IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 12 Ser. 4 (December. 2024), PP 08-16
www.iosrjournals.org

Evaluation the Accuracy of Three-Dimensional virtual Surgical Planning for Maxillary Positioning in Orthognathic Surgery: Prospective Clinical Study

Abdalrahman J. Karabala[1], **Moustafa M. Taha**[2], **Mahmoud Yehia Abdul Aziz**[2]
[1]*(Department of Dentistry, Faculty of Dentistry, Damascus University, Syria)*
[2]*(Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ain Shams University, Egypt)*

Abstract:
Background: *Dento-facial distortions was known as a specific type of deformities which affect jaws and dentition. The incidence of dentofacial deformaties is rely on genetic and sociofactors. Orthognathic surgeries purposed to rectify dento-facial distortion, functional and aesthetic issues. The success was no only depend on the orthogathic surgeries, but although; accuracy and detailes management plan. Therefore; this study aims to evaluate the accuracy of 3D virtual surgical planning for maxillary positioning and orientation in orthognathic surgery via comparison of preoperative planning and postoperative actual results.*
Materials and Methods: *In this prospective clinical study was enrolled 11 patients diagnosed with dentofacial abnormalities of the jaws cannot be managed with conventional orthodontics techniques underwent orthognathic surgery was conducted at outpatient clinic of the department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ain Shams University.*
Results: *The results showed non statistically significant difference between the virtual plan and the actual postsurgical outcome. Only minor inaccuracies were present; none of these discrepancies affected the clinical result for the sample included in this study. The inter-observer reliability was assessed by weighted Kappa, which was 0.947, indicating almost perfect agreement between the two assessors. Assessment of the points distances to the FHP in the virtually plan 3D model (mean=45.72mm, SD=8.49mm) in the comparison to the postoperative 3D model (mean=45.80mm, SD=8.54mm) showed a non-significant statistical difference where P=0.186. Assessment of the points distances to the MSP in the virtually plan 3D model (mean=17.09mm, SD=8.54mm) in the comparison to the postoperative 3D model (mean=17.10mm, SD=8.49mm) showed a non-significant statistical difference where P=0.877. Assessment of the points distances to the CP in the virtually plan 3D model (mean=55.85mm, SD=12.39mm) in the comparison to the postoperative 3D model (mean=55.85mm, SD=12.36mm) showed a non-significant statistical difference where P=0.960.* ***Conclusion:*** *No significant differences between 3D virtual surgical planning for maxillary positioning and orientation and postoperative 3D model. 3D virtual surgical planning was highly accurate in dentofacial abnormalities.*
Key Word: *Dentofacial Abnormalities; 3D virtual plan; Postoperative; Orthognathic surgeries;* Maxillary; Jaws

---

Date of Submission: 07-12-2024 Date of Acceptance: 17-12-2024

I. Introduction

Two-jaw orthognathic surgery, Lefort I osteotomy of the upper jaw combined with sagittal split ramus osteotomy (SSRO) or intraoral vertical ramus osteotomy (IVRO) of the lower jaw, is an the most effective methodology to correct severe dento-maxillofacial destortions.[1] The success of two jaw surgery relies on surgical technique and accurate surgical planning.[2] Conventional treatment planning for two-jaw surgery involves diagnosis with 2D cephalometric radiograph, face-bow transfer and model surgery on plaster dental cast, and fabrication of intermediate and final occlusal splint. There are several three-dimensional (3D) VSP protocols, such as the Computer-Aided Surgical Simulation (CASS), which represents a paradigm shift in surgical planning for patients with dentofacial deformities.[3] Using cone beam computed tomography (CBCT) scans and software programs, a computerized composite skull model of the patient is generated to accurately represent the dentition, the skeleton and the soft tissues.[4] Virtual surgical planning and Rapid Prototyping (RP) technology offers new possibilities to obtain a comprehensive 3D evaluation of the dental arches and the surrounding skeletal structures to simulate different surgical plans and predict the corresponding results, as well as to facilitate the transfer of the virtual surgical plan to actual outcome using 3D-printed splints and guiding templates.[5] The current study aims to evaluate the accuracy of 3D virtual surgical planning for maxillary positioning and orientation in orthognathic surgery via comparison of preoperative planning and postoperative actual results

II. Material And Methods

In this prospective clinical study was enrolled 11 patients diagnosed with dentofacial abnormalities of the jaws cannot be managed with conventional orthodontics techniques underwent orthognathic surgery was conducted at outpatient clinic of the department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ain Shams University.

