Virtual Planning in Orthognathic Surgery

Planificación Virtual en la Cirugía Ortognática

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SUMMARY: Recent advances in software and hardware technologies have greatly contributed to the treatment of dentofacial deformities through virtual planning in orthognathic surgery. Computed tomography and scanning models have significantly improved the results of both planning and execution of orthognathic surgeries. This study aims to conduct a literature review on virtual planning to reach a more reliable and predictable protocol in which surgeons and orthodontists can rely to make more accurate and predictable plans. As a result, we have observed that, although there is some uncertainty the execution of the virtual planning, we consider that the results are very encouraging and reliable.

KEY WORDS: Orthognathic surgery; Virtual planning.

INTRODUCTION

Over the past years orthognathic surgery has proved to be a valuable tool for the correction of dentofacial deformities. According to Hammoudeh *et al*. (2015), it is estimated that, in the United States alone, more than 1.5 million subjects have undergone orthognathic surgery.

Technological advances over the last 15 years have considerably contributed to the development of such surgical modality. The evolution of tomographic images and the development of software to assist treatment planning were critical to this advance.

Undoubtedly, we are experiencing an unprecedented moment for the diagnosis and treatment planning of dentofacial deformities. Nowadays, the main concerns involving subjects with such deformities include, in addition to facial harmony and occlusal stability, airway concerns, and joint stability. The benefits drawn from this evolution process directly affect subjects, leading to more predictable and reliable results.

From the surgeon and the orthodontist point of view, all these changes have increased the demand for results. Fortunately, modern technology has provided us with an accurate and undoubtedly efficient tool - the virtual planning.

The virtual surgical planning uses computer graphics to enhance results predictability, standardize technique, and improve communication between subject and professional.

Alike any new technology or technique, it is important to establish guidelines and protocols so that the best results can be obtained to benefit both subjects and professionals.

Therefore, the objective of this work was to review the literature in order to find an efficient protocol to achieve the best virtual planning outcome.

Virtual planning in orthognathic surgery. Relevant articles and protocols established and published in the

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literature were reviewed and the reality of virtual planning in orthognathic surgery was adapted, taking into consideration the scenario of buco-maxillofacial and orthodontic surgery in Brazil.

To simplify understanding and methodology, the entire process of virtual planning in orthognathic surgery was established and divided into different processes that include: Clinical and image diagnosis; 3D image acquisition; movement planning and virtual surgery; splints and surgery.

Since the early twentieth century, buco-maxillofacial surgery, not yet formally established as a modality, tries to take its first steps towards the treatment of deformities (Levine *et al*., 2012). Historically, the earliest descriptions concerning orthognathic surgery date back to 1906 when a case of surgical treatment of prognathism was described at the University of Washington (Hausamen, 2001).

The bases of the orthognathic surgery itself were established after studies by Obwergeser on sagittal osteotomies, and Bell on maxillary vascularization (Hammoudeh *et al*.). After that, technological advances regarding equipment and conducts have stood out, leading to a swift progression in planning and surgical procedures (Xia *et al*., 2011).

According to Van Sickels & Richardson (1996) the use of steel wire instead of rigid fixation plates have brought a major breakthrough in orthognathic surgery. The advancement in materials has led to a number of technical developments that resulted in improved stability of the cases operated (Brasileiro, 2009; Sato *et al*., 2010).

Another important change in the execution and safety of treatments occurred as the piezosurgery technique become more popular. The use of motors with vibration, not friction, to perform osteotomies, reduced morbidity in orthognathic surgery, and provided benefits related to the reduction of edema and paresthesias associated with surgical procedures (Pappalardo & Guarnieri, 2014).

However, the most significant change in recent years in orthognathic surgery may be the development of imaging, software, andhardware capable to provide more accurate and predictable planning than unadjustable articulators and conventional surgeries.

Before the new 3D approach, the traditional method was-and still is-used, consisting of a properly assembled semi-adjustable articulator and cephalometric analysis based on radiographs for treatment planning. According to Moreira & Leal (2013), plaster models and radiographs are limited to a certain extent and distorted throughout their preparation, which impairs the accuracy of measurements, particularly in cases involving facial asymmetry.

Clinical and imaging diagnosis. Despite the emergence of technological innovations, clinical diagnosis remains paramount to the diagnosis and planning of any case. The treatment plan for cases of dentofacial deformity correction requires, in addition to clinical examination, radiographs, photographs and even videos for complementary diagnosis (Bianchi *et al*., 2010).

Imaging exams commonly used for traditional orthognathic surgery planning involve panoramic radiography and x-rays (Gateno *et al*., 2003b).

