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DIGITAL ERA IN ORTHOGNATHIC SURGERY

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Abstract:

Due to recent advances in dentistry aiming at improvement of dentoskeletal deformities diagnosis techniques, and ideal management plans that suits patients, it became crucial to obtain as much data as possible from a wide variety of sources. These include cephalograms, dental casts, photographs, records of face bow, complete physical examination, and casts mobility measurement, based on surgical simulation. Moreover, a thorough analysis of the normal method in dental surgeries has concluded that it basically lacks accuracy, has certain biases, and has limited control over movements, especially in translation and rotation.

However, the introduction of three-dimensional imaging techniques has led to significant improvements in this field. Currently, surgeons can get data that is more accurate than using only lateral cephalogram. This significantly improved pre-surgical planning and thus post-surgical outcomes. Recently, several software has been used to provide accurate pre-surgical three-dimensional planning, to allow dentists and surgeons to create a simulation of the surgery and predict outcomes in tissues.

Technicians were recently able to combine three-dimensional CT techniques with laser dentition models to create a digital craniomaxillofacial-dentition model. The use of this model lead to significant improvement in post-surgical outcomes regarding facial symmetry. In fact, the average difference between the pre-surgical design, and the actual post-surgical outcomes is less than two mm. therefore, this digital craniomaxillofacial-dentition model has allowed accurate planning, stimulation of the surgery, and prediction of post-surgical outcomes, leading to significant improvements in orthognathic surgery accuracy, and facial symmetry recovery.

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INTRODUCTION:

Abnormal morphology or volume of the jaw, upper or lower jaw anomalies, along with anomalies in other bones in the face are all parts of dento-maxillofacial deformities. Dento-maxillofacial deformities usually happen as a result of dysplastic changes, and are usually associated with other stomatognathic abnormalities, occlusal abnormalities, and morphological deformities in the face. The treatment of dento-maxillofacial deformities and associated anomalies is usually challenging and requires comlex surgical techniques and combination of orthodontic and orthognathic methods. Universally, orthoganthic surgical approaches are essential in model surgery, and require accurate planning of the dental model before intervening [1].

The location and shape of dento-maxillofacial deformities are usually three-dimensional. They usually appear as jaw structural abnormalities. Traditional modeling in craniofacial approach pays special attention on dental occlusion with no direct reflection on the jaw's mobility. This poses a significant problem regarding facial symmetry. Therefore, improvements of these models were essential to develop more advanced models that consider facial symmetry and can be applied on a wide variety of dento-maxillofacial deformities [1].

The introduction of digital medicine is considered a huge step in recent medicine; using digital technologies, it is possible to design surgeries within a virtual environment that allows for accurate simulation of the surgery, prediction of outcomes, and thus better surgical planning. These sophisticated advantages and features of digital modeling has been dramatically developing and becoming wide spread in orthoganthic surgeries. However, CT reconstruction in digital model surgeries remains to be of low accuracy due to the creation of artifacts by dentition appliances. This setback has led to a significant limitation in the use of digital models. Therefore, a concept of combining three-dimensional CT scanning and dentition model laser scanning was introduced. This concept aims at the establishment of a digital craniomaxillofacial dentition model [2].

ORTHOGNATHIC SURGERIES:

Orthognathic surgeries are usually planned based on the diagnosis and the shape of the deformity and are performed to repair the deformity and restore function. The most common surgery of the maxilla is Le Fort I. Le Fort I surgery basically moves the maxilla in all possible dimensions, and segments it into several pieces (ranging between two and five) to give the ability to match the arch of the mandible. In cases where there is involvement of the zygomatic buttresses and/or the nasal prominence, it is recommended to perform instead, Le Fort II or Le Fort III osteotomies. If the case requires maxillary alveolar segment correction, Wunderer and Schuchardt osteotomies are recommended [4].

Surgeries of the mandible ramus include vertical sub-sigmoid osteotomy and sagittal split osteotomy. These two types are usually done in patients who have jaw asymmetry, or who need jaw set back. Another type of osteotomy (called Hofer osteotomy) is used in patients who have an abnormal angulation of the anterior alveolar segment of the mandible that requires correction. If there is a deformity in prominences of the chin in any direction, or there is hypoplasia, asymmetry, or hyperplasia, it is recommended to perform genioplasty. Surgical approaches are many, and other types are beyond the scope of this paper. Generally, the choice between these approaches is usually done on a case bases, and depends on patient's preferences, surgeon's experience, and the type of the anomaly [5].