Study Design: Prospective clinical study

Study Location: Outpatient clinic of the department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ain Shams University

Study Duration: November 2014 to November 2015.

Sample size: 11 patients.

Sample size calculation: The sample size was estimated on the basis of a single proportion design. Distance to FHP "mm" regarding UI in simulated mean was 50.2±4.67 and in postoperative mean was 49.5±4.71, and mean difference 0.60±0.07 with a large effect size (f = 0.775). A sample size of 11 patients in the study group was determined to provide 80% power for independent samples T test at the level of 5% significant and Confidence interval 95% using G. Power 3.19.2 software

Inclusion criteria:

1. Patients with maxillary deformities
2. Patients with no medical compromising conditions
3. Both sexes will be accepted
4. Age range of patients 18-30 years

Exclusion criteria:

1. Patient with bone and syndromic diseases. (Diabetes, Syndromic patients)
2. Vulnerable groups (prisoners, orphans, disabled, ...)

Procedure methodology

After written informed consent was obtained, a well-designed questionnaire was used to collect the data of the recruited patients retrospectively.

Pre-surgical preparation: Laboratory evaluation was included Full blood count (CBC), coagulation profile, Serum creatinine measurement and AST and ALT levels.

Surgical procedure: The surgeries were conducted with general anesthesia and nasotracheal intubation. Patients were prepped using betadine and surgical scrub. Articaine 4% with vasoconstrictor (Epinephrine 1:100,000) was injected into the submucosa for preemptive pain relief and to assist with controlling bleeding. Each patient underwent a Le Fort I maxillary osteotomy, following a maxilla-first approach, along with Bilateral Sagittal Split Osteotomy.

LeFort I Osteotomy: An intraoral incision was made extending between the first molars, positioned at least 5 mm above the mucogingival junction, using electrocautery. Subperiosteal dissection was then performed with a mucoperiosteal elevator to expose the entire surface of the maxilla, including the infraorbital neurovascular bundle, piriform aperture, and zygomatic maxillary buttress. Subperiosteal tunneling continued until reaching the pterygomaxillary fissure. A lateral osteotomy of the maxillary sinus's front wall began at the highest point of the zygomatic buttress. It was then advanced posteriorly, keeping it centered with mallet strikes. Digital pressure was applied to the anterior maxilla to perform a controlled downward fracture under hypotensive anesthesia, aiming to minimize bleeding. Rowe's disimpaction forceps were utilized to mobilize the maxilla, followed by the insertion of Tessier mobilizers to achieve additional mobilization. The upper jaw was placed in the intended intermediate position utilizing the intermediate occlusal wafer. Four titanium plates were used to stabilize the maxilla, positioned bilaterally at the zygomatic buttress (L-shaped plates) and at the pyriform region. After completing the surgery, a proline 3.0 suture was used for alar cinch, and the flap was closed in a single layer with a continuous running suture using 4-0 vicryl.

The bilateral sagittal split osteotomy: The cut was made at the back of the lower jaw behind the third molar and continued outward along the cheek side within the opening towards the area around the second premolar. A flap was elevated, involving the release of the temporalis tendon connected to the ascending ramus, and a lingual flap was created to expose the inner aspect of the ramus. The lingula was uncovered to shield the inferior alveolar nerve, and a horizontal cut was made above it, just before the rear edge of the mandible. The proximal segment of the mandible was positioned according to the planned final placement, guided by the final surgical wafer. The wound was closed with a single layer of continuous running sutures using 4-0 Vicryl (Assut sutures, Switzerland). Occasionally, guiding elastics were applied either during the surgery or after extubation.

