Open Access Library Journal
2023, Volume 10, e10397
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Virtual Planning versus Traditional Planning in Orthodontic-Surgical Treatment: A Review

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How to cite this paper: Sahim, S. and El Quars, F. (2023) Virtual Planning versus Traditional Planning in Orthodontic-Surgical Treatment: A Review. *Open Access Library Journal*, **10**: e10397.
https://doi.org/10.4236/oalib.1110397

Received: June 18, 2023
Accepted: July 24, 2023
Published: July 27, 2023

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Abstract

The success of orthognathic surgery depends on careful preparation preoperatively, accurate operative plan implementation and prevention of postoperative relapse. In general, preoperative plan is the most important step of the workflow process of orthognathic procedures. After years of clinical validation and feedback, traditional surgical planning TSP has been the standard procedure before orthognathic surgery. However, obvious limitations have been observed in TSP, especially in the treatment planning for complex dentofacial deformities. Minor errors may accumulate during the various steps of conventional articulator model surgery and it can lead to errors during surgery. The development of computer-aided surgical simulation represents a revolution in surgical planning to overcome many limitations of TSP. In these protocols, computerized reconstructed skull models are generated to accurately represent the skeleton, dentition, and soft tissues of the face. Virtual surgical planning VSP allows surgeons to design individually adapted osteotomy plans and evaluate different surgical scenarios. The main purpose of this article was to compare traditional surgical planning and virtual surgical planning in orthognathic surgery by highlighting the advantages and limits of each technique.

Subject Areas

Orthodontics

Keywords

Virtual Surgical Planning, Traditional Surgical Planning, Accuracy, Orthognathic Surgery, Orthodontics

1. Introduction

Orthodontic-surgical treatment is indicated in patients who present with a three-dimensional position of the bone bases incompatible with the oral functions or severe malocclusions which are uncorrectable with mere orthodontic compensation [1]. The growing number of adult patients seeking orthodontic treatment has led, more and more frequently, to consider surgical-orthodontic options [2].

The treatment planning and management of orthognathic surgical cases is one of the great challenges in orthodontics. A careful diagnostic protocol is required to simulate surgical displacements and to predict orthodontic movements necessary to easily achieve a well-balanced and stable surgical occlusion [3]. Therefore, the precision of presurgical orthodontic protocol plays a key role in the success of orthognathic surgery by planning the tooth-jaw relationship, site of osteotomy, distance of bone mass movement, and surgical approach [4].

In traditional surgical planning (TSP), the diagnostic information collected from preoperative clinical and radiographic assessments, as well as the model analysis, are integrated to establish a treatment goal and to derive a surgical plan. This is a time-consuming procedure that requires a lot of laboratory work [5]. In this traditional planning, most surgeons digitally or manually trace the lateral cephalogram and plan sagittal maxillomandibular movements based on the correction of predefined cephalometric measurements. Because most of these movements are in the 1- to 10-mm range, small errors and discrepancies in each step of the workup can lead to inaccurate and unpredictable final results [6].

Recently, improved CBCT scanning, advanced 3D surface acquisition technologies along with readily available computer-aided designing software have revolutionized orthognathic planning [7]. With the introduction of 3D virtual setups, it is possible to integrate the orthodontic setup with the virtual orthognathic planning. By using CBCT data and digital dental models, the position of the dental arch and each individual tooth can be analyzed with reference to the position and orientation in the face and skull of the patient [3]. The 3D patient data creates a step-wise guide toward accurate diagnosis, 3D cephalometric measurements, virtual planning of the surgical steps, and predicting the consequences of these steps on the dentoskeletal complex and soft tissue envelope [8]. Therefore, the virtual surgical planning (VSP) helps the orthodontist to predict hard and soft tissue changes after the surgery to optimize orthodontic preparation for surgery. It also allows orthognathic surgery planning as well as an accurate 3D printing of surgical splints [9] [10].

The three-dimensional virtual treatment planning involves many steps including data collection, pre-planning phase, planning session and manufacturing of surgical splints (**Figure 1**) [11].

The purpose of this review is to compare VSP and TSP in orthodontic-surgical treatment by highlighting the advantages and limits of each technique.

