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Retrospective study of predictability in virtual surgical planning in linear and angular maxillary movements after orthognathic surgery in malocclusion Class II and III patients. A retrospective study – Part I

Estudio retrospectivo de la predictabilidad de la planificación quirúrgica virtual en movimientos maxilares lineares y angulares después de cirugía ortognática em pacientes Clase II y Clase III. Parte I

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ABSTRACT: A retrospective study was developed to find the Virtual Surgical Planning (VSP) predictability in maxillary movements after orthognathic surgery. Linear and angular measurements were done in malocclusion class II and III patients through face and skull Computed Tomography (CT) with dental scan (called Compound Skull), using surgical planning, comparing with postoperative CT with at least 6 months. Eight patients participated of the study. The results to the simulated and real movements of maxillary points were compared, calculating their linear and angular differences. The cephalometric analysis were done using the Proplan software (Materialise Proplan CMF, São Paulo, Brazil). Eight measurements were done and evaluated through of the t test, Bland-Altman, Wilcoxon and the Dahlberg error, in addition to being evaluated by clinically acceptable bias (+/- 2mm). In the total, 3 differences were statistically significant (anterior facial height, HFP/ULM, HFP/UI). The VSP seems to be a precise and reproducible method as a way of elaborating treatments, reliably transferred to the patient through surgical guides. Although the three differences were statistically significant, when clinical measurements compared with them, none gave clinically significant.

KEY WORDS: Orthognathic surgery, malocclusion, facial asymmetry.

INTRODUCTION

The planning to the orthognathic surgery begun with Downs, in 1951, through the tele radiography analysis in lateral view. The image acquisition technology advances allowed add protocols to use the 3D image in Oral and Maxillofacial Surgery. Firstly, Virtual Surgical Planning (VSP) was implemented and made a safer surgery predictability.

The orthognathic surgery success depends of the surgical technique and the surgical planning. The VSP, combine with surgery made with computer, have been research object. It englobe various forms of planning and surgical execution, that improve advances systems of image generations, software analysis, virtual planning, prototyping technology, robotics and image orientation systems (Stokbro *et al*., 2014).

The surgical planning is created from a anatomic reconstruction, that may be study to development and try different types of treatment. The VSP appears to be an accurate and reproducible method for planning the surgical treatment of maxilla and mandible repositioning (Stokbro *et al*., 2014). It is performed through a composite skull model from Computerized Tomography (CT) of face and 3D scan of teeth, obtained a 3D virtual model more close from reality (Mazzoni *et al*., 2010; Schendel & Jacobson, 2009; Swennen *et al*., 2009). Thus, the VSP aims to choose the most favorable treatment plan for facial proportions associated with an occlusal correction to obtain an adequate functional and aesthetic result (Bell, 2011).

Bone interferences, need of bone grafts or facial recontour to gain symmetry can be visualize in VSP. The VSP allows cost reduction due the surgical time decrease and complications (Baker *et al*., 2012).

The analogical strategy use the articulator, plaster models and cephalometric analysis in radiography. Being that plaster models and radiographies suffer distortions and limitations, the measurements precision were limited, particularly in cases with facial asymmetries (Stokbro *et al*., 2014).

Unfortunately, in a conventional planning mistakes can add in the occlusal plane and can lead to treatment planning errors. Besides that, others mistakes can occur, as articulator mounting, facial arch register, wax bite register and changes in Natural Head Position (NHP) (Gateno *et al*., 2003).

The VSP offer advantages as different movements reproduction of maxilla and mandible; can be used to diagnosis in 3D model, makes available the dental arch relationship and bone structures, help in the correct centric relation from temporomandibular joints, enables idea of soft tissues changed in post operative and transfer every planning to the operate room through the surgical guides (Hsu *et al*., 2013; Centenero & Hernández-Alfaro, 2012; Xia *et al*., 2007). The success of the orthognathic surgery is related to the precision of surgical planning. The differences into VSP and surgical results when they were lower than 2 mm, were not clinically significant (Stokbro *et al*., 2014; Haas *et al*., 2015). The aim of this research is to evaluate the VSP precision and predictability in cases of class II and III malocclusion.

MATERIAL AND METHOD

The VSP have been used to orthognathic surgery routinely in HFC Healthy Hospital, in Piracicaba, São Paulo Brazil, since 2017. A retrospective study was performed in a group of 8 patients (4 male and 4 female). Six patients presented Angle class II and 2 Angle class III. They were treated with orthognathic surgery planned with the same 3D protocol from 2017 January to 2019 November. This research was approved by College São Leopoldo Mandic Ethics Committee and follow the STROBE declaration regarding the design of observational studies.

To be include in the research, the patients were submitted to bimaxillary orthognathic surgery with orthodontic treatment previously. Every surgeries were planned in the same software and based in the images from 3D Proplan (Materialise Proplan CMF, São Paulo, Brazil).

Were excluded patients with monomaxillary orthognathic surgery, surgery first model, and with previous trauma on facial bones, tumors, cleft lip or another strategy of orthognathic surgery.

The same surgical team planned the orthognathic surgeries. The facial skeleton was digitally recreated using Digital Imaging and Communications in Medicine (DICOM) from preoperative CT. The cuts were 0.6 mm of thickness in axial, coronal and sagittal axis. Teeth scan were performed after the installation of hooks and saved in STL format. The orthognathic surgery was planned through 3D cephalometric measurements and facial analysis. By the software, were obtained the composite skull and they were under NHP using a sequency of facial pictures. Then, the scan images were superimposed with the CT.

The Le Fort I and mandibular sagittal osteotomies were drawn. When necessary, the segmentation osteotomies were designed as well. The maxilla and mandible were moved to finals positions, with aim to create facial harmony in the 3 dimensions (Xia *et al*., 2015). The results were transferred to patients during the surgery by the surgical guides, printed through Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) system, by Moonray printer, using photopolymerizable resin.