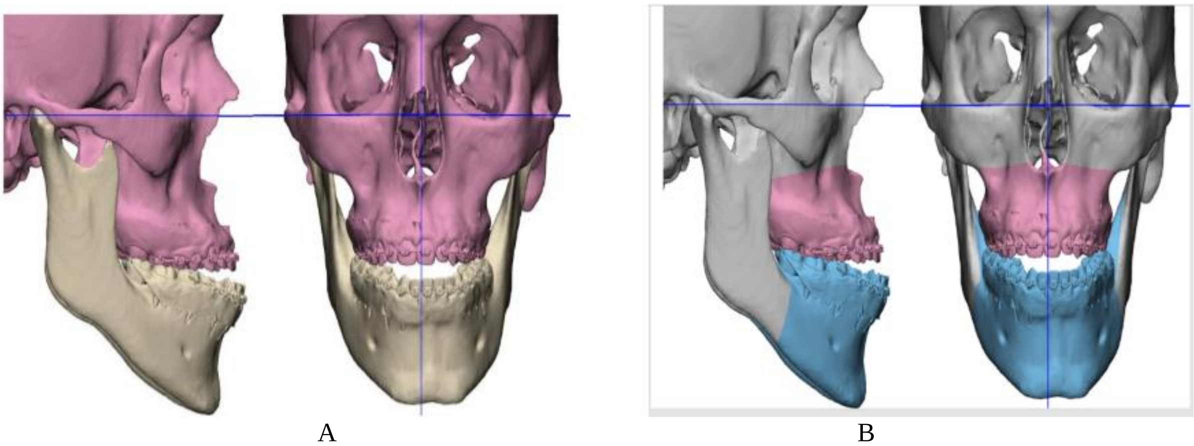
Postoperative guidelines and follow-up procedures: After surgery, care emphasized pain and swelling management, as well as ensuring sufficient fluid intake. Methods to minimize swelling included applying ice, elevating the head, and administering corticosteroids. Patients were advised to apply ice packs for 20 minutes per hour on the first day and avoid facial trauma. Pain was managed using nonsteroidal anti-inflammatory drugs. Prophylactic antibiotics were prescribed for five days post-surgery. Regular check-ups were conducted weekly during the first month after treatment, followed by monthly visits for the next three months.

Radiographic Evaluation: One week after the surgery, a CT scan was performed. The DICOM files were imported into Mimics software and rendered into 3D models as previously noted. Using Mimics Medical 19.0 and 3-matic Medical 11.0, the preoperative virtual plan was overlaid on the actual postoperative 3D model by aligning several fixed reference points on the skull, such as the infraorbital foramina. Following superimposition, five fixed landmark points were identified on both the virtually planned repositioned maxilla and the actual postoperative maxilla, all in identical locations. These points included the most inferior-mesial point of the upper central incisor, the tips of the upper canines (right and left), and the mesiobuccal cusp tips of the upper first molars (right and left). The distances from each point to the three spatial planes were measured in both the preoperative virtual plan and the actual postoperative 3D model. By comparing these measurements, we could identify any deviations from the planned surgery across all three planes that might affect the final aesthetic and functional results.

Statistical analysis: Data was analyzed Statistical package for Social Science (SPSS) 22.0. IBM, United States. Descriptive statistics were done for numerical parametric data as mean±SD (standard deviation) and minimum & maximum of the range and for numerical non parametric data as median and 1st& 3rd inter-quartile range, while they were done for categorical data as number and percentage. The level of significance was taken at P value <0.050 is significant, otherwise is non significant. The p-value is a statistical measure for the probability that the results observed in a study could have occurred by chance.

