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Precision in orthognathic surgery with model surgery and occlusal wafers – An insight

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Abstract
Orthognathic surgeries have become more common in the day-to-day practice. The accuracy of placing the jaws as planned prior to surgery has been of concern for several years now. occlusal wafers have come to the rescue in the recent years. The model surgery procedure has been carried out in the conventional method and with recent introduction of digitization, virtual model surgery and wafer fabrication have been introduced. There have been various modifications in the method of wafer fabrication and also in the wafers itself to make it easier to use. This article draws a summary of the model surgery procedure along with methods of occlusal wafer fabrication and its modifications

Keywords: occlusal wafers, model surgery, occlusal splint

Introduction

Facial aesthetics and proportion are unique characteristics that have a natural way of expression. Orthodontics as a speciality has gained popularity over the years as a result of increased aesthetic demands. The number of patients with skeletal discrepancy has increased. Treatment of the patients with skeletal discrepancy can be broadly divided into categories based on the amount of growth potential remaining. Growth modification can be a major contribution when orthodontists can use the remaining growth to their advantage. Whereas, in situations where the growth is completed, the modalities reduce to either a camouflage treatment or a surgical intervention. As per the studies conducted earlier, the major reasons for refusal of Orthognathic surgery by the patients is generally because of the longer treatment duration, possible pre and post-surgical complications, fear of a surgical treatment and most of all affordability of the cost [1].

The first orthognathic surgery was reported by Hullihen in the year 1849 where he had performed surgery on a patient who reported with a scar from burn in childhood, hence leading to prognathism [2]. The choice of treatment procedure was initially based only on facial appearance (Hullihen, 1849, Angle, 1903 and Blair, 1907). Kostecka (1931), used unarticulated models to evaluate the occlusion. The first history of use of a surgical splint is dated back to 1935 where Wassmund used wax to articulate the models and German silver alloy splint for fixation [3]. Through the years, when the accuracy became a point of concern, Heggie in the year 1987 came up with the idea of using a calibrator similar to vernier calliper to assess the maxillary position during surgery [4].

The concept of surgery has been changing over decades. The use of an anatomical articulator with facebow transfer for bimaxillary osteotomies has become the present trend to achieve accuracy of maxillary position. The use of a single occlusal splint for single jaw surgeries, and both an intermediate and final splint for bi-jaw surgeries is carried out. The diagnosis of the skeletal deformity in all three planes of orientation, and planning the treatment well before-hand is the key to a successful treatment which could be provided by an interdisciplinary team of an Orthodontist and a Surgeon.

Types of Splint

1. **Intermediary Splint:** Used only in Bimaxillary surgery procedures. After the initial procedure of maxillary osteotomy and positioning of the maxilla, the intermediate splint is used for conforming the accurate position of maxilla in all three planes of space. This is followed by placing osteosynthesis screws and fixating the maxilla with the craniofacial complex.
2. **Final Splint:** It is the splint which can be used both peri-operatively and post-operatively. The final splint is used for a final check of the position of the maxillomandibular complex according to the model surgery. Per-operatively it can be used when: there has been incomplete pre-surgical preparation, there is lack of post-operative stability, and when there are uncompensated absent teeth and wedging is a possibility.

Maxilla or Mandible – Which First?

In a classic sequence, usually the sequence follows the repositioning of the maxilla first followed by the mandible. In contrast to this, Lindorf and Steinhauser in the year 1978, attempted in moving both the jaws in bimaxillary osteotomies, the method used in here was moving the mandible forward first. The reason for this was stated that when there was a large mandibular advancement required, if the maxilla was repositioned first, there might be a shift in the final position during maxillomandibular fixation [5].

Hence, this method proposed repositioning the mandible first over a yet to be mobilized maxilla using intermediate splints. The repositioning of the maxilla was done thereafter and the final splints used to place the maxilla in its final

desired position [5]. The reason explained by Taylor *et al* states that the mouth needs to be propped wide open for adequate visualizing when it comes to mandibular osteotomy, and if the maxilla is repositioned prior it might lead to iatrogenic altering of the already repositioned maxilla. If the saggital split is done prior, the maxillary repositioning would not require as much mouth opening and result in a more stable position of the maxilla [6].

