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Thematic Article

The Evolution of Surgical Planning in Orthognathic Surgery

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Abstract

Orthognathic Surgery is considered the gold-standard treatment to correct dento-facial deformities. Since the first procedure in the 19th century, a plethora of techniques were developed and modified.

Virtual planning arises as an interesting tool to provide additional visualization, clarifying the procedure and give instruments to perform a precise surgical procedure. In conjunction with patient-matched implants, the surgeons have in their hands the best solution to provide the more precise result to the patients.

The purpose of this article is to review the literature regarding different types of devices related to an orthognathic surgery, regarding traditional and new tools.

Keywords: *Orthognathic Surgery; Virtual Planning; Patient-Matched Devices; 3d Printing; Additive Manufacturing*

Abbreviations

VSP: Virtual Surgical Planning; CASS: Computer-Assisted Surgical Simulation

Introduction

Orthognathic surgery emerged as a technical procedure to correct dento-skeletal deformities, correcting both esthetical and functional alterations, which includes occlusal, respiratory and articular abnormalities. The history of orthognathic surgery arises from the middle of 19th century, when Hullinen [1] first published a case of bony surgery to correct a facial deformity.

Since then, numerous surgical modifications emerges, bringing the possibility to correct bone abnormalities, adding accuracy to the final result with pre-surgical planning, culminating in the actual state-of-the-art protocol, which combines virtual planning and patient-matched devices using powerful software and additive manufacturing technologies. The purpose of this article is to show the actual state of the virtual planning in orthognathic surgery, comparing with traditional techniques.

Review of Literature

Originally, maxillofacial surgeons simply perform osteotomies and fix the bone segments into the desired position without any type of reference apparatus. With the advent of model surgery, first proposed by Angle [2], some advances occurred, however, the antiquate protocol was considered obsolete for some authors, who found inconsistencies and high amount of deviations from the proposed treatment and the final result in the real patient [3]. Ellis and Tsang., *et al.* propose some variations on the actual model surgery procedure [4,5], nonetheless the steps to prepare the model surgery remains the same as a decades ago, as showed below:

1. Mold the patient for dental casts;
2. Face-bow transfer;
3. Mount on the articulator;
4. Double-check the mounting comparing to patient's mouth;
5. Perform the model surgery based on previous facial and cephalometric analysis;
6. Manufacturing the splints.

All these steps, in different ranges, have distortions or inaccuracies, leading the surgeon into imprecise results as showed by Ellis., *et al* [4].

Above are described the evolutionary steps into what today we can consider the state-of-the-art in planning and executing an orthognathic surgery.

Splints e Virtual Surgical Planning (VSP)

Okumura., *et al.* [6] were the first authors to publish the possibility of use three-dimensional computed tomography in adjunct to scanned dental cast for pre-orthognathic surgery planning and simultaneously permit occlusal and morphological evaluation, specifically for bone interferences and anatomical landmarks.

Evolving on that aspect, Xia JJ., *et al.* [7], publish a scope for what was published after and consider the first step into the modern era of VSP creating the CASS (computer-assisted surgical simulation) protocol [8], particularized years later [9,10]. This protocol provides very accurate results but requires complex apparatus to replicate. Other authors, thinking on simplification, stated different methods to achieve accurate results using, for example, lasers to replicate the natural head position [11], instead of an extra-oral gyroscope or suggesting semi-automated voxel registration for pre and post-surgical comparison for accuracy evaluation [12].

One of the major concerns regarding the application of the VSP on daily basis is the cost, especially related to the initial expenses related to software and hardware implementation, but thinking on global costs, both for the surgeon and the biological costs for the patient are minimized as related by some authors [13,14]. These authors describe the time and costs saved by the surgeon compared to traditional methods of pre-surgical planning, fact corroborated by Steinhuber., *et al* [15].

In figure 1, it's possible to identify different stages on surgical planning in a orthognathic surgery.

Figure 1: *Initial, Intermediate and Final position in an orthognathic case.*

In terms of accuracy, the literature is clear to provide information regarding the precision of the VSP compared to traditional methods [16,17], especially for asymmetric cases [18], showing exceptional results.