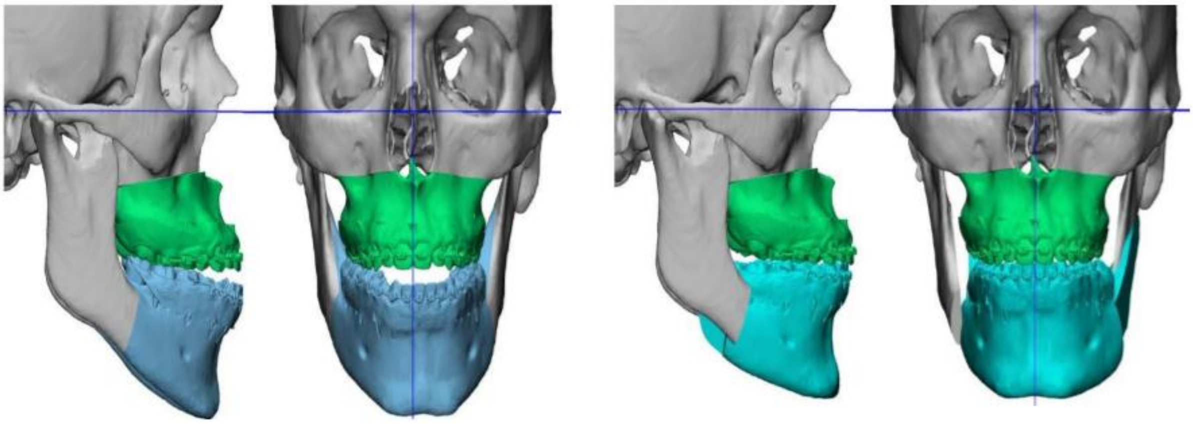
A **B** **C**

Figure 1 (a-c): Optical scans of the maxillary and mandibular arches, as well as their planned postoperative occlusion.



A B

Figure 2 (A) Formation of a 3D composite model combining the skull and dental features. (B)Virtual osteotomies performed