Procedure of Model Surgery

Steps of Model Surgery

The procedure starts with the initial diagnosis that is followed by planning of the surgery in every step to assure adequate accuracy. The diagnosis begins with the associated skeletal discrepancy that needs to be localised and the exact region of interest identified. It also involves localising the dental problems associated and the choice of surgery to be either surgery first or surgery intermediate approach involving pre surgical orthodontics followed by the orthognathic surgery and then the post-surgical orthodontics.

The surgery intermediate approach would involve decompensation of the naturally compensated malocclusion, to express it to the fullest potential, followed by a surgical procedure to ideally position the jaws and the teeth in their respective jaws, as well as in relation to each other [7].

The steps involved in the procedure of model surgery are as follows:

1. Making of impressions
2. Study models
3. Face bow transfer
4. Articulation of the models
5. Marking of lines in the articulated models
6. Model surgery
7. Fabrication of Occlusal Splints (intermediate and final)[7]

Making of Impressions

The impressions need to be recorded with alginate or polyvinyl siloxane material as they demand high accuracy. The accuracy of models is of high importance in cases of orthognathic surgery since it might lead to occlusal interferences or discrepancy in occlusal splint fabrication. Inaccurate occlusal splints might lead to difficulty in accurate positioning of the jaws during the surgical procedure.

It is always a better option to take multiple sets of impressions and choose the cast with maximum accuracy for the purpose of model surgery and occlusal wafer fabrication.

Making of Models

The impressions are poured with dental stone in a uniform manner. The stone models are trimmed and it is made sure the model is flat and in line with the occlusal plane. After the trimming is done a basing of the cast of only the study models is done with a total height of 70cms, where the anatomic portion of the model is 2/3rd the artistic portion which would be 1/3rd.

Facebow Transfer

Facebow transfer is usually done to register the three-dimensional relationship of the maxilla to the cranial base to reproduce in the articulator. There is no clear evidence that an accurate model orientation is observed by face bow transfer [5]. The first step is to adapt the bite fork to the maxillary teeth. The facebow is then placed on the ear rods and locked in place along with fixation of the nasion pointer. Then the whole assembly is fitted with the bite fork and tightened [8].

The use of a facebow is important because it helps in placing the maxilla in the exact orientation with the cranial base. This orientation favours and helps in a more accurate process of the orthognathic surgery in both the model and in the surgery table.

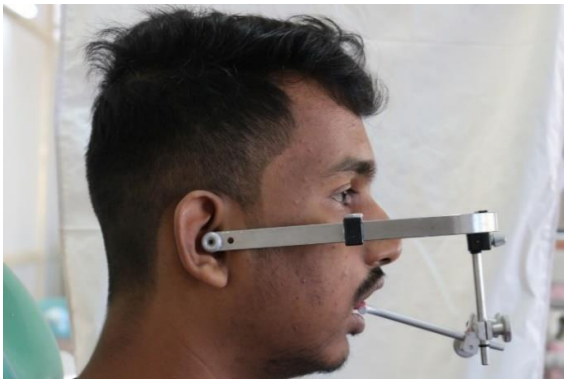

Fig 1: Facebow Transfer to record the orientation of the maxilla.

Fig 2: Facebow Transfer transferred to a Hanau articulator

Articulation of Models

Fig 3: Mounting of maxillary cast with respect to cranial base and mandibular cast with respect to the maxillary cast.

The selection of articulators is the first step. There are three types of articulators - Simple hinge articulator, Semi adjustable and fully adjustable articulators. Simple hinge articulators can be used in single jaw procedures with

movement along only a single plane of space [9].