PATIENT EVALUATION:

The best step in accurate planning of the surgery, and getting good surgical outcomes, is to obtain an accurate right diagnosis. It is essential to perform a thorough assessment of the patient before taking any further management. Both the surgeon and the orthodontist should be involved in the decision and the assessment process, with continuous discussions between them both, and between them and the patient. After the whole assessment process is done, treatment plan is put to achieve best surgical outcomes.

Proper assessment includes a thorough history that includes demographic characteristics, medical history, dental history, family history, along with any relevant history that may affect management. After obtaining this history, full physical examination should be performed. During later steps of evaluation, articulated dental models are used. It is crucial to understand the social profile and psychological profile of the patient, as this will help reaching a better decision on how to proceed with surgery.

Frontal and Profile Analyses:

Evaluation should be divided into two steps: the frontal analysis and the profile analysis. The frontal analysis is addressed first and means the association between the vertical height and the facial width. Generally, the average of the height to width ratio is about 1.3:1, and 1.35:1 in women, and men, respectively. Some individuals have short facial types (also called square faces). This subgroup of patients

can have class II vertical deficiency of the maxilla, along with hypertrophy of the masteries. On the other hand, some individuals may have long thin faces. These individuals can have narrow noses, anterior open bites, VME, and/or a high palatal vault. To analyze transverse facial proportions, physicians usually use the 'rule of fifth' methods, which divides the face equally into 5 parts [1].

To assess facial asymmetry, dentists usually draw an imaginary line between the glabella, nose tip, philtrum center, and soft tissue pogonion. This assessment should also extend to assess balance of the face, cheeks, prominences of the zygomatic bone, and eyes levels. The relationship on the vertical axis is usually examined by dividing the face into lower, middle, and upper parts. It is important to evaluate soft tissues and skeletons in details, especially when it comes to symmetry [4].

The second analysis is the profile view, which is somewhat similar to the frontal view, regarding dividing the face into lower, middle, and upper parts. However, in this analysis, it is important to pay more attention to cheeks, prominences of the lip, nose, the naso-labial angle, the prominence of the chin, and the labial-mental fold [4].

Lateral Cephalometric Analysis:

Previously, and before the introduction of three-dimensional imaging techniques, the gold standard was to perform a lateral cephalometric analysis. lateral cephalometric analysis was preferred as it helped evaluating both the soft tissues, and bones, and provided thorough description of special landmarks. It also compared between these landmarks with regarding the distances and the angulations and calculated average numbers. Therefore, lateral cephalometric analysis has been considered to be a very useful method to detect problems and assess severity of deformities. However, lateral cephalometric analysis still has several limitations. For example, in patients who have anatomical variations in the location of the deformity, the use of lateral cephalometric analysis may lead to inaccurate results, because it measures landmarks based on the normal anatomy. Another limitation is the inability to separately analyze right skull and left skull, because it depends on two-dimensional techniques. On the other hand, a three-dimensional image is able to provide a separate analysis of each side. This is of special importance in cases where asymmetry is present. Therefore, when using lateral cephalometric analysis, it is important for both the dentist and surgeon to avoid making decisions on a single finding [3].

PROTOCOL FOR 3D ORTHOGNATHIC:

The single most important goal of orthoganthic surgeries is the production of a harmonious occlusion, and the recovery of facial appearance. This is achieved by restoring the right position of jaw bones and teeth. Because of recent advances in surgical techniques, patients have been having higher expectations of post-surgical outcomes, making it more important to plan surgery carefully and accurately, and to target a safe operation that actives patients' expectations. Recent three-dimensional modalities and associated softwares that are easy to use, have allowed dentists to provide better surgical plans with more favorable outcomes. Recently, the use of cone beam CT scanning has been increasing due to the ability of this technique to give three-dimensional information of hard tissues as well as soft tissues, using a relatively low dose of radiation, when compared to other radiological modalities. Another advantage of cone beam CT scanning is the ability to capture soft tissues with patients in the upright position. This helps significantly when performing simulation of the surgery [3].

To detect a three-dimensional image of the face, a three-dimensional stereophotogrammetrical is used. This stereophotogrammetrical camera will capture six two-dimensional images simultaneously. Of these six images, four are grey-scale, and the other two are fully colored. Then, the camera will use these six images to generate a single three-dimensional image of the face, by projecting a polygon pattern. All this process is done while the patient's head is in the natural upright positions and with having eyes opened. The result of cone beam CT scanning is an accurate three-dimensional digital image of the patient's face [4].