on the maxilla (Le Fort I) and mandible (BSSO).



A B

Figure 3: (A) Repositioning of the maxillary segment. (B) Repositioning of the mandibular segment for optimal occlusion.

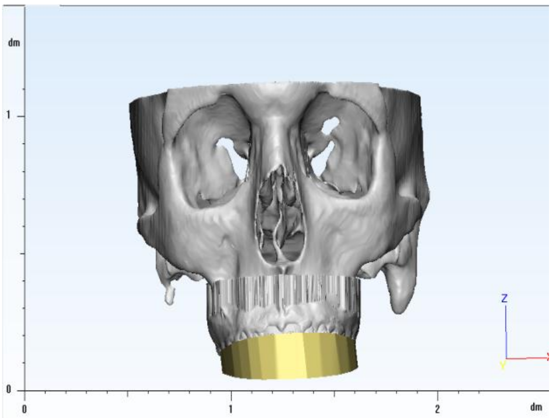
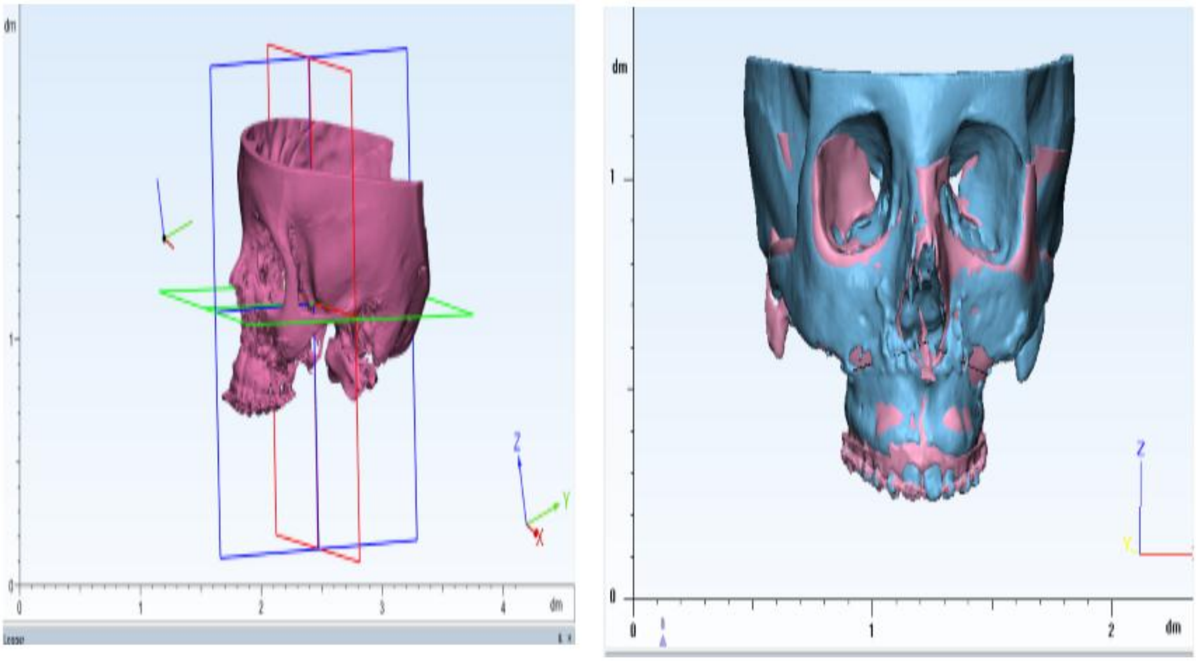
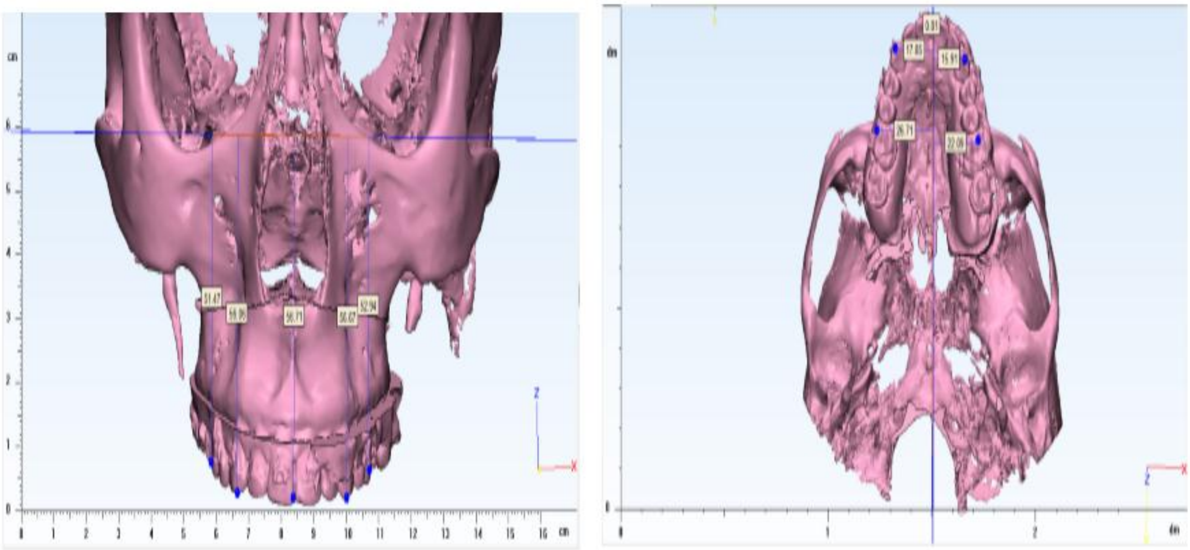