(For the sake of understanding the model surgery has been depicted in bi-jaw surgery model)

In cases of bi-jaw osteotomies, it is always a better choice to go for a semi adjustable or a fully adjustable articulator. The facebow transfer is generally transferred to these articulators, so that the maxillary orientation is transferred into the respective articulators [9].

Marking of lines in the articulated model

Two set of lines namely vertical and horizontal are usually marked. The vertical lines are used to measure the amount of saggital advancement and the horizontal lines help to move the jaws along their respective occlusal planes during advancement or setback, and also measurement of the movement of the jaws vertically. The horizontal line consists of a single osteotomy cut along the occlusal plane of the respective jaws [9].

The first step involves marking of the vertical lines, along the mesial contact point of the first molar, and mesial contact point of the canines. There is a vertical line also drawn at the midline along both the maxillary and mandibular cast.

Any discrepancies in the dental midline are corrected in the pre surgical orthodontics. Skeletal midline discrepancies are corrected during the surgical procedure by correcting the etry. These lines help in assessing the pre-treatment and post-treatment changes in the molar and canine relationships and the amount of movement.

Model Surgery

After the lines are marked as reference points, the planned surgery is done according to the necessity. If it's a single jaw surgery, the lines are confined to the respective jaw. And in bijaw osteotomies lines are drawn in both the maxillary and mandibular casts. The horizontal lines are marked along the occlusal plane of the respective casts. During the model surgery the jaws are moved according to their respective occlusal planes.

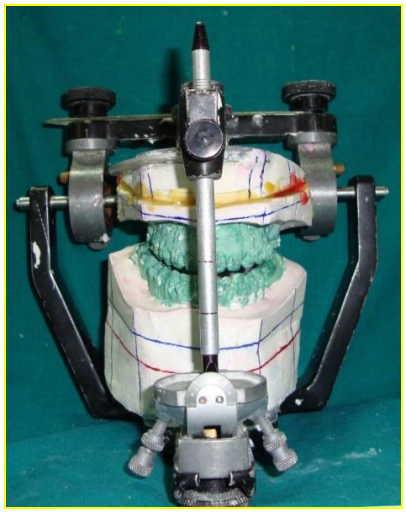

Fig 4: Model Surgery done with the lines drawn. Red lines depict the osteotomy cuts. Maxillary advancement of 6mm carried out and maxillary position stabilised with sticky wax

After the lines are marked, jaws are repositioned by moving along the osteotomy cuts till the desired final position is obtained. When it's a bi-jaw surgery, the maxilla is repositioned first, stabilised with sticky wax followed by positioning the mandible.

Fig 5: Model Surgery done with the lines drawn. Red lines depict the osteotomy cuts. Bilateral Mandibular set back of 8mm done.

Once the jaws are moved to their positions, stabilizing is done with sticky wax. Then the amount of movement of the jaw is measured with the help of the lines marked prior to treatment. Care should be taken especially for the mandible, to move it along the plane of occlusion.

Fabrication of Occlusal Splints

In case of single jaw surgeries, only a final occlusal splint is fabricated. After the model surgery has been completed, separating media is applied. The cold cure monomer and polymer are mixed and in the dough stage and placed on the occlusal surface of the teeth. The articulator is opened and closed multiple times to make the indentations of the teeth from opposing arch.

Fig 6: Fabricated Occlusal splint with cold cure acrylic material.

In case of bi-jaw osteotomies, an intermediate splint is also fabricated. So once the final splint fabrication is completed, the mandibular cast is removed from the articulation and the alternate mandibular cast is attached for fabrication of the intermediate splint. The intermediate splints help the surgeon to perform the movement of the planned surgery step wise. After the maxillary mobilisation, the intermediate splint is placed between the maxillary and mandibular arches and ligated with steel ligatures. This helps in accurate positioning of the maxillary arch before proceeding with the

mandibular osteotomy [10]

Fig 7: Model surgery done with final splints on place.