The same team performed the surgical procedures. The frontal and lateral cephalometries virtual views were obtained from 3D planning and compared to define the movements in maxilla using the cranial bones as landmark. The surgical movements were measured to compare the pre and post-operative cephalometries using superimposition.

A new CT was obtained at least 6 months after the surgery to perform the analysis. The results by simulation and by surgical procedure were compare and the differences calculated in linear and angular measurements.

Were realized a descriptive and exploratory analyzes of measurement in linear and angular data (Tables I, II and III) on VSP and post-operative CT (Fig. 1 to 8). Analyzed the systematic and aleatory errors by t-paired test, Dalberg error and Bland and Altman Methodology.

In the analysis, difference between surgical plan and the post operative result less than in 2 mm in linear measurements, and less than 4 degrees in angular measurements are considerate clinically with no significance (Stokbro *et al*., 2014; Tng *et al*., 1994; Donatsky *et al*., 1997; Padwa *et al*., 1997; Kaipatur & Flores-Mir, 2009; Xia *et al*., 2009; Shehab *et al*., 2013; Zhang *et al*., 2016; Swennen, 2017).

Table I. Linear Measurements.

LINEAR MEASURE	ABREVIATION	DEFINITION
Anterior Facial Height	AFH	Distance between the cephalometric points Nasion (N - most anterior
Horizontal Frankfurt	HFP/ UI	Distance between the Frankfurt horizontal plane (which passes
Horizontal Frankfurt	HFP/URM	Distance between the Frankfurt horizontal plane and the mesiobuccal
Horizontal Frankfurt	PHF/ULM	Distance between the Frankfurt horizontal plane and the mesiobuccal
Coronal Plane / Ponit A	Coronal/A	Distance from the Coronal Plane (vertical plane passing through point
Coronal Plane / Upper	Coronal/UI	Distância do Plano Coronal e a parte incisal do elemento 11

Linear measures, in lateral norm, analyzed. Acronym for abbreviation and definition of each measure. * Measurements taken on the left side.

Table II. Linear measures in frontal view.

LINEAR MEASURE	ABREVIATION	DEFINITION
Midline / Upper Incisor	M/UI	Maxillary midline deviation

Linear measures, in frontal norm, analyzed. Acronym for abbreviation and definition of each measure.

Table III. Angular measurements in right lateral norm.

ANGULAR MEASURE	ABREVIATION	DEFINITION
Maxilla Occlusal Plane / Horizontal Frankfurt Plane	MOP/HFP	Angle formed between the occlusal plane of the maxilla passing through the incisal part ofe lement 11 and the occlusal part of element 46 and the Frankfurt horizontal plane

Angular measures analyzed. Acronym for abbreviation and definition of each measure.

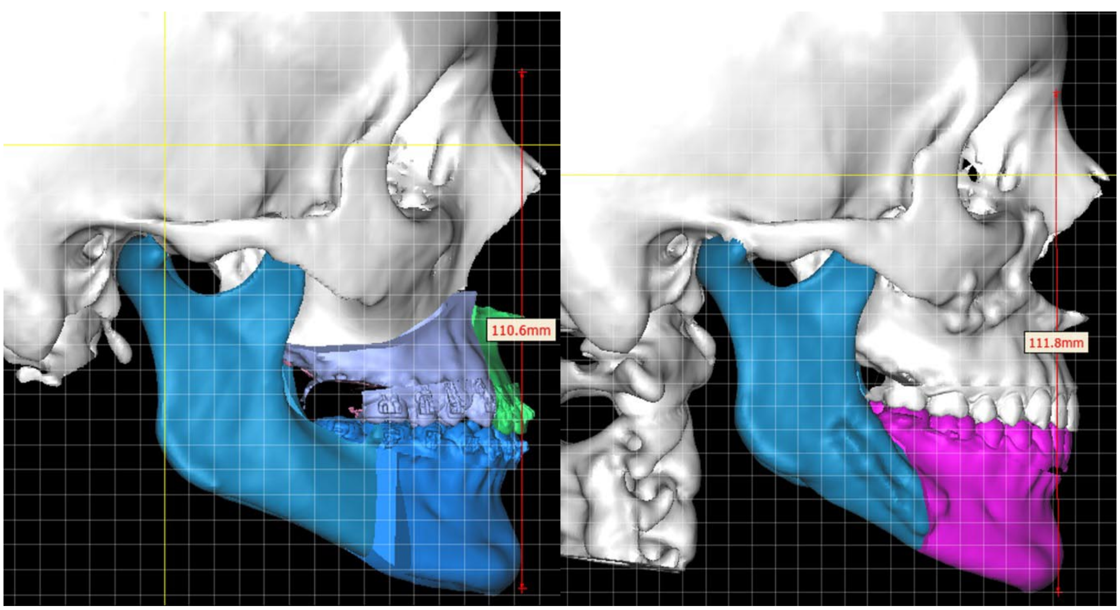

Fig. 1. Measurements of anterior facial height preoperatively (110.6 mm) and postoperatively (111,8 mm).