Figure 4: Intermediate Wafer



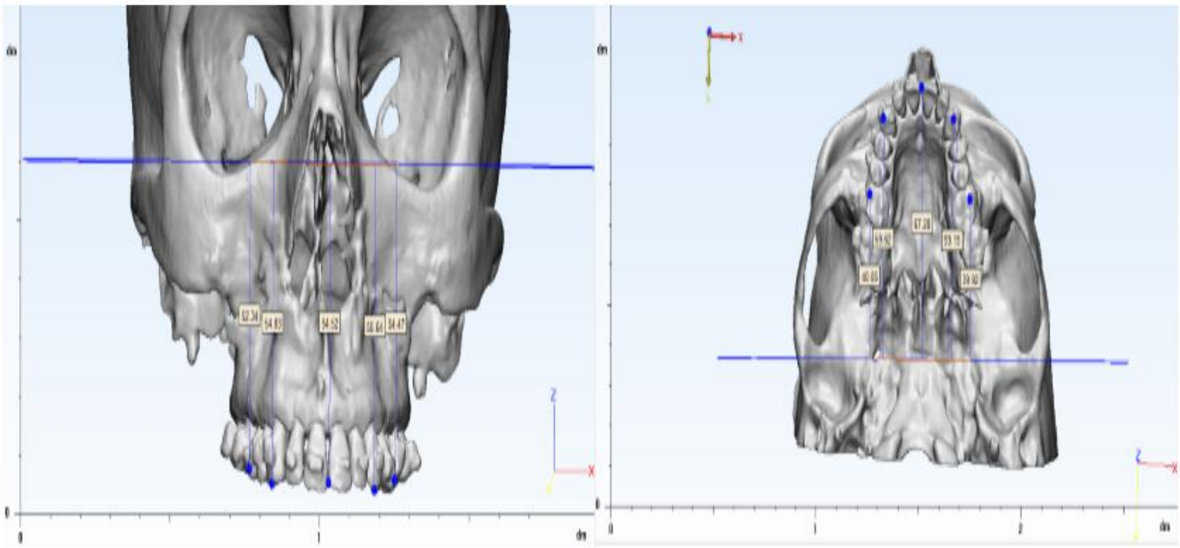
A B

Figure 5: (A) Establishing the three planes in space: coronal, axial, and sagittal. (B) Alignment of the virtually planned repositioned maxilla with the actual postoperative maxilla.



A B

Figure 6: (A) **Determining the distance from the specified points to the FHP plane in the virtual planning model. (B) Determining the distance from the specified points to the MSP plane in the virtual planning model.**



A B

Figure 7: (A) Determining the distance from the specified points to the FHP plane in the postoperative model. (B) Determining the distance from the specified points to the CP plane in the postoperative model


A **B**


C **D**

Figure 8: Extraoral photos, (a-b) preoperative c-d) postoperative showing frontal view at rest, RT lateral view.


A **B**

C **D**

Figure 9: intraoral photos(a-b) preoperative c-d) postoperative showing occlusion from frontal view, RT lateral.

III. Result

The study included eleven patients with ranged age 19 to 25 years mean 21.91±1.87 years old, complaining from skeletal maxillary deformity. Seven Females and four Males patients were included.

Table 1: Shows demographic data, patient age, sex and type, amount of maxillary movement.

Demographic data	Total cases (n=11)
Sex	
Male	4 (36.4%)
Female	7 (63.6%)
Age "years"	
Range	19-25
Mean±SD	21.91±1.87

After superimposition of the postoperative 3D model over the virtually planned one, the distance between the selected points and the three planes of space for both the virtual plan and the actual outcome were measured. The mean of the measured distances for each plane was compared between the virtual plan and the actual postoperative to assess the accuracy of waffers in planning transfer to the theatre. Two assessors undertaken the CT analyses, each one of them collected two separate sets of records. The results showed non statistically significant difference between the virtual plan and the actual postsurgical outcome. Only minor inaccuracies were present; none of these discrepancies affected the clinical result for the sample included in this study. The inter-observer reliability was assessed by weighted Kappa, which was 0.947, indicating almost perfect agreement between the two assessors. Assessment of the points distances to the FHP in the virtually plan 3D model (mean=45.72mm, SD=8.49mm) in the comparison to the postoperative 3D model (mean=45.80mm, SD=8.54mm) showed a non-significant statistical difference where P=0.186. The mean difference between each "Plan" pint and its counterpart "Post" point was 0.076±0.056mm (Table 2).

Table 2: Showing the mean ± SD values, of measurements from the "Plan" and "Post" landmark points to the FHP.

	FHP		Paired sample t-test			
	Mean	**±SD**	**MD**	**±SE**	**t-test**	**p-value**
Virtual Plan	45.72	8.49	0.076	0.056	1.355	0.186
Postoperative	45.80	8.54				

P-value >0.05 is insignificant difference

Assessment of the points distances to the MSP in the virtually plan 3D model (mean=17.09mm, SD=8.54mm) in the comparison to the postoperative 3D model (mean=17.10mm, SD=8.49mm) showed a non-significant statistical difference where P=0.877. The mean difference between each "Plan" pint and its counterpart "Post" point was 0.009±0.055mm (Table 3).

Table 3: Showing the mean ± SD values, of measurements from the "Plan" and "Post" landmark points to the MSP.

	MSP		Paired sample t-test			
	Mean	**±SD**	**MD**	**±SE**	**t-test**	**p-value**
Virtual Plan	17.09	8.54	0.009	0.055	0.156	0.877
Postoperative	17.10	8.49				

P-value >0.05 is insignificant difference

Assessment of the points distances to the CP in the virtually plan 3D model (mean=55.85mm, SD=12.39mm) in the comparison to the postoperative 3D model (mean=55.85mm, SD=12.36mm) showed a non-significant statistical difference where P=0.960. The mean difference between each "Plan" pint and its counterpart "Post" point was 0.003±0.067mm (Table 4).