The major problem is that photographs and radiographic images two-dimensional (2D), whereas clinical examination is three dimensional (3D).

This may be one of the first signs of diagnostic divergence to reflect throughout the planning and execution of the case (Martínez *et al*., 2013).

Therefore, for a more accurate treatment plan, it is important to observe the subject through three-dimensional aspects both clinically and with the aid of computed tomography. Thus, we will have a prediction of both hard and soft tissues (Bianchi *et al*.).

Scanning models and 3D images acquisition. According to Plooij *et al*. (2011) and Azeredo *et al*. (2013), the acquisition of tomographic images can be obtained through multislice tomographs and Cone Bean tomographs in DICOM files. However, multislice scanners produce the best image definitions and are, therefore, the ones of choice, especially for soft tissue plans.

Another important factor to be observed regarding image acquisition for surgical planning is the reduced quality of images of the dental surfaces obtained from tomography. Scanned images of the teeth are necessary to compensate for this problem. For accuracy purposes, these should be superimposed to the CT (Plooij *et al*.).

This problem led researchers (Gateno *et al.*, 2003a) to develop methods to superimpose images of the teeth obtained through tomography with images of the teeth obtained through the scanning of models. Gateno *et al.* (2003a) used fiducial markers to facilitate the overlap of images. Thus, it is possible to accurately use tomography images of the teeth and of soft and hard tissues. This is known as composite skull.

However, for the images obtained by the composite skull to adequately represent the deformity of the subject, it is important to avoid differences between the positioning of the teeth in position of centric relation (CR), in which most surgical cases are planned, and the position in which the subject will perform the tomographic exam (Sant`Ana *et al.*, 2006). A possible solution to this problem is a bite guide made by the surgeon to be used by the subject at the time of the CT scan.

Another concern regards obtaining the natural head position and the fact that the subject performs the multislice tomography in the supine position whereas natural position is standing upright. The position of the composite skull obtained on the CT scan must, therefore, be transported to the natural head position (HNP). According to Freire-Maia *et al.* (2005), the natural head position is the most suitable for orthodontic and surgical diagnosis and planning, and corresponds to a standardized and reproducible position with the head in upright posture and eyes focused on a distant point at eye level.

Movement planning and virtual surgery. After obtaining the well positioned composite skull, faithfully representing the evaluated subject, it is necessary to perform the surgery on a virtual model.

According to Aboul-Hosn Centenero & Hernández-Alfaro (2012) there are currently dozens of software solutions for virtual planning in orthognathic surgery, with their own advantages, disadvantages and peculiarities. The point in common is that, regardless of the software, the surgeon must have the ability and knowledge to interact with the images and files and extract the information and planning necessary to carry out the case.

Virtual planning software allows for the planning of osteotomies exactly as the ones to be performed on the subject. It is also the moment when craniometric points are marked. At this point, the surgeon can evaluate and inspect diverse anatomical surfaces such as nasal septum, maxillary sinus, condyles etc. and plan for any surgical alteration caused by anatomical variations observed (Zinser *et al.*, 2013).
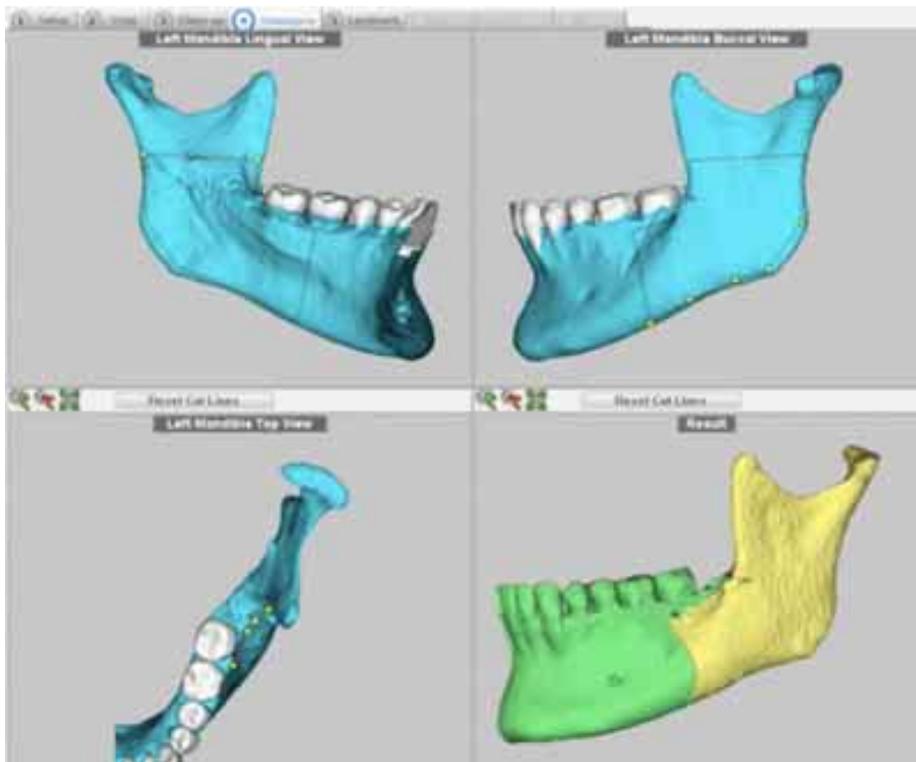