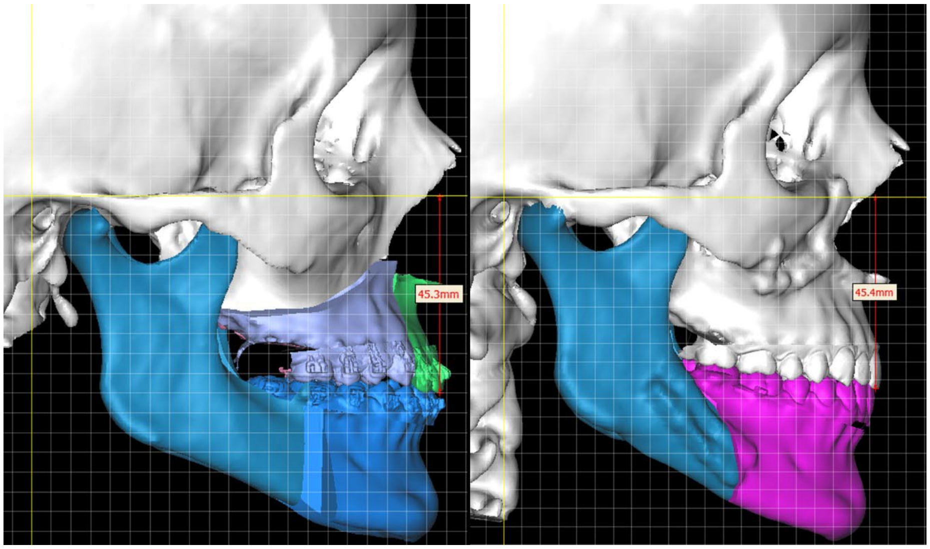

Fig. 2. Measurements from the Frankfurt Horizontal Plane to the Upper Incisor preoperatively (45.3 mm) and postoperatively (45.4 mm).

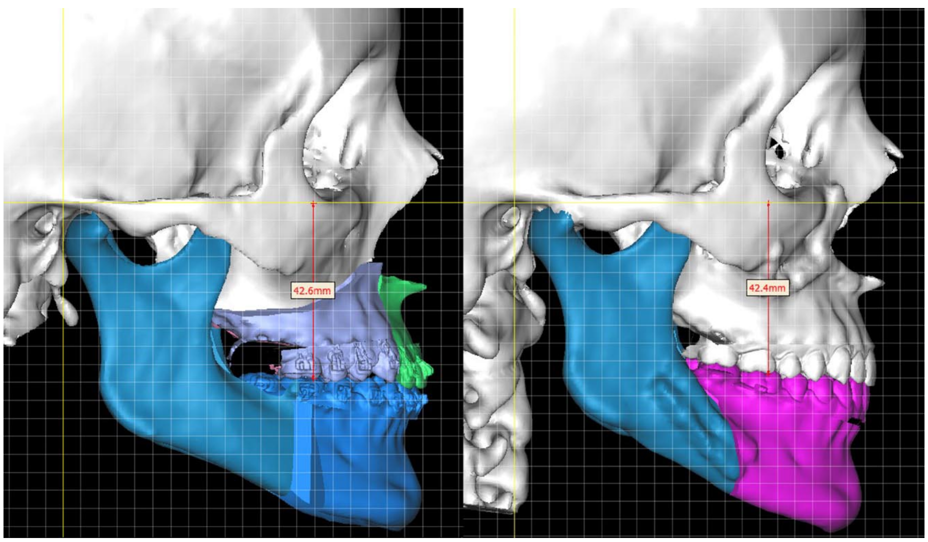

Fig. 3. measurements in the Horizontal Plane from Frankfurt to the Upper Right Molar preoperatively (42.6 mm) and postoperatively (42.4 mm).

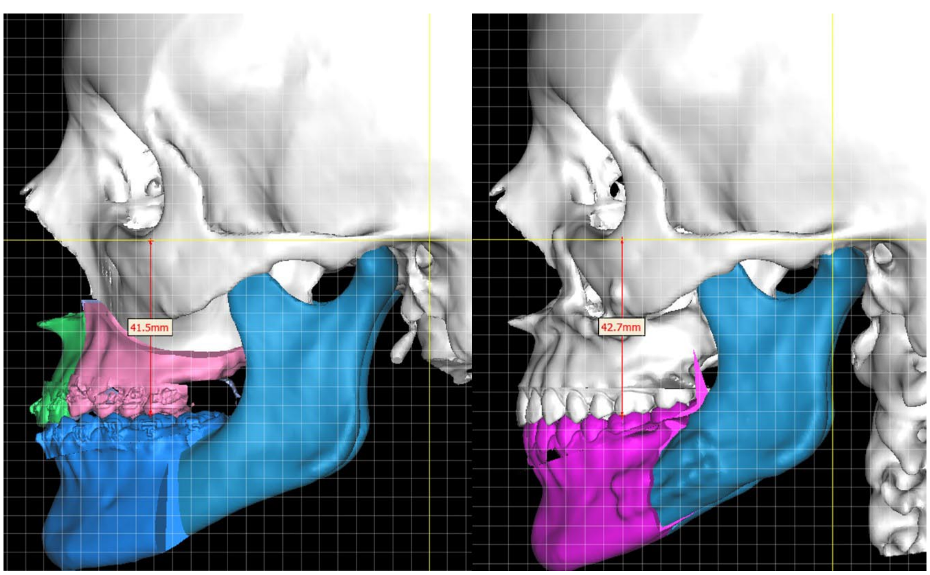

Fig. 4. Measurements in the Frankfurt Horizontal Plane of the Upper Left Molar preoperatively (41.5 mm) and postoperatively (42.7 mm).

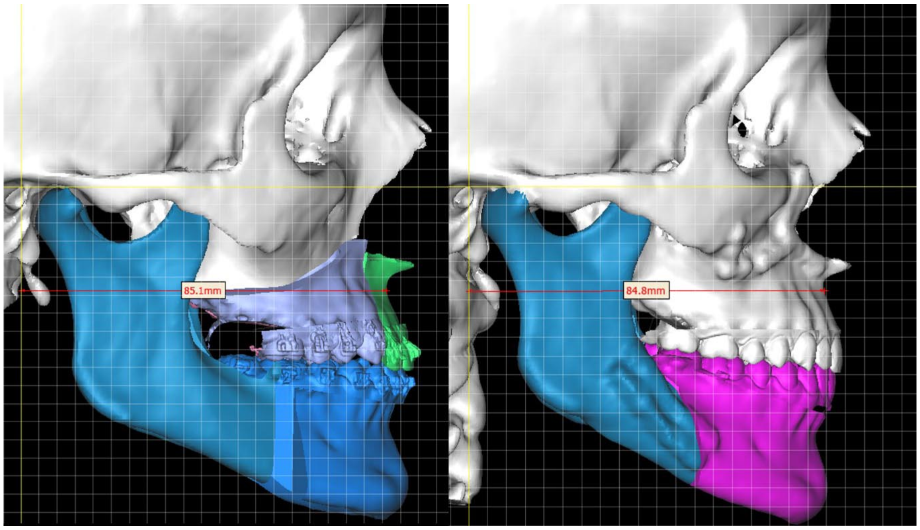

Fig. 5. Measurements from the Coronal Plane to point A preoperatively (85.1 mm) and postoperatively(84.8 mm).