3D AUGMENTED OR COMPOSITE MODEL:

When performing a normal CT imaging, medal fillings and brackets lead to the generation of artifacts in the resulting image, thus causing misleading results when trying to visualize the interocclusal relationship. To provide a three-dimensional skull model, with clear details of the dental surfaces, several modalities have been developed. With the use of two separate three-dimensional techniques, physicians are able to obtain a three-dimensional dental model. These two techniques are the surface acquisition systems (including probe scanning and laser surface scanning), and techniques of volumetric imaging (like CT scanning). In some advances cases, we may also use another technique called rapid-prototyping to produce a three-dimensional stereolithographic model. These models can be used to perform surgery later [3].

DIGITAL COPY OF THE PATIENT:

Usually, the DICOM format is used to export copies of cone beam CT scanning data. This format segments skin surfaces and the skull by thresholding. Resulting three-dimensional images show textured soft tissue surfaces, and augmented dentition. This digital copy of the patient will be later used for the accurate planning and simulation of the surgery [3].

COMPUTER PLANNING SOFTWARE:

Several software and programs are available for dentists and surgeons to do the required orthognathic workup. These programs will help reach a correct accurate diagnosis, plan proper surgery, and improve surgical outcomes.

3D Cephalometric Analysis:

As we previously mentioned, limitations of the classic lateral cephalometric analysis include the inability of identification of variations in anatomical landmarks into a med-sagittal plane. This is of special importance when a patient has facial asymmetry. On the other hand, when using a three-dimensional model of the skull, the location of the landmarks is more obvious. An increasing trend in this field, is to perform three-dimensional cephalometric analysis on normal individuals and in large numbers to be able to provide accurate references that will help in making the diagnosis [3].

Virtual Surgery:

Using a three-dimensional model, a virtual surgery can be performed allowing the visualization of possible mobility of bones, and identifying any possible problem that can occur during the real surgery. Using this virtual model, different possibilities of surgical approaches could be tried until the surgeon finds the ideal surgical approach that is associated with the best outcomes, shortest time in the surgery, and lowest number of obstacles and complications [3].

CAD/CAM:

To further prevent errors in the classic surgical model, computer-aided design/computer-aided manufacturing (CAD/CAM) technology have been used to produce surgical splints that will lead to better outcomes. In this case, a Nemoceph 3D-OS software (Software Nemotec SL, Madrid, Spain) is used on a patient who has craniofacial microsomia to test the feasibility of three-dimensional planning, the precision of it, and the ability of this model to predict post-surgical outcomes [6,7].

These three-dimensional pictures can be used to aid surgeons before performing Le Ford osteotomies and BSSO line. Conventional plan and physical examination were performed for the maxilla, while a semi-automatic approach was used in the mandible to be able to simulate the correct intercuspation of teeth. Then, a three-dimensional post-surgical model was produced to predict the outcomes. To achieve better visualization, measurement, and analysis of facial asymmetries, and to provide a reconstruction template, the mirror imaging technique could be used [8].

CONCLUSION:

In comparison to the classic planning of orthognathic surgeries, modern three-dimensional visualization has many advantages. It is challenging to simulate an operation on a normal dental cast, especially when the surgery is complicated or involves both jaws. Even when it is possible, this simulation is usually inaccurate and leads to several errors in estimations. Therefore, the use of these newer techniques have allowed a more accurate replication and simulation of the actual surgery, along with the ability to give more access to the patients' anatomy in a better quality. This will increase the rate of detecting deformities that a classic two-dimensional image will not detect. In addition, these techniques will allow to perform several simulations with applying alternative surgical options, different types of osteotomies, and different possible bone movements, allowing a better choice of the surgical approach. This is not possible using normal dental casts [9].

However, these new techniques still have their limitations that include the absence of a single technique that is able to accurately detect the facial skeleton, soft tissues, and dentition in the full quality. Instead, each of these is captured separately. In addition, the used program in clinical settings is not able to visualize soft tissues and provide accurate simulation of them. Some newer software has been released to overcome this problem using morphing programs. However, these newer programs may not be able to provide accurate results as they have not been validated yet [10].

Further studies are still needed to develop and improve three-dimensional imaging acquisition techniques, and software associated with them to provide better pre-surgical simulations and predict outcomes more accurately [11].

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