Fig. 1. Image of mandibular osteotomies planned with Dolphin Imaging Software (version 11.8; Dolphin Imaging and Management Solutions, Chatsworth, CA).
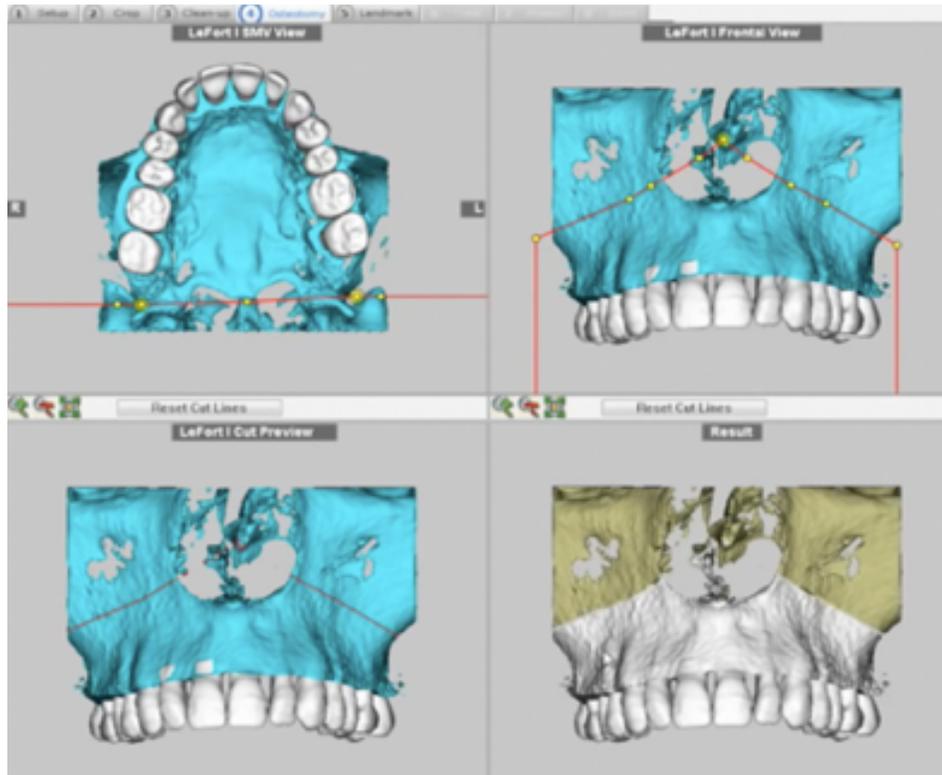
Fig. 2. Image of maxillary osteotomies planned with Dolphin Imaging Software (version 11.8; Dolphin Imaging and Management Solutions, Chatsworth, CA).

With the plan obtained through clinical and imaging examination in place, the surgeon will perform the necessary course of action based outcomes planned by the team and expected by the subject. According to Bianchi *et al*., this will allow for a reproducible plan and, consequently, safety for surgeon, orthodontist and subject.

A major contribution provided by CT images and planning software is a more accurate evaluation of the subject's airway. According to Becker *et al*. (2012) maxilla and mandible movements significantly influence the airway volume of the subject. Therefore, should be considered in this phase of planning (Fig. 2).

Splint Fabrication. Surgical splints bring planning and execution of the surgical case together. According to Swennen *et al*. (2009), splints fabricated from software files bring much more precision to surgery.

Although fairly accurate, splints still have some limitations. First, the material used must be approved from a biosafety standpoint. Another main problem is that they still require wear and tear to remove interference, especially in the bundles.

In Brazil, there are several companies that currently print the splint or surgical guide at an increasingly lower cost.

Such surgical guides are usually printed on 3D printers in our country, but they can also be milled. The latter have the disadvantage of presenting a higher final cost (Aboul-Hosn Centenero & Hernández-Alfaro).