2. Comparison between VSP and TSP

Many studies explored the advantages between virtual surgical planning (VSP)

Data Collection

1. Obtain intraoral and extraoral photographs with a standardized background (white or blue wall)
2. Fabricate stone or digital models (intraoral scans) in reproducible centric occlusion
3. Deliver data to processing center for rendering (digital upload or physical media)
4. Often stone casts are sent with digital scans as reference mark to the final occlusion
5. Though optional, casts are particular helpful in segmental surgical planning

↓

Pre-Planning

1. Stone models are superimposed with CT images to check for inaccuracies
2. Once verified, scans are imported into digital cephalometric program such as Dolphin
3. Cephalometric points and planned osteotomies are imported into the digitized facial skeleton
4. Coordinate planning session with surgeon, engineer, and possibly orthodontist

↓

Planning Session (Digital Model Surgery)

1. First, assess for maxillary cant and maxillary dental and facial midline (refer to clinical photos)
2. Le Fort osteotomy is virtually placed based on anatomical landmarks (i.e. canine apices)
3. If required, interdental maxillary osteotomies can be placed at this time
4. Cephalometric measurements are placed in the lateral view (SNA, SNB, maxillary depth, etc.)
5. Determine vertical position of maxilla based on clinical photos
6. Once the maxilla is in the ideal position, the mandible can be placed into class 1 canine occlusion
7. The type of mandible osteotomy (SSO vs. VRO) should be made known to all planning members
8. A genioplasty can be virtually executed at this point, if necessary

↓

Manufacturing Considerations

1. Osteotomy guides are typically based on occlusal surfaces for stability
2. Occlusal splints are fabricated to guide the final position of the osteotomy segments
3. Stereolithic models allow evaluation of critical landmarks (i.e. neurovascular bundle)

Figure 1. Steps of virtual surgical planning in orthognatic surgery. SNA, Sella Nasion, A; SNB, Sella Nasion, B; SSO, Sagittal Split Osteotomy; VRO, Vertical Ramus Osteotomy [11].

and traditional surgical planning (TSP). They compared the accuracy of the procedure, the simulation of soft tissue, the improvement of communication, the surgical accuracy and the time and cost required.

2.1. Accuracy of the Procedure

The virtual planning eliminates some laboratory steps and reduces the errors associated to manual procedures. Thanks to the digital method, the setup is faster and more repeatable because the procedure is standardized and the teeth are moved with completely measurable parameters and values [1]. Three-dimensional cephalometry using standardized CT scanning protocols has the advantage that all measurements are life-sized scale (1:1), which allows both cross-sectional and longitudinal comparison of 3D distances, linear projective, and orthogonal measurements [12]. Three-dimensional imaging provides information and images of craniofacial structures free from perspective distortion, with none of the magnification or superimposition associated with 2D images [9].

The repeatability of this procedure would reduce human error in cephalometric analysis, in face-bow record and the assembly on the articulator. According to Xu *et al.* [13], the most common error that occurred in the articulator procedure was in reproducing the angle between the occlusal and the horizontal planes. A variable errors in terms of replicating the angulation of the occlusal plane were ranged from 1˚ to 20˚. This procedure caused excessive or insufficient movement in the vertical and sagittal direction. Quast *et al.* [14] found that in most cases, the angle in the sagittal dimension was higher in the articulator-based model than in the computer-based model. The angle in the transverse dimension was as often under- as over-represented. The type of malocclusion, skeletal class, vertical relationship, and degree of asymmetry, had no significant impact on the amount of error. Metzger *et al.* [12] reported that rotational and translational movements of the plaster models were insufficiently controlled during the model surgery stage. Ho *et al.* [15] also compared three-dimensional planning of the final digital occlusion with the conventional dental cast approach. They found that the proposed intraoral scan and setup process of the final digital occlusion was reliable and accurate.

Another advantage of virtual planning is that the clinician can evaluate how well the guides fit the dental arches without repeating alginate impression to evaluate presurgical results and without causing unfavorable phenomena such as jiggling movements [9].

2.2. Simulation of Soft Tissue

Prediction of surgical and orthodontic outcome also integrate the soft tissue envelope and photographic 3D images [16]. The ability to accurately simulate the response of soft tissues to planned surgical movements can be a viable tool for communication with patients and evaluating treatment options [17] [18]. The development of simulation software also provides the aesthetic standards for different populations (aesthetic-centered virtual planning) [8].

According to Chen *et al.* [4], the VSP technique showed clinically significantly greater precision for soft tissue prediction in the sagittal plane than the traditional technique. However, Elshebiny *et al.* [17] found that Dolphin 3D software had limitations in predicting midface soft tissue changes in patients who received a double-jaw surgery. Franto-nasal angle differences might be due Le Fort I osteotomies that can rotate the base of the nose superiorly after maxillary impactions or advancements, and widening of the alar bases with a tendency for the tip of the nose to rotate downward and back.

Therefore, only approximate results can be expected for the soft tissue. Virtual planning may be helpful to simulate the result after surgery, especially the position of the lips after orthognathic surgery, but has a lower precision when compared to the bones [19]. In some cases, soft tissue remodeling disharmony could occur after hard tissue changes [20].