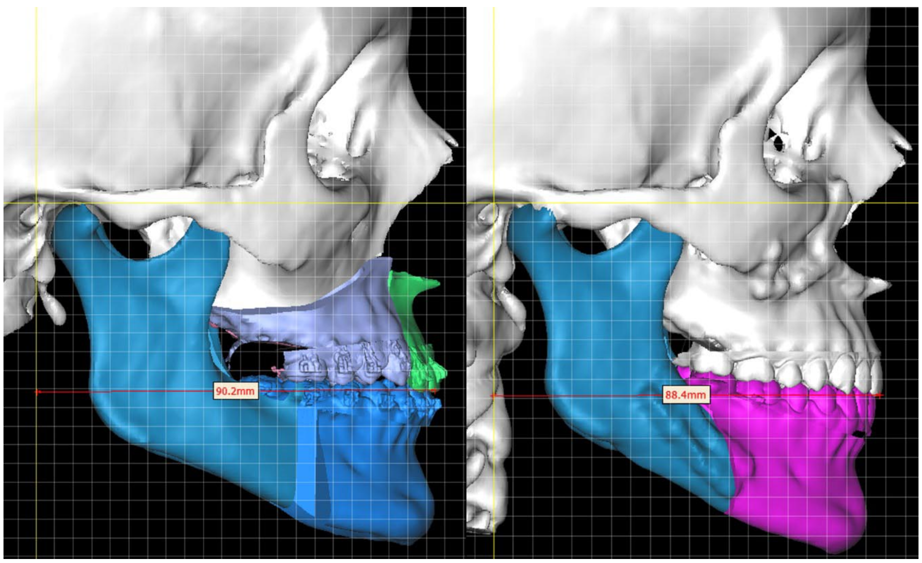

Fig. 6. Measurements from the Coronal Plane to the Upper Incisor preoperatively (90.2 mm) and postoperatively (88.4 mm).

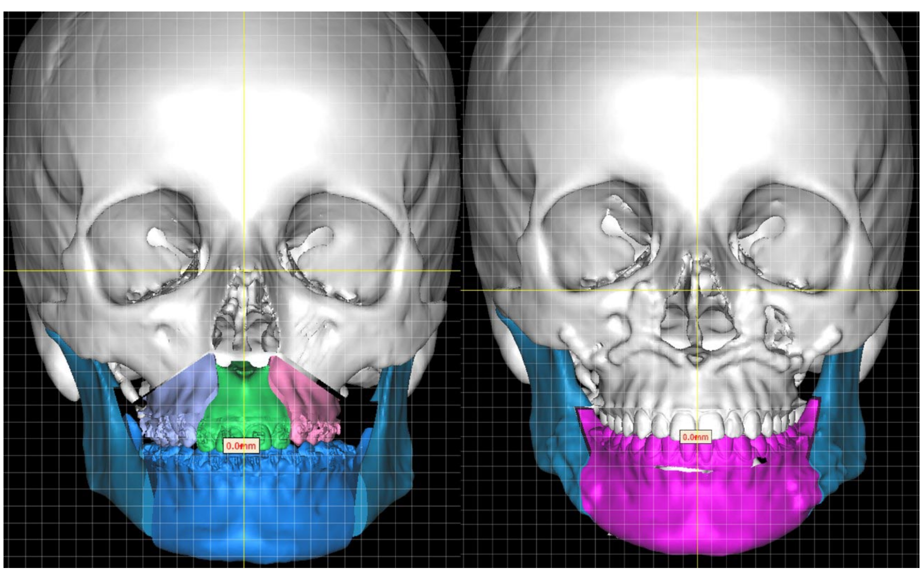

Fig. 7. Measurements from the Midline to the Upper Incisor preoperatively (0.0 mm) and postoperatively (0.0 mm).

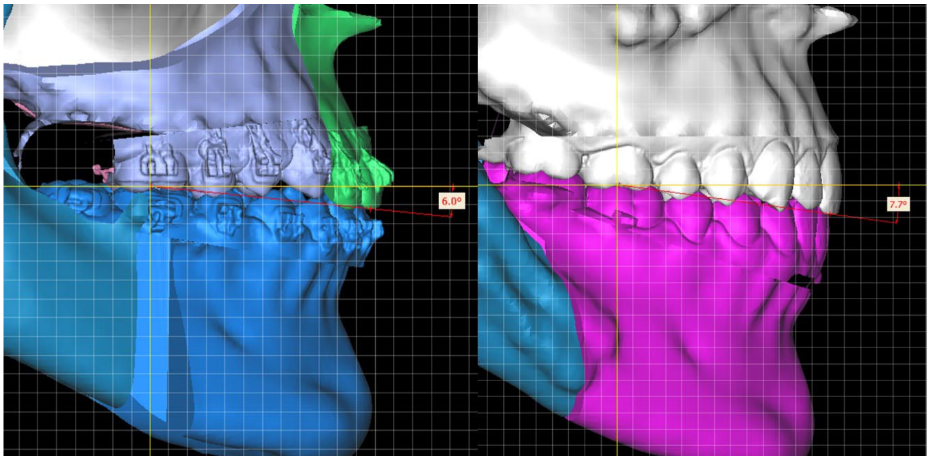

Fig. 8. Measurements of preoperative (6.0°) and postoperative (7.7°) occlusal plane angular measurements.

