locking stumps in case of mandibular osteotomy template is needed, and interdental holes which helps in inter-maxillomandibular fixation during the procedure, superior to the occlusal splint is the le-fort osteotomy plane surgical guides.

The Connectors and Stumps: The maxillary template connectors are bilateral extensions from the occlusal planes which connect the superior maxillary osteotomy plane surgical guide to the occlusal splint. It may also vary in length based on the patient specific need for osteotomy levels.

Osteotomy planes: It is a bilateral osteotomy plane of maxillary osteotomy. The planes are connected to the occlusal splint through the connectors and the aids for the surgical maxillary osteotomy. They may or may not be symmetrical in accordance to each patient (patient specific) depending on the connector length. The maxillary osteotomy planes have 2 osteotomy surfaces which are highly patient specific depending on the amount of differential maxillary osteotomy needed, and therefore each plane and template thickness may vary depending on the need. Hence the thickness or the amount of bone to be resected can be done with more or less approximate incision.

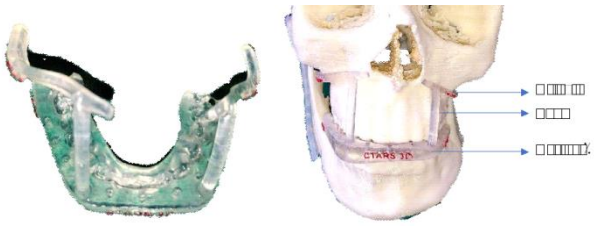

Figure 5: Surgical Guide and Template for Maxillary Lefort I Osteotomy showing

1. Occlusal Plane
2. Two Connectors
3. Differential Osteotomy planes on right and left sides

Total Joint Replacement (TJR)

The TJR component template is composed of two units – (i) fossa template unit and (ii)condylar-ramus template unit. These two units are designed to totally mimic the final prosthesis component, the number of drilling holes, the position of the screw holes area designed exactly identical to the final prosthesis, the structural dimension of the TJR template are developed mirror image to the final TJR component. They are fabricated using the same material as the other surgical guides using 3D printing in the preparation for model surgery. It is essential to perform IMF before the procedure.

Single Stage osteotomy for occlusal correction with CASS / VSP aids

With the advent of concomitant CASS in TJR and simultaneous orthognathic surgery it eliminates the need for two separate surgeries and general anesthesia which leads to decrease in morbidity of patients. After TJR with the intermediate splint positioned, the Lefort I osteotomy with or without a sagittal split osteotomy can be performed using respected surgical guides, the lefort-I osteotomy is done by placing the maxillary osteotomy surgical guide, the manbile & maxillary segments are fixed in position using final splint after placing IMF (Fig 6 and 7). And this computer guided patient customized protocol for TJR with concomitant orthognathic surgery serves as a hybrid single stage procedure providing following advantages similar to Sembronio et al:

- With CASS and VSP eliminates the errors from traditional hybrid approach
- VSP - custom made surgical guides eliminates the surgical error. Hence the need for intermediate and final splints are questionable even though they are used.
- With CASS virtual jaw movements enables the 3D interactive cephalometric analysis of pre and post-surgical jaw movements possible pre-surgically.

Since the surgery is virtually planned and customized for each patient, the surgical sequence is interchangeable in a patient allowing the surgeon to perform procedure according to his preferences (mandible/maxilla/ condylectomy first). Based on the

sterility protocol and to prevent cross contamination of the prosthesis, surgical procedures of the TMJ are performed first in order to exclude the surgical site from the oral cavity.

In conclusion, as a single stage procedure the workflow with VSP, executes the surgical procedure in a customized way by considering the principles of pitch, yaw and roll into the surgery providing a harmonious functional & esthetic balance and psychological wellbeing to the patient, spontaneously after the surgery.

Figure 6: Intermediate Splint

Figure 7: Final Splint

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