2.3. Communication Improvement

Virtual surgery is a very powerful tutorial and communication tool for colleagues, trainees, and patients [19]. VSP has better visualization than articulator model surgery and can provide additional information and details about the case, as well as the potential problems that are supposed to occur during the operation [13]. The virtual simulation also facilitates communication between the different members of the treatment team especially the orthodontist and the maxillofacial surgeon. This is particularly useful when orthodontist and surgeon are separated by long distances as they can quite easily perform simulations together by computer and exchange comments, and even make "live" modifications [2].

Another advantage of digital planning is the improvement of data management, as all the information is stored in the computer [13].

2.4. Accuracy of the Surgery

A useful advantage of 3D planning is that it increases the knowledge of the anatomy of each particular patient because the surgical procedure has been performed several times before on "the same" virtual patient [19]. Virtual planning enables an accurate surgical plan, executed with precision during the real surgery and helps deciding the osteotomy line in surgical procedures, even when no cutting or positioning guides are made [9] [21]. It also allows orthodontists and surgeons to review the possible surgical options, which might produce more accurate and stable surgical outcome compared to conventional surgical planning [22] [23].

The comparison between VSP and TSP techniques showed a similar surgical accuracy for hard tissue in the sagittal plane, although the VSP technique was significantly more accurate in certain reference areas, especially in the anterior area of the maxilla. Both the VSP and TSP techniques had significantly better surgical accuracy for the maxilla than for the mandible. Accuracy in the coronal plane was regarded as the main disadvantage of the TSP technique, especially for the diagnosis and treatment of patients with asymmetric deformity [4]. Thus, the 3D planning was especially relevant for the correction of facial asymmetries [5].

Fawzy *et al.* [8] assessed the effect of the deformity pattern on the VSP applicability. Some aspects in planning, such as rotational movement of the maxillaemandibular complex around the Y axis (Yaw movement), were more predictable using the 3D virtual planning. Less VSP applicability was found in cleft-related dentofacial deformities compared to the noncleft group. This could be attributed to restricted movement of the maxillary segment because of scar tissue resulting from the primary cleft repair. Data analysis also revealed no significant difference in the VSP applicability between surgery-first and orthodontic-first groups.

VSP-driven workup was effective and accurate when comparing pre-treatment and post-treatment cephalometric measurements complications [11]. Growth and relapse considerations were factored into the plan. VSP allowed a virtual run through of different scenarios to arrive at the best overall treatment choice. Hence, 3D planning improved efficiency, accuracy and reproducibility in orthognathic surgery which reduced complications and reoperations [19] [24].

2.5. Time and Cost

Park *et al.* [25] found that the time investment in VSP was significantly smaller than that in conventional surgical planning, and the difference was greater in group I (Le Fort I osteotomy and bilateral sagittal split osteotomy) than in group II (only bilateral sagittal split osteotomy). According to Xu *et al.* [13], VSP planning took about three hours, while articulator model surgery required double the time of VSP.

Although the VSP technique requires more time for software planning, but it has an advantage in terms of time saving when considering the entire preoperative process [4]. Accompanied by the use of an accurate computer-aided splint, the VSP technique could effectively reduce the operative time [26]. These findings are significant because a prolonged operative time is closely correlated with increased postoperative complications [11].

Many studies compared the cost reduction between VSP and conventional planning. They revealed that the total cost of the VSP was similar to that of the traditional technique [4] [25]. Resnick *et al.* [26] found that VSP for bimaxillary orthognathic surgery was even less expensive than standard planning. However, high spending was required to buy machines and software, and patients had to pay more money, which was the most considered factor of VSP [13] [27].

3. Conclusions

The virtual planning has revolutionized the orthodontic-surgical treatment. It helps the orthodontist to plan the orthodontic movements and to predict hard and soft tissue changes that may occur as a result of the surgery.

VSP can simulate the orthognathic surgery and improve communication with patients and surgeons. It leads to more precision during surgery, fewer complications, and reduction of the operative time.

Virtual planning associated with 3D printing tremendously creates a more efficient process from presurgery to postsurgery. The guiding templates and splints fabricated by rapid prototyping technique enable precise control during surgery. However, there is a learning curve to develop proficiency using planning software and printer settings.