RESULTS

8 patients were included being 4 male and 4 female, with an average of 24 years ± 7.69 (varying from 17 to 37 years). Every patients were satisfied with results, including facial profile and occlusion.

Table IV and Fig 9 to 16 shows the results of cephalometric measurements performed on planning and post operative CT . The Dahlberg error represent the aleatory error between the measurements. It can be seen that the relative Dahlberg error was large in the standard frontal measurements and in the angular measurements. In angular measurements the Dahlberg error varied from 3.14° (OP/HFP), being large in relation to the averages of the measurements. For the other variables, the relative error ranged from 1.9% (PHF/MSD). The systematic errors of each measure were also analyzed (Bland-Altman method, t test and Wilcoxon). The average bias in angular measurements varied 1.79º (PO/PHF).

Although three linear measures (anterior facial height, HFP/UI, HFP/ULM) had a statistically significant difference between planning and postoperative period, the spatial distribution of biases in the Bland-Altman graphs indicated that there is no relationship between biases and the averages of the measures.

Table IV. Analysis of the accuracy of cephalometric measurements performed in surgical planning in relation to the postoperative result.

Variable	Measurement				Dahlberg Error	Dahlberg relative error	Bias (IC 95%)	p-value
	Surgical Planning		Post Operative					
	Average (Standard deviation)	Median (Min; max)	Average (Standard deviation)	Median (Min; max)				
Lateral Norm (mm)								
Anterior facial height	117.28 (7.47)	118.40 (105.10-126.60)	120.10 (8.28)	120.20 (109.20-130.80)	2.40	2.0%	2.83 (-1.11; 6.76)	[1]0.0053
HFP/UI	49.33 (3.41)	49.30 (44.60-54.10)	50.58 (3.66)	51.35 (44.10-54.70)	1.14	2.3%	1.25 (-0.87; 3.37)	[1]0.0137
HFP/URM	45.73 (3.07)	46.30 (41.30-49.90)	46.21 (3.41)	45.95 (41.70-51.10)	0.86	1.9%	0.49 (-1.84; 2.82)	[1]0.2845
HFP/ULM	44.61 (2.89)	44.30 (41.40-48.80)	46.01 (3.81)	44.30 (42.10-51.80)	1.47	3.2%	1.40 (-1.83; 4.63)	[1]0.0470
Lateral Norm - anteroposterior (mm)								
Coronal Plane/A	93.23 (5.78)	91.10 (86.00-102.10)	91.88 (4.06)	90.90 (87.70-98.20)	1.81	2.0%	-1.35 (-5.91; 3.21)	[1]0.1444
Coronal Plane/UI	97.48 (6.15)	94.80 (92.30-109.30)	96.28 (4.48)	95.30 (92.20-105.30)	1.91	2.0%	-1.20 (-6.29; 3.89)	[1]0.2321
Frontal Norm (mm)								
Midline/UI	0.00 (0.00)	0.00 (0.00-0.00)	-0.48 (1.08)	-0.30 (-1.70-1.50)	0.79	332.9%	-0.48 (-2.60; 1.65)	[2]0.2249
Angular Measurement (degree)								
PO/PHF	8.65 (2.64)	8.70 (5.30-12.80)	10.86 (3.24)	10.60 (5.50-15.40)	3.14	32.5 %	1.79 (-6.93; 10.51)	[1]0.3589

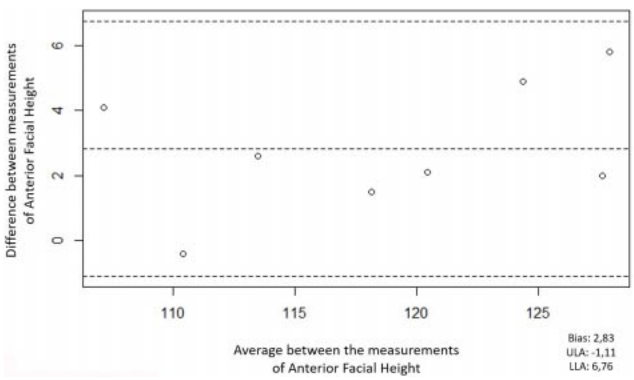

Fig. 9. Scatter plot for the difference and mean of the variable Anterior facial height between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

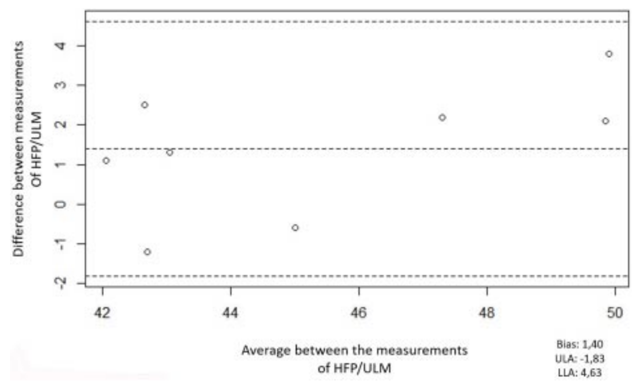

Fig. 12. Scatter plot for the difference and mean of the HFP/ULM variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

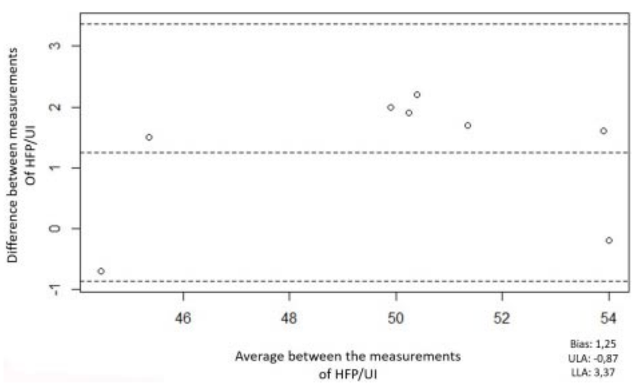

Fig. 10. Scatter plot for the difference and mean of the HFP/UI variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