Table 4: Showing the mean ± SD values, of measurements from the "Plan" and "Post" landmark points to the CP.

	CP		Paired sample t-test			
	Mean	**±SD**	**MD**	**±SE**	**t-test**	**p-value**
Virtual Plan	55.847	12.39	0.003	0.067	0.050	0.960
Postoperative	55.850	12.36				

Q-value >0.05 is insignificant difference

IV. Discussion

Traditional methods for planning maxillofacial and orthognathic surgeries have been dependable for years, but recent technological advancements are moving the field toward more effective and precise approaches. The benefits of virtual planning for orthognathic surgeries include 3D visualization of anatomy, deformities, and pathologies, which offer time savings, greater precision, and improved communication.[6]

The virtual model surgery technique was based on the approach developed by Shaheen et al., which utilized Pro Plan software (Materialise, Leuven, Belgium).[7] This software can be considered a specialized version of Mimics (Materialise, Leuven, Belgium), which we employed in our planning. Shaheen et al. method for dental model registration, using a specific scanning protocol and point registration, reduced the number of scans required for the patient. Additionally, it maintained soft tissue contours and lip positions better than other methods that rely on multiple scans, fiducial markers, and bulky equipment.[8,9,10] The team also offered a solution that we adopted to prevent occlusal collisions in the final splint by scanning the dental models in their final occlusion.

We chose Mimics (Materialise, Leuven, Belgium) as our software because our team had prior experience using it for planning resections and trauma cases. The software is highly versatile, supports various modalities, and is often considered the industry gold standard.[10]

Patients with maxillary deformities were selected for the study to evaluate the final wafers and planning. Those with systemic diseases or syndromes that could complicate treatment planning and impact results were excluded.

Virtual planning and rapid prototyping were relatively new to our team, and the literature is filled with various planning protocols, software, and techniques.[11] It was essential to validate the selected technique and assess its accuracy in our practice before applying it clinically to prevent potential complications for our patients.

Stokbro et al. also made a survey on 30 patients they are also evaluated the influence of segmentation on positional accuracy and transverse expansion and genioplasty in placement of the chin segment. The virtual surgical plan was compared with the postsurgical outcome by using three linear and three rotational measurements. The influence of maxillary segmentation was analyzed in both superior and inferior maxillary repositioning. In addition, transverse surgical expansion was compared with the postsurgical expansion obtained. An overall, high degree of linear accuracy between planned and postsurgical outcomes was found, but with a large standard deviation. Rotational difference showed an increase in pitch, mainly affecting the maxilla. Segmentation had no significant influence on maxillary placement. A posterior movement was observed in inferior maxillary repositioning. A lack of transverse expansion was observed in the segmented maxilla independent of the degree of expansion.[12]

Schneider et al. perform a prospective randomized trial to compare conventional (csp) versus customized VSP in bimaxillary orthognathic surgery. The VSP appears to be a more accurate method for orthognathic treatment planning with significant differences in the angle outcome (SNA $p < 0.001$; SNB $p = 0.002$; ANB $p < 0.001$). There were significant differences in splint accuracy in favor of CAD/CAM splints ($p = 0.007$). VSP significantly reduced the duration of operation ($p = 0.041$). [13]

Sun et al.present and discuss a workflow regarding computer-assisted surgical planning for bimaxillary surgery and intermediate splint fabrication. Three different modalities were utilized to obtain this goal: cone beam computed tomography (CBCT), optical dental scanning, and 3-dimensional printing. A universal registration block was designed to register the optical scan of the wax bite to the CBCT data set. Integration of the wax bite avoided problems related to artifacts caused by dental fillings in the occlusal plane of the CBCT scan. Fifteen patients underwent bimaxillary orthognathic surgery. The printed intermediate splint was used during the operation for each patient. A postoperative CBCT scan was taken and registered to the preoperative CBCT scan. The difference between the planned and the actual bony surgical movement at the edge of the upper central incisor was 0.50 T 0.22 mm in sagittal, 0.57 T 0.35 mm in vertical, and 0.38 T 0.35 mm in horizontal direction (midlines). There was no significant difference between the planned and the actual surgical movement in 3 dimensions: sagittal ($P = 0.10$), vertical ($P = 0.69$), and horizontal ($P = 0.83$). In conclusion, under clinical circumstances, the accuracy of the designed intermediate splint satisfied the requirements for bimaxillary surgery. **[14]**