Intermediate Splints

The alternative names for an intermediate splint are interpositional splint or piggyback splint. The maxilla can be positioned even without the use of a splint, but it should be technically feasible to position the maxilla without the assistance of the mandible. This method of not using a splint is called the Free-hand approach. Over the years various external registration devices like intermediate splints, and the assistance of facebow transfer have been used.

Maxillary morphology is not similar to the contour of the dental arch, making it difficult to depict the surgical osteotomy cuts exactly similar like that done during the model surgery. The maxilla, in engineering terms can be defined by Pitch (occlusal plane angle), Roll (occlusal cant) and Yaw (horizontal arch rotation). These movements are difficult o quantify at surgery because there are no structures to which one can relate the dental arch for comparison purposes.

Using a splint to help position the maxilla, the maxilla not only provides the proper anteroposterior and mediolateral position of the maxilla, but it also provides the proper pitch, roll and yaw. Using the mandible and an intermediate splint to position the maxilla, the surgeon has to only assess the position in vertical dimension to establish the final position of the maxilla. Once the proper vertical dimension is established, the maxilla is corrected in all three planes of space using the intermediate splint and this hence removes the 'guesswork' done by the surgeon in the surgery table.

Precise planning of the orthognathic surgery has to be done and the model surgery to be very accurate so that there is no discrepancy in the maxillary positioning [11].

Why not Intermediate Splints?

Less pre-surgical preparation in the laboratory is one of the major reasons why intermediate splints are being avoided. It takes more than 4mm of facial change for a lay person to identify and detect a change. Therefore, precise surgical positioning of osteotomised can be less vigorously focused on, when the surgeon can give "acceptable" results [11].

Alternative material used for intermediate splint

After the proper positioning of the maxilla and the mandible, the final splint is fabricated. After the final splint is fabricated, the uncut mandibular model is repositioned in the intermediate position. If a segmental maxillary surgery is planned, the final splint is luted with the maxillary cast and polyvinyl siloxane bite registration material is used for preparation of the intermediate splint. The material becomes rigid within 1 minute and is trimmed with a scalpel blade to interdigitate with the dentition/ splint and interferences with soft tissues or orthodontic appliances are removed.[12]

The major advantages of using polyvinylsiloxane bite registration material are:

- Ease of fabrication
- Better accuracy when compared to acrylic splints
- Polyvinylsiloxane material is an extremely dimensionally stable material with negligible compressibility [12].

Virtual Wafer Fabrication

In cases where there is a requirement of movement of both the jaws for surgical repositioning, there is a lot of laboratory procedures involved for accurate positioning of the jaws during a surgical procedure. The excess of manual work needed for laboratory procedures has been of concern during the years, and the possibility of human error is comparatively high. The possibility of errors is usually placement of reference lines, or sectioning of casts, or during final positioning of the maxilla.

3D virtual model surgeries have been recently introduced and have been of great success in the field of Orthodontics. The use of 3D planning for virtual wafer fabrication has made the process of model surgery planning easier and less time consuming with increased accuracy [13].

Procedures for virtual wafer fabrication

Lauren *et al*. proposed the first computer-based design and fabrication of flat-plane and full-coverage occlusal splints with guidance ramps, and made the digital splints commercially available.[13] The steps involved are similar to the manual fabrication of splints. The steps involved in virtual wafer fabrication are similar to that done during model surgery procedure. The recorded impressions are poured with stone and the casts are scanned and 3D virtual dental casts are obtained. These casts are mounted on the 3D virtual articulator using the co-ordinates used during facebow transfer, repositioning of the casts according to the planned STO in 3D virtual articulator, fabricating a 3D virtual wafer and materializing the wafer [14].