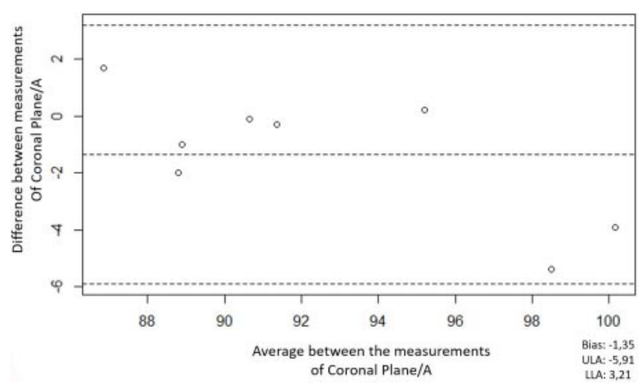

Fig. 13. Scatter plot for the difference and mean of the Coronal Plane/A variable between surgical planning and the postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

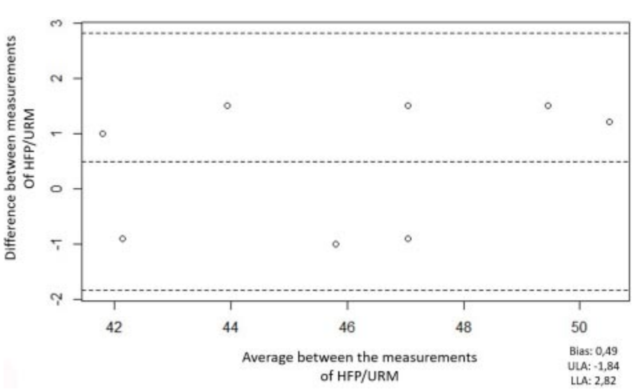

Fig. 11. Scatter plot for the difference and mean of the HFP/URM variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

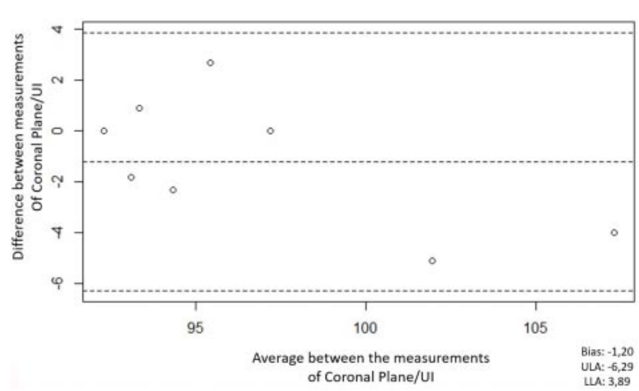

Fig. 14. Scatter plot for the difference and mean of the Coronal Plane/UI variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

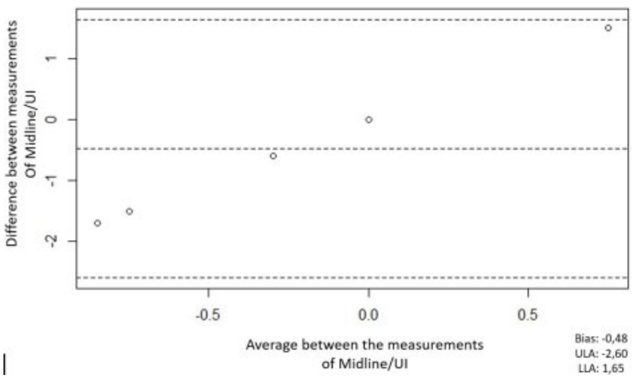

Fig. 15. Scatter plot for the difference and mean of the Midline/UI variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

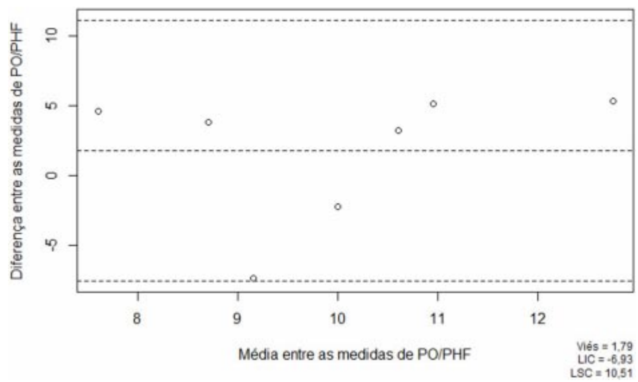

Fig. 16. Scatter plot for the difference and mean of the OP/HFP variable between surgical planning and postoperative period. ULA: upper limit of agreement; LLA: lower limit of agreement. Bland-Altman method.

Table V presents the frequencies and percentages of patients with clinically acceptable bias in cephalometric measurements. It is observed that for the lateral measurements, the percentage of patients with clinically acceptable bias ranged from 75.0% (AFH and HFP/UI) to 100.0% (HFP/URM). In lateral, anteroposterior measurements, this percentage ranged from 50.0% (Coronal Plane/UI) to 75% (Coronal Plane/A, Coronal Plane B), and for angular measurements, 62.5% (OP/HFP).

DISCUSSION

Lin *et al*., in 2015, reviewed the reports published in last 10 years about procedures assisted by computer in orthognathic surgery, including surgical planning, simulation, trans-operative transmission of virtual planning and post operative evaluation. They concluded that the use of assisted technique by computer produce ideals functionals and aesthetic results, patients satisfaction, precisely information of treatment plan and easy trans-operative manipulation.

This study provides an objective qualification to surgical precision to VSP. The approach more useful was the linear and angular measurements (Centero & Hernandez-Alfaro, 2012; Zinzer *et al*. 2012). These measurements were based in the identification of cephalometric points that are propense a human errors varying of 0.3 to 2.8 mm according with Makram and Kamel, in 2014. Besides this method, there are two another register methods. Point, surface or voxel

Table V. Frequency (%) of patients with clinically acceptable bias in the cephalometric measurements taken in the surgical planning in relation to the postoperative result (<2 mm in linear measurements and <4º in angular measurements).