V. Conclusion

No significant differences between 3D virtual surgical planning for maxillary positioning and orientation and postoperative 3D model. 3D virtual surgical planning was highly accurate in dentofacial abnormalities..

References

[1]. Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.© 2014 John Wiley & Sons, Ltd. Published 2014 by John Wiley & Sons, Ltd.

[2]. Chew MT (2006) Spectrum and management of dentofacial deformities in a multiethnic Asian population. Angle Orthod 76:806–809

[3]. Bailey LJ, Haltiwanger LH, Blakey GH, Proffit WR. Who seeks surgical-orthodontic treatment: a current review. Int J Adult Orthodon Orthognath Surg 2001; 16:280–292.

[4]. Xia JJ, Gateno J, Teichgraeber JF, Yuan P, Chen KC, Li J, Zhang X, Tang Z, Alfi DM. Algorithm for planning a double-jaw orthognathic surgery using a computer-aided surgical simulation (CASS) protocol. Part 1: planning sequence. Int J Oral Maxillofac Surg. 2015;44(12):1431-1440.

[5]. Ritto FG, Schmitt ARM, Pimentel T, Canellas JV, Medeiros PJ. Comparison of the accuracy of maxillary position between conventional model surgery and virtual surgical planning. Int J Oral Maxillofac Surg. 2018;47(2):160-166.

[6]. Medelli'n-Castillo HI, Pedraza Torres JE. Rapid Prototyping and Manufacturing: A Review of Current Technologies. In: Volume 4: Design and Manufacturing. Lake Buena Vista, Florida, USA: ASMEDC; 2009. p. 609-21

[7]. Shaheen Eman, Coopman R, Jacobs R, Politis C. Optimized 3D virtually planned intermediate splints for bimaxillary orthognathic surgery. A clinical validation study in 20 patients. J Cranio-Maxillofac Surg. 2018;46(9):1441-7.

[8]. Swennen G.R.J., Mommaerts MY, Abeloos J, De Clercq C, Lamoral P, Neyt N, Casselman J, Schutyser F. A cone-beam CT based technique to augment the 3D virtual skull model with a detailed dental surface. Int J Oral Maxillofac Surg. 2009;38(1):48-57

[9]. Shaheen E., Sun Y, Jacobs R, Politis C. Three-dimensional printed final occlusal splint for orthognathic surgery: design and validation. Int J Oral Maxillofac Surg. 2017;46(1):67-71.

[10]. Yuan P, Mai H, Li J, Ho DC-Y, Lai Y, Liu S, Kim D, Xiong Z, Alfi DM, Teichgraeber JF, Gateno J, Xia JJ. Design, development and clinical validation of computer-aided surgical simulation system for streamlined orthognathic surgical planning. Int J Comput Assist Radiol Surg. 2017;12(12):2129-43.

[11]. Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Virtual planning in orthognathic surgery. Int J Oral Maxillofac Surg. 2014;43(8):957- 65.

[12]. Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Surgical accuracy of three-dimensional virtual planning: a pilot study of bimaxillary orthognathic procedures including maxillary segmentation. Int J Oral Maxillofac Surg. 2016;45(1):8-18.

[13]. Schneider D, Kämmerer PW, Hennig M, Schön G, Thiem DGE, Bschorer R. Customized virtual surgical planning in bimaxillary orthognathic surgery: a prospective randomized trial. Clin Oral Investig. 2019; 23(7):3115-3122.

[14]. Sun Y, Luebbers HT, Agbaje JO, Schepers S, Vrielinck L, Lambrichts I, Politis C. Accuracy of upper jaw positioning with intermediate splint fabrication after virtual planning in bimaxillary orthognathic surgery. J Craniofac Surg. 2013;24(6):1871-6.