The virtual wafer fabrication involves performing the model surgery done on the virtual articulators. The maxilla is accurately positioned using the STO after which the intermediate splint is fabricated using the CAD CAM system. This is converted into a stereolitho graphic file (STL) file and fabrication of the intermediate splint is done. [14] The softwares available for model surgery have graphics designed to simulate the amount of movement required in different planes of space in terms of millimetres. The movements that happen in the three planes of space are:

- In the saggital dimension: advancement/retraction, roll

forward/backward (autorotation)
- In the vertical dimension: impaction/disimpaction (differential or symmetrical), lowering/raising parallel to the occlusal plane.
- In the transverse dimension: rotation to the right/left, translation to the right/left [10].

Designing of the Computer Aided Splint

A blank block of splint that is smooth and standardized for storage in the software are used in the beginning. The various shapes and designs are obtained from this standard form of splint. The blank is also designed to fit majority of the surgical procedures with at thickness of 1.5 mm in the anterior and 4mm in the posterior [10].

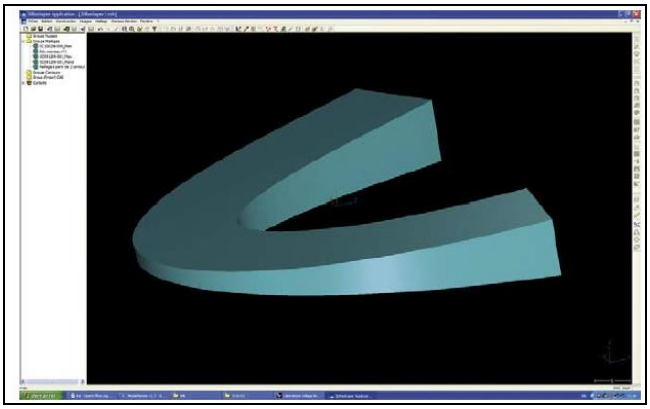

Fig 8: Blank splint which is standardized with a 1.5mm thickness anteriorly and 4mm posteriorly. (Courtesy: Dahan S, Le Gall M, Julié D, Salvadori A. New protocols for the manufacture of surgical splints in surgical-orthodontic treatment. International orthodontics,2011:9(1):42-62.

A negative replica of the models in the blank splint introducing a dentulous splint. This is used with subtraction manufacturing for fabrication of the splint. The method of subtraction has helped in the indentations on the surface of the splint. This procedure is done twice to get the indentations of the splint on both the sides. The result obtained is the image of the intended surgical splint, an intended 3D object to reproduce the occlusion. [10]

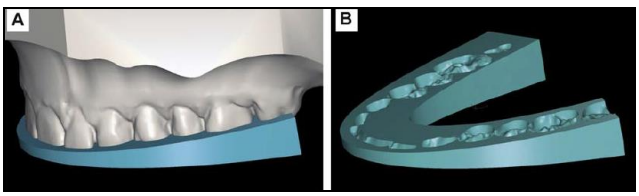

Fig 9: The negative replica used for final hard splint fabrication (Courtesy: Dahan S, Le Gall M, Julié D, Salvadori A. New protocols for the manufacture of surgical splints in surgical-orthodontic treatment. International orthodontics. 2011 Mar 1;9(1):42-62.

The CAD CAM design is transferred into a STL file and transferred to a 3D printer. The 3D object is then split into 120 layers, with 0.3µm in thickness in each layer owing to the accuracy. The final product is then printed out in resin material ready to be used by the surgeon [10].

Fig 10: Final virtual splint available ready for use by the surgeon. (Courtesy: Dahan S, Le Gall M, Julié D, Salvadori A. New protocols for the manufacture of surgical splints in surgical-orthodontic treatment. International orthodontics. 2011 Mar 1;9(1):42-62.

Conclusions

Surgical splints namely occlusal wafers have been a great aid for placing the maxilla and the mandible in their accurate positions during the surgery making it easier for the surgeon to exactly follow the planned surgical position of both the jaws separately as well as with respect to each other. The introduction of CAD CAM into the procedures of model surgery and splint fabrication have increased the accuracy ten-fold. The splint fabrication method has become much simpler and also providing accurate results.

The use of occlusal wafers makes the process of guess work by the surgeon to be reduced and the planned STO being implemented.

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