Variable	Post operative average	Frequency (%)
Lateral Norm (mm)		
AFH	120.10	6 (75.0%)
HFP/UI	50.58	6 (75.0%)
HFP/URM	46.21	8 (100.0%)
HFP/ULM	46.01	7 (87.5%)
Lateral norm - anteroposterior (mm)		
Coronal Plane/A	91.88	6 (75.0%)
Coronal Plane/B	88.37	6 (75.0%)
Coronal Plane/UI	96.28	4 (50.0%)
Frontal Norm (mm)		
Midline/UI	-0.48	8 (100.0%)
Angular measurements (degree)		
OP/HFP	10.89	5 (62.5%)

register. Tucker *et al*. (2010) and Baan *et al*. (2016) used the voxel register in cranial part, with positive effect in results. Hsu *et al*. (2013), Hernandez-Alfaro & Guijarro-Martinez (2013) presented a valid method by overlap.

A systematic review of Stokbro *et al*. (2014) reported only seven clinical studies validating the VSP protocol in orthognathic surgery and only one of them considered bimaxillary procedures with maxilla segmentation (Stokbro *et al*, 2016). In these seven studies, the authors qualified the virtual planning precision compare the final mandible position. The two techniques to distance measurements from planning result to final result were surface or teeth point of reference (Hsu *et al*., 2013; Centenero & Hernández-Alfaro 2012; Xia *et al*., 2007; Zinser *et al*., 2012).

In our study, the orthognathic surgery accuracy assisted by computer was significatively in the most of the parameters included. In our results there were significant changes between the anterior facial height, both planned and reached, in agree with results of De Riu *et al*. (2018).

In this study were found statistic differences in the upper incisor and upper left molar in relation to Frankfurt Horizontal Plane, showing differences with Heufelder *et al*. (2017). This relation probably occur due the post operative orthodontic treatment (intrusion or extrusion process), considered that the post operative CT were done at least 6 months after the surgery. Although the statistic difference, only in 1 patient the measure varied more than 2 mm in upper left molar (3.8 mm) e only in 1 patient varied more than 2 mm in upper incisor (3.6 mm).

CONCLUSION

We can conclude that the VSP show precision and reproductivity to planning surgical procedures. The maxillary surgical movements show confidence in the virtual planning.

Conflict of interest: none

Financing: none

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RESUMEN: Se desarrolló un estudio retrospectivo para encontrar la predictibilidad de la Planificación Quirúrgica Virtual en los movimientos maxilares después de la cirugía ortognática. Se realizaron mediciones lineales y angulares en pacientes con maloclusión clase II y III mediante Tomografía Computarizada (TC) de rostro y cráneo con escáner dental (denominado Cráneo Compuesto), utilizando planificación quirúrgica, comparando con TC postoperatoria con al menos 6 meses. Ocho pacientes participaron del estudio. Se compararon los resultados de los movimientos simulados y reales de los puntos maxilares, calculando sus diferencias lineales y angulares. Los análisis cefalométricos se realizaron utilizando el software Proplan (Materialise Proplan CMF, São Paulo, Brasil). Se realizaron ocho mediciones y se evaluaron mediante la prueba t, Bland-Altman, Wilcoxon y el error de Dahlberg, además de ser evaluadas por sesgo clínicamente aceptable (+/- 2mm). En total, 3 diferencias fueron estadísticamente significativas (altura facial anterior, HFP/ULM, HFP/UI). El VSP parece ser un método preciso y reproducible como forma de elaboración de tratamientos, trasladado de forma fiable al paciente a través de guías quirúrgicas. Aunque las tres diferencias fueron estadísticamente significativas, cuando se compararon las mediciones clínicas con ellas, ninguna dio resultados clínicamente significativos.

PALABRAS CLAVE: Cirugía ortognática, maloclusión, asimetría facial.

REFERENCES

Aboul-Hosn Centenero S, Hernández-Alfaro F. 3D planning in orthognathic surgery: CAD/CAM surgical splints and prediction of the soft and hard tissues results - our experience in 16 cases. J Craniomaxillofac Surg. 2012; 40(2):162-8. https://doi.org/10.1016/j.jcms.2011.03.014

Baker SB, Goldstein JA, Seruya M. Outcomes in computer-assisted surgical simulation for orthognathic surgery. J Craniofac Surg. 2012; 23(2):509–13. https://doi.org/10.1016/j.joms.2009.06.030

Bell RB. Computer planning and intraoperative navigation in orthognathic surgery. J Oral Maxillofac Surg. 2011; 69(3):592-605. https://doi.org/10.1016/j.joms.2009.06.030

Baan F, Liebreqts J, Xi T, Schreurs R, de Koning M, Bergé S, Maal T. A new tool for assessing the accuracy of bimaxillary surgery: the OrthoGnathicAnalyser. PLoS One. 2016; 11(2):e0149625. https://doi.org/10.1371/journal.pone.0149625

Donatsky O, Bjorn-Jorgensen J, Holmqvist-Larsen M, Hillerup S. Computerized cephalometric evaluation of orthognathic surgical precision and stability in relation to maxillary superior repositioning combined with mandibular advancement or setback. J Oral Maxillofac Surg. 1997; 55(10):1071-9. https://doi.org/10.1016/s0278-2391(97)90282-2

De Riu G, Virdis PI, Meloni SM, Lumbau A, Vaira LA. Accuracy of computer-assisted orthognathic surgery. J Craniomaxillofac Surg. 2018; 46(2):293-298. https://doi.org/10.1016/j.jcms.2017.11.023

Gateno J, Xia J, Teichgraeber J, Rosen A. A new technique for the creation of a computerized composite skull model. J Oral Maxillofac Surg. 2003; 61(2):222-7. https://doi.org/10.1053/joms.2003.50033