Surgery. Detailed measurements of the anatomical relationship with vital structures can be performed by the software itself. Such preoperative analyzes and measurements guarantee to the buco-maxillofacial surgeon, through 3D information, the reduction of surgical time and minimization of risks and complications inherent to the surgery (Moreira & Leal). The fact that it is a precise and much more predictable procedure than conventional planning and surgery is possibly the major advantage of using virtual orthognathic surgery planning.

In 2016, Resnick *et al*. published a study comparing the surgical time with 3D planning and 2D planning and came to the conclusion that 3D virtual planning is faster and cheaper than 2D planning.
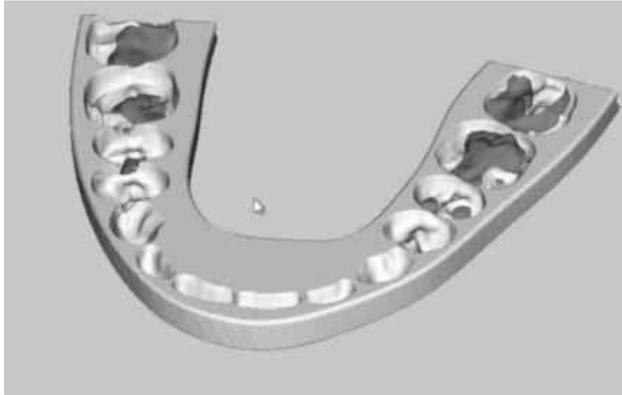
Fig. 3. Image of virtual surgical guide preview.

Fig. 4. Image of printed virtual surgical guide.

DISCUSSION

This study intends to review the literature regarding virtual planning in orthognathic surgery. The works evaluated show that virtual planning is a set of techniques with extremely positive results regarding the improvement of predictability, stability and safety of subject. Although its results are encouraging, there are controversial points that need to be addressed.

One of the first issues that arise in the discussion of virtual planning implementation, concerns the lack of knowledge or absence of studies that solidify the 3D cephalometry.

Martinez *et al.*, in a comparative study of 2D and 3D plans in subjects undergoing orthognathic surgery concluded that although there were gaps in 3D planning, it was still more accurate than 2D surgical planning. Another problem is the poor quality of the images obtained for the virtual planning.

Although it is possible to perform virtual orthognathic surgery from cone bean scans, the images obtained may present a lower resolution. According to Azeredo *et al.* care should be taken when interpreting images obtained through cone bean tomography since there may be discrepancies in relation to the images obtained through multislice tomographs.

According to most authors, it is important to observe the natural positioning of the head during preoperative photographs and tomographies (Freire-Maia *et al.*). For these authors, an inaccurate positioning can generate a false diagnosis of the subject's deformity and, consequently, the wrong planning.

In Brazil, and most countries, virtual planning is performed by the surgeon and a laboratory that can (depending on the surgeon's willingness and intimacy with software and hardware), scan templates, print surgical splints, and assemble the composite skull. This process is, undoubtedly, responsible for the time reduction in surgical planning when compared to the conventional planning mentioned by some authors such as Resnick *et al.* (2016).

Another point that can cause the surgeon to outsource the assembly process of the composite skull and delegate a few steps of surgical planning is the cost of software and hardware.

In Brazil, the cost of software alone can reach ten thousand dollars. It is certainly a limiting factor for the development of such technique in this country.

CONCLUSION

After reviewing the literature regarding virtual planning in orthognathic surgery and considering the evolution of the process in recent years, there is no doubt that it is a planning technique that contributes to the care of subjects with dentofacial deformities.

However, in addition to the need for further studies to deepen knowledge in 3D cephalometrics, for example, the growth of virtual planning and excellence of planning will certainly require investments in two main areas: cost reduction of the software and hardware required for planning, and creation of trusted protocols for more predictable planning. Thus, there will be improvement in the safety of surgical procedures, in addition to more satisfied subjects and surgeons.

RESUMEN: Los recientes avances en las tecnologías de software y hardware han contribuido en gran medida al tratamiento de las deformidades dentofaciales a través de la planificación virtual en cirugía ortognática. Los modelos de tomografía computarizada y exploración han mejorado significativamente los resultados tanto de la planificación como de la ejecución de cirugías ortognáticas. Este estudio tiene como objetivo llevar a cabo una revisión de la literatura sobre la planificación virtual para llegar a un protocolo más confiable y predecible en el que los cirujanos y ortodoncistas pueden confiar para hacer planes más precisos y predecibles. Como resultado, hemos observado que, aunque existe cierta incertidumbre en la ejecución de la planificación virtual, consideramos que los resultados son muy alentadores y confiables.

PALABRAS CLAVE: Cirugía ortognática; Planificación virtual.

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