Positioning and cutting guides

Cutting paths can be precisely defined in the three-dimensional environment, avoiding important anatomical structures as nerves, vessels or tooth roots for example (Figure 2).

Figure 2: *Anatomical models representing important structures.*

These guides are intended to replicate the exactly planned path and transfer into the real patient, providing optimal osteotomy lines, with safety margins in a case of a tumor or the desired cutting line in a case of an orthognathic surgery (Figure 4).

Additionally, positioning guides can be used as repositioning tools for the jaws final positions. Innumerous authors published different methods for transferring this planning into the surgical field [19,20]. The main disadvantages for this technique are the bulky guides, requiring additional dissection and consequentially more edema and longer paresthesia.

Fixation devices

To fixate the jaws into the final position, the surgeon can evolve from the traditional methods, bending the plates during the surgical procedure, following the movements provided by the splints and/or positioning guides, to a pre-bent system, that can be provided in two ways. Regular off-the-shelf plates that could be molded into the patient anatomy provided by an anatomical model [21] (Figure 3) or by a patient-specific plate made exclusively to the patient [22] (Figure 4).

Figure 3: *Bended plates using an anatomical model as reference.*

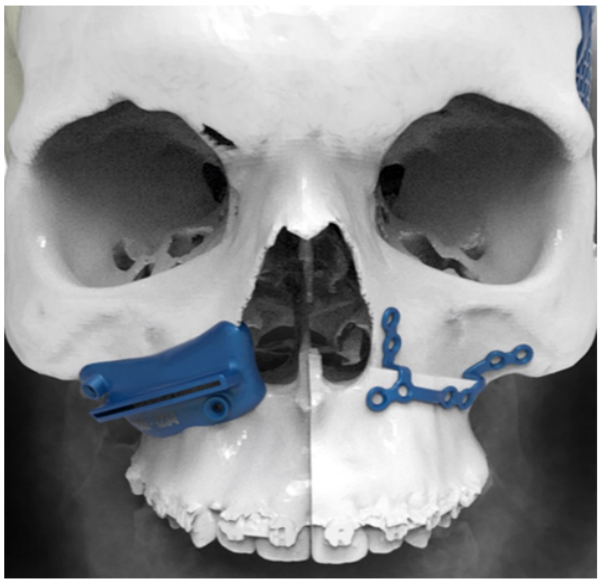

Figure 4: *Patient-specific cutting guide and patient-specific implant.*

Both methods above provide precisely fixation to the jaws into the final position, but the pre-bent plates on the anatomical model requires additional work, with the disadvantage to produce stress areas on the plate steps.

As showed by Heufelder., *et al.* [23] and Suojanen., *et al.* [24], patient-specific implants for orthognathic surgery, in conjunction to drilling guides, provide excellent stability and previsibility.

Modern softwares used to design this type of systems can provide additional information like optimal bone thickness areas (Figure 5) where the screws theoretically can be more stable, avoiding thin areas and providing the possibility to control plate curvatures precisely.

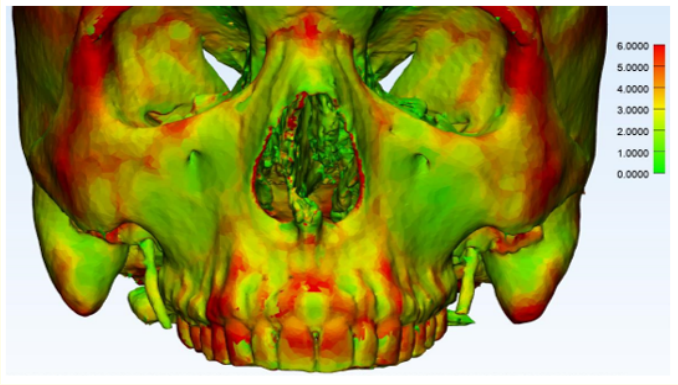

Figure 5: *Thickness map, showing in red thicker areas to insert screws.*

Conclusion

The era of virtual planning is evolving each day, providing predictability and accuracy to surgeons and patients. There are some aspects still under development, with promising results. More studies are necessary regarding different manufacturing techniques, materials and clinical randomized studies, specially related to mandibular positioning.

Conflict of Interest

There is no conflict of interest.

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