Acknowledgements

Special thanks to the Department of Orthodontics of the Faculty of Dentistry of the University Hassan II of Casablanca.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Farronato, G., Giannini, L., Galbiati, G., Pisani, L., Mortellaro, C. and Maspero, C. (2014) Verification of the Reliability of the Three-Dimensional Virtual Presurgical Orthodontic Diagnostic Protocol. *The Journal of Craniofacial Surgery*, **25**, 2013-2016. https://doi.org/10.1097/SCS.0000000000001046

[2] Dahan, S., Le Gall, M., Julié, D. and Salvadori, A. (2011) Nouveaux Protocoles d'élaboration des gouttières chirurgicales dans les traitements orthodontico-chirurgicaux. *International Orthodontics*, **9**, 42-62. https://doi.org/10.1016/j.ortho.2010.12.010

[3] Baan, F., de Waard, O., Bruggink, R., Xi, T., Ongkosuwito, E.M. and Maal, T.J.J. (2020) Virtual Setup in Orthodontics: Planning and Evaluation. *Clinical Oral Investigations*, **24**, 2385-2393. https://doi.org/10.1007/s00784-019-03097-3

[4] Chen, Z., Mo, S., Fan, X., You, Y., Ye, G. and Zhou, N. (2021) A Meta-Analysis and Systematic Review Comparing the Effectiveness of Traditional and Virtual Surgical Planning for Orthognathic Surgery: Based on Randomized Clinical Trials. *Journal of Oral and Maxillofacial Surgery*, **79**, E1-471. https://doi.org/10.1016/j.joms.2020.09.005

[5] Sun, Y., Luebbers, H.-T., Agbaje, J.O., Schepers, S., Vrielinck, L. and Lambrichts, I. (2013) Accuracy of Upper Jaw Positioning with Intermediate Splint Fabrication after Virtual Planning in Bimaxillary Orthognathic Surgery. *Journal of Craniofacial Surgery*, **24**, 1871-1876. https://doi.org/10.1097/SCS.0b013e31829a80d9

[6] Levine, J.P., Patel, A., Saadeh, P.B. and Hirsch, D.L. (2012) Computer-Aided Design and Manufacturing in Craniomaxillofacial Surgery: The New State of the Art. *Journal of Craniofacial Surgery*, **23**, 288-293. https://doi.org/10.1097/SCS.0b013e318241ba92

[7] Hatamleh, M., Turner, C., Bhamrah, G., Mack, G. and Osher, J. (2016) Improved Virtual Planning for Bimaxillary Orthognathic Surgery. *Journal of Craniofacial Surgery*, **27**, 568-573. https://doi.org/10.1097/SCS.0000000000002877

[8] Fawzy, H.H. and Choi, J.-W. (2019) Evaluation of Virtual Surgical Plan Applicability in 3D Simulation-Guided Two-Jaw Surgery. *Journal of Cranio-Maxillofacial Surgery*, **47**, 860-866. https://doi.org/10.1016/j.jcms.2019.03.005

[9] Farronato, G., Galbiati, G., Esposito, L., Mortellaro, C., Zanoni, F. and Maspero, C. (2018) Three-Dimensional Virtual Treatment Planning: Presurgical Evaluation. *Journal of Craniofacial Surgery*, **29**, 433-437. https://doi.org/10.1097/SCS.0000000000004455

[10] Yi, C.R. and Choi, J.-W. (2019) Three-Dimension-Printed Surgical Guide for Accurate and Safe Mandibuloplasty in Patients with Prominent Mandibular Angles. *Journal of Craniofacial Surgery*, **30**, 1979-1981. https://doi.org/10.1097/SCS.0000000000005626

[11] Hua, J., Aziz, S. and Shum, J.W. (2019) Virtual Surgical Planning in Oral and Max-

illofacial Surgery. *Oral and Maxillofacial Surgery Clinics of North America*, **31**, 519-530. https://doi.org/10.1016/j.coms.2019.07.011

[12] Metzger, M.C., Hohlweg-Majert, B., Schwarz, U., Teschner, M., Hammer, B. and Schmelzeisen, R. (2008) Manufacturing Splints for Orthognathic Surgery Using a Three-Dimensional Printer. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, **105**, E1-E7. https://doi.org/10.1016/j.tripleo.2007.07.040

[13] Xu, R., Ye, N., Zhu, S., Shi, B., Li, J. and Lai, W. (2020) Comparison of the Postoperative and Follow-Up Accuracy of Articulator Model Surgery and Virtual Surgical Planning in Skeletal Class III Patients. *British Journal of Oral and Maxillofacial Surgery*, **58**, 933-939. https://doi.org/10.1016/j.bjoms.2020.04.032

[14] Quast, A., Santander, P., Witt, D., Damm, A., Moser, N. and Schliephake, H. (2019) Traditional Face-Bow Transfer versus Three-Dimensional Virtual