Hsu SS, Gateno J, Bell RB, Hirsch DL, Markiewicz MR, Teichgraeber JF, Zhou X, Xia JJ. Accuracy of a computer-aided surgical simulation protocol for orthognathic surgery: a prospective multicenter study. J Oral Maxillofac Surg. 2013; 71(1):128-42. https://doi.org/10.1016/j.joms.2012.03.027

Haas Jr OL, Becker OE, Oliveira RB. Computer-aided in orthognathic surgery – systematic review. Int J Oral and Maxillofac Surg. 2015; 44:329-42. https://doi.org/10.1016/j.ijom.2014.10.025

Hernandez-Alfaro F, Guijarro-Martinez R. New protocol for threedimensional surgical planning and CAD/CAM splint generation in orthognathic surgery: an in vitro and in vivo study. Int J Oral Maxillofac Surg 2013; 42:1547. https://doi.org/10.1016/j.ijom.2013.03.025

Heufelder M, Wilde F, Pietzka S, Mascha F, Winter K, Schramm A, Rana M. Clinical accuracy of waferless maxillary positioning using customized surgical guides and patient specific osteosynthesis in bimaxillary orthognathic surgery. J Craniomaxillofac Surg. 2017; 45(9):1578-1585. https://doi.org/10.1016/j.jcms.2017.06.027

Kaipatur NR, Flores-Mir C. Accuracy of computer programs in predicting orthognathic surgery soft tissue response. J Oral Maxillofac Surg. 2009; 67(4):751-9. https://doi.org/10.1016/j.joms.2008.11.006

Lin HH, Lo LJ. Three-dimensional computer-assisted surgical simulation and intraoperative navigation in orthognathic surgery: a literature review. J Formos Med Assoc. 2015; 114(4):300-307. https://doi.org/10.1016/j.jfma.2015.01.017

Mazzoni S, Badiali G, Lancellotti L, Babbi L, Bianchi A, Marchetti C. Simulation guided navigation: a new approach to improve intraoperative three-dimensional reproducibility during orthognathic surgery. J Craniofac Surg. 2010; 21:1698–705. https://doi.org/10.1097/scs.0b013e3181f3c6a8

Mazzoni S, Bianchi A, Schiariti G, Badiali G, Marchetti C. Computer-Aided design and computer-aided manufacturing cutting guides and customized titanium plates are useful in upper maxilla waferless repositioning. J Oral Maxillofac Surg. 2015; 73:701-7. https://doi.org/10.1016/j.joms.2014.10.028

Makram M, Kamel H. Reeb graph for automatic 3D cephalometry. IJIP. 2014; 8(2):17-29.

Padwa BL, Kaiser MO, Kaban LB. Occlusal cant in the frontal plane as a reflection of facial asymmetry. J Oral Maxillofac Surg. 1997; 55(8): 811-816. https://doi.org/10.1016/s0278-2391(97)90338-4

Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Virtual planning in orthognathic surgery. Int J Oral and Maxillofac Surg. 2014; 43:957-965. https://doi.org/10.1016/j.ijom.2014.03.011

Schendel SA, Jacobson R. Three-dimensional imaging and computer simulation for office-based surgery. J Oral Maxillofac Surg. 2009; 67:2107–14. https://doi.org/10.1016/j.joms.2009.04.111

Shehab MF, Barakat, AA, AbdElghany K, Mostafa Y, Baur DA. A novel design of a computer-generated splint for vertical repositioning of the maxilla after Le Fort I osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013; 115(2):16-25. https://doi.org/10.1016/j.oooo.2011.09.035

Swennen GR, Mollemans W, Schutyser F. Three-dimensional treatment planning of orthognathic surgery in the era of virtual imaging. J Oral Maxillofac Surg. 2009; 67:2080–92. https://doi.org/10.1016/j.joms.2009.06.007

Swennen G (ed). 3D Virtual Treatment Planning of Orthognathic. Surgery. Berlin: Springer: 2017.

Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Surgical accuracy of threedimensional virtual planning: a pilot study of bimaxillary orthognathic procedures including maxillary segmentation. Int J Oral Maxillofac Surg. 2016; 45(1):8-18. https://doi.org/10.1016/j.ijom.2015.07.010

Tng TT, Chan TC, Hägg U, Cooke MS. Validity of cephalometric landmarks. An experimental study on human skulls." Eur J Orthod. 1994; 16(2):110-120. https://doi.org/10.1093/ejo/16.2.110

Tucker S, Cevidanes LH, Styner M, Kim H, Reyes M, Proffit W, Turvey T. Comparison of actual surgical outcomes and 3-dimensional surgical simulations. J Oral Maxillofac Surg. 2010; 68(10):2412-21. https://doi.org/10.1016/j.joms.2009.09.058

Xia JJ, Gateno J, Teichgraeber JF, Christensen AM, Lasky RE, Lemoine JJ, Liebschner MA. Accuracy of the computer-aided surgical simulation (CASS) system in the treatment of patients with complex craniomaxillofacial deformity: A pilot study. J Oral Maxillofac Surg. 2007; 65(2):248-54. https://doi.org/10.1016/j.joms.2006.10.005

Xia J, Young RW, Wang D. Wang D. A computer assisted threedimensional surgical planning and simulation 3D soft tissue planning and prediction. Int J Oral Maxillofac Surg 2009; 29:250–258.

Zhang N, Liu S, Hu Z, Hu J, Zhu S, Li Y. Accuracy of virtual surgical planning in two-jaw orthognathic surgery: comparison of planned and actual results. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016; 122(2):143-51. https://doi.org/10.1016/j.oooo.2016.03.004

Zinser MJ, Mischkowski RA, Sailer HF, Zöller JE. Computer-assisted orthognathic surgery: feasibility study using multiple CAD/CAM surgical splints. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012; 113(5):673-87. https://doi.org/10.1016/j.oooo.2011.11.009