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Sagittal Discrepancies of Intraoperative Results between 2D and 3D Planning in Orthognathic Surgery: A Series of 44 Cases

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ABSTRACT
Pre-surgical planning in orthognathic surgery is a process of vital importance for obtaining satisfactory results for both the clinician and the patient. There are different planning methods, among which 3D software is one of the most important. These allow precise observation of the movements of bone and soft tissue structures, which until recently could not be predicted. Despite its advantages, many specialists continue to plan using the 2D method. The aim of this paper is to present the discrepancies between 2D and 3D preoperative planning and the intraoperative results of 44 patients undergoing bimaxillary orthognathic surgery and, together with this, to expose the variables that possibly influence the occurrence of these differences.

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Introduction
Bimaxillary orthognathic surgery is a surgical tool that aims to treat dentofacial deformities by repositioning the maxillomandibular complex in a functional and aesthetic manner [1,2]. The success of this surgery depends both on the surgical technique and also on thorough and accurate preoperative planning [1,2].

For many years, orthognathic surgery planning was performed by 2-dimensional hard and soft tissue analysis, including photographs, radiographs and cephalometric analysis [2,3]. To evaluate the three-dimensional details of the occlusion, it was also common to perform a study of plaster cast models brought into occlusion through a facebow articulator set-up.

Despite being a method widely used by specialists, this two-dimensional planning provides limited information on the skeletal anomalies that patients may present [2-4].

Currently, 3D virtual surgical planning has established itself as an excellent alternative for guiding orthognathic surgery to the required magnitude and direction of hard and soft tissue movements [5,6]. In addition, these new technologies allow the fabrication of occlusal splints using three-dimensional (3D) impressions, which provide greater accuracy [6]. This virtual approach has many advantages over conventional surgical planning, including the freedom to analyse skeletal movements and anatomical repairs in 3 dimensions, the possibility of verifying areas of bone contact and/or collision, and the expression in soft tissue of movements at the maxillomandibular bases [1].

On the other hand, it allows the creation of stereolithographic models that enable surgeons to accurately approach surgical procedures and the pre-fabrication of cutting guides and rigid internal fixation devices [3]. Despite these advantages, 3D procedures can be complex to perform, and could lead to errors or discrepancies in the positioning of the jaws at the time of surgery [3]. The literature describes a discrepancy range of less than or equal to 2 mm as acceptable differences between the different 3D computer programmes and the intraoperative results of skeletal movements.

The aim of this paper is to present the experience of 44 clinical cases of orthognathic surgery operated on in 2022, in which there were discrepancies between the 2D and 3D plan and the intraoperative results. The variables of age, gender, type of planning for orthognathic surgery, computer programs used and magnitude of the discrepancies in the operated cases were evaluated. As a complement, a bibliographic review of the variables that may influence the difference between these skeletal movements was carried out.

Case Series

Methodology

A retrospective case series study of 44 patients undergoing bimaxillary orthognathic surgery with joint 2D and 3D planning, independent of the skeletal anomaly they presented, was carried out. The patients were evaluated and underwent surgery in private practice in 2022 in the city of Santiago, Chile. The medical records, epidemiological data, preoperative planning and intraoperative results of all patients included in the study were reviewed. An Excel® spreadsheet was used for data analysis, tabulation and comparison. For all cases, pre and intraoperative discrepancies were calculated and averaged (Table 1 and 2).

Two main programmes were used to carry out the 3D planning; these were the Dolphin and Nemoceph software. The 2D planning was carried out using two methods: manual planning by means of cephalometry performed on acetate sheets with Delaire cephalometry and manual STO (Surgical treatment objetives). The 2D and 3D pre-surgical planning was performed by two experienced maxillofacial surgeons, who were also in charge of performing the surgeries and measuring the post-surgical results and discrepancies. Regardless of the type of programme and pre-planning, the need for mentoplasty was decided intraoperatively for each case when necessary.

Results

100% of the patients included in this study underwent bimaxillary orthognathic surgery to compensate for their skeletal anomaly. In all the cases analysed, 2D and 3D preoperative planning was carried out jointly, and patients of both sexes were included in the analysis, with 66% of the total being predominantly female. Patients were between 18 and 45 years of age, with a predominant age range of 18 to 31 years. The decision to perform a mentoplasty was taken intraoperatively and was actually performed in 30% of the cases. Maxillary segmentation of the OLF1 was necessary in only 9 patients. The variables described above are listed in Table 1.

Table 1: Results obtained for the Variables Analyzed in a Total of 44 Patients undergoing Bimaxillary Orthognathic Surgery with 2D and 3D Pre-Surgical Planning

Variable		Percentage% (n)
Sex	Female	66% (n=29)
	Male	34% (n=15)
Age Range (13-year interval, done for convenience)	18 to 31 years old	84% (n=37)
	32 to 45 years old	16% (n=7)
3D Planning Software	Dolphin	52% (n=23)
	Nemoceph	48% (n=21)
Bimaxillar Orthognathic Surgery	With mentoplasty	30% (n=13)
	Without mentoplasty	70% (n=31)
Need for Jaw Segmentation in OLF 1	Yes	20% (n=9)
	No	80% (n=35)

All patients studied (n=44) had discrepancies between preoperative planning and postoperative results. The analysis developed divides the magnitude of the discrepancies between 2D and 3D planning into three groups; less than or equal to 2 mm, between 2 to 5 mm and greater than 5 mm. Considering the OLF1 and OSRMB osteotomies, it should be noted that OLF1 osteotomies present discrepancies of less than or equal to 2 mm. In the case of OSRMB, the highest percentage of patients had discrepancies of 2 to 5 mm. The details of the results obtained are described in Table 2.

Table 2: Ranges of Discrepancies obtained (mm) between Preoperative Planning and Intraoperative Results of Bimaxillary Orthognathic Surgery divided into: Le Fort 1 Osteotomy (OLF1) and Sagittal Bilateral Mandibular Branch Sagittal Osteotomy (OSRB) in a Total of 44 Operated Patients

Type of Pre-Surgical Planning	Osteotomy performed	Pre- and Post-Operative Discrepancy Ranges	Percentage of Patients
2D + 3D (n=44)	OLF1	< ó = 2mm	60% (n=26)
		2-5 mm	38% (n=17)
		> 5 mm	2% (n=1)
	OSRB	< ó = 2 mm	30% (n=13)
		2-5 mm	60% (n=26)
		> 5 mm	10% (n=5)

Discussion

Virtual surgical planning and 3D printing of surgical splints have become the gold standard for orthognathic surgery, offering new possibilities to visualise and plan the relationship between dental arches and adjacent bone structures in a virtual model [2]. There are articles studying the fidelity of virtual planning, describing a value of up to 2 mm as an acceptable discrepancy [7,8]. In the present work, different findings are reported when analysing in detail the postoperative results obtained in 44 cases performed with bimaxillary orthognathic surgery. For the Le Fort 1 osteotomy (OLF1), 40% of the discrepancies exceeded 2 mm in the sagittal direction; on the other hand, in the case of sagittal branch osteotomy (OSRMB), it was found that 70% of the differences between planning and postoperative results exceeded 2 mm in the sagittal direction. The authors agree that these percentages can be interpreted as excessively high, considering that the planning was performed using 2 different methodologies, however the results obtained could be explained by a combination of factors experienced both pre- and intraoperatively.

Among the relevant factors to evaluate in order to avoid major discrepancies, we believe that in preoperative planning it is essential to determine a standard positioning at the time of imaging examinations, either Cone Beam Computed Tomography (CBCT) where the patient is standing or Computed Axial Tomography (CAT) with the patient lying down. This determines changes in the orientation of the temporomandibular joints when imaging with condyles in fossa, and there may be differences between patients even with the same type of CT scan.

In the case of Cone Beam scans, there may be differences between operators when taking these scans with respect to the natural position of the head (PNC), so it must be ensured that when the scan is taken, the condyles are in physiological position, placed in the glenoid cavity, as a position different from this will consequently affect surgical planning and in the case of CT scans there may be significant differences in the positioning of the patient's head in dorsal decubitus [8,9].

On the other hand, one of the factors influencing discrepancies is condylar settling during surgery, as this significantly affects mandibular positioning and is a source of intraoperative inaccuracy [10]. Insufficient seating of the condylar segments could lead to unintentional changes in the surgical plan, especially in the anteroposterior and mediolateral direction [10]. This factor is also considered by De Riu et al, who describe a mandibular underprojection probably associated with imperfect condylar seating and suggest that virtual planning cannot exempt the treating surgeon from constant intraoperative monitoring, comparing planned and actual results in real time [9]. On the other hand, the possible existence of a difference between the condylar rotation axis established by the software used and the patient's actual condylar rotation axis could lead to discrepancies in mandibular positions and movements [7,9]. One method to verify joint position in surgery is intraoperative CT which can be useful in general, but when the learning curve in mandibular fixation is developed, failures at this stage are rare and the implied costs and additional radiation to the patient are not justified.
Another important factor is the positioning of the surgical splints, because if this does not have an adequate engagement by means of a good intermaxillary fixation technique, it can generate occlusal discrepancies that would alter the postoperative result, causing differences in the 3 senses of space [10].

Finally, it is important to note that caution should be exercised when deciding to operate on the mandible first, as all of the above factors could transfer discrepancies to the maxilla.

Taking these variables into account, emphasis should be placed on respecting surgical protocols and plans to avoid major discrepancies, which could lead to intraoperative and postoperative complications. A thorough knowledge of the variables in the planning phase is essential to achieve optimal surgical results.

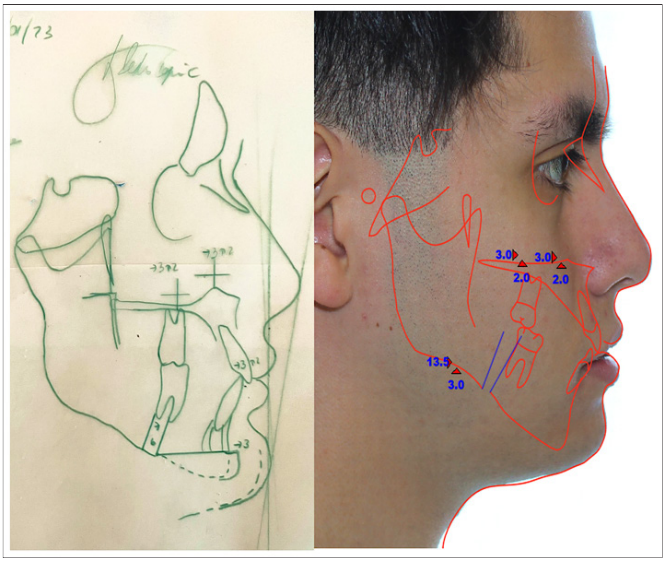

Figure 1: 2D Manual and Virtual VTO with a 3mm Maxillary Advancement and a 2mm Impaction. OSRM of 7mm

Figure 2: Pre and Post-Operative Image of a Patient undergoing Bimaxillary Orthognathic Surgery.

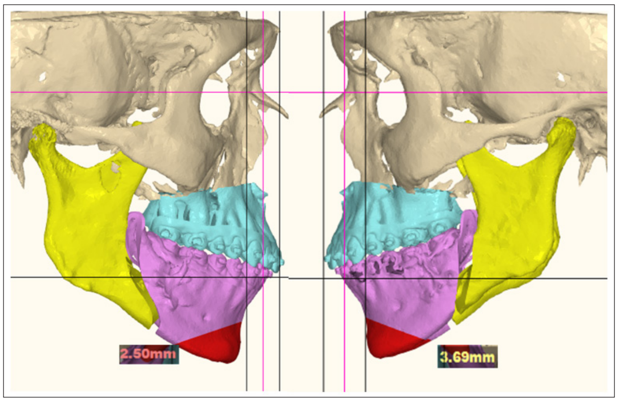

Figure 3: 3D Virtual Planning with NemoCeph Software, Demonstrating Maxillary Advancement of 3mm with Impaction of 2mm. Right OSRM of 2.5mm and left OSRM of 3.69mm

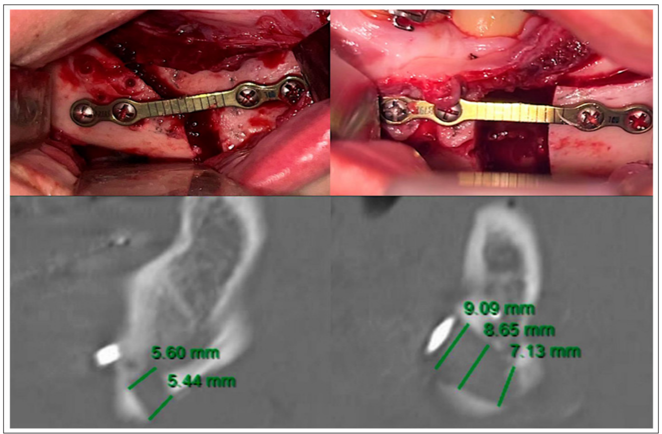

Figure 4: Intraoperative Images. Post-Surgical CT Scan, Showing Right OSRM of 5.6mm and Left OSRM of 9mm

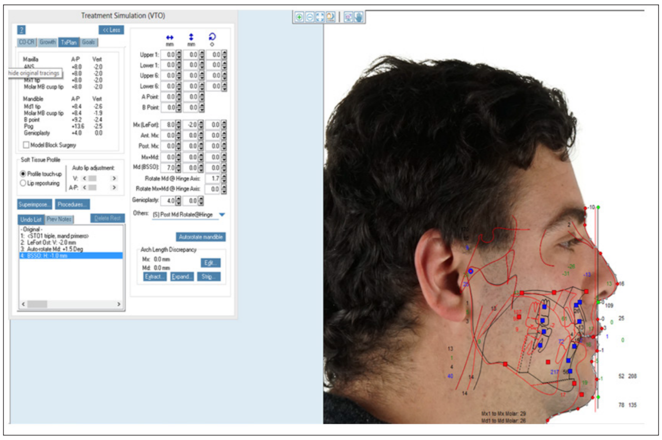

Figure 5: 2D VTO with 8mm Maxillary Advancement Planning with 2mm Anteroposterior Impaction and 8mm OSRM Advancement

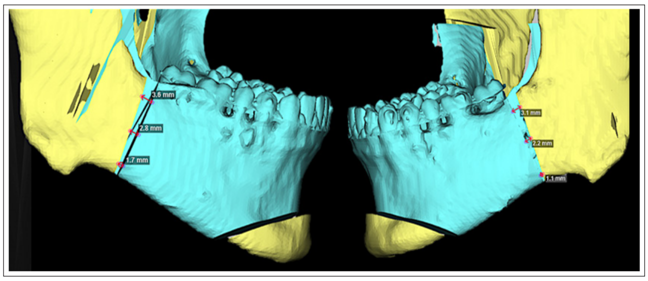

Figure 6: 3D Virtual Planning with Dolphin Software, Demonstrating the Right OSRM of 1.7mm and Left OSRM of 1.1mm

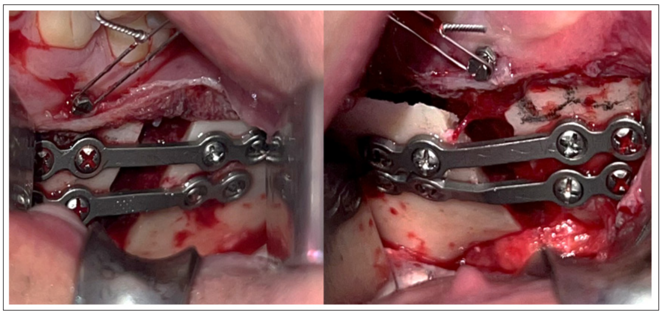

Figure 7: Intraoperative Images. An 8mm GAP is seen on the Right Side and 6mm on the Left Side

Conclusion

A number of variables should be taken into account when planning and performing bimaxillary orthognathic surgery, as any error can cause significant variability between the virtual results obtained preoperatively and the actual intra- and postoperative results. The pre- and post-operative variation of maxillomandibular skeletal movements is multifactorial and could be attributed to the positioning of the head and condyles when performing preoperative CBCT or CT, as well as being related to skull base positioning, orientation of the head with respect to the true horizontal and the CNP at the time of pre-operative imaging examinations. Special attention should be paid to the reproduction of mandibular movements in the virtual software, as this could generate an anterior mandibular rotation versus the intraoperative movement involving posterior and superior stabilisation of the mandibular branches.

On the other hand, it should be borne in mind that the decision to operate on the maxilla or mandible first is extremely important, as a change in the fixation movements implies that the jaws will change position with respect to the initial plan, which is why it is convenient and necessary for the surgeon to continuously verify intraoperatively the effective establishment of the desired maxillomandibular position. Furthermore, it is suggested that in cases of possible errors or doubts, especially in the case of inexperienced specialists, an intraoperative imaging examination should be carried out to rectify any discrepancies that may arise, so that they can be corrected in the same surgical act and the patient can be spared the need for a new operation.

Declarations

Conflict of Interest: The authors declare that the research was carried out in the absence of any commercial or financial relationship that could be interpreted as a potential conflict of interest.

Ethics: The use of the clinical cases with their respective images is supported by the informed consent signed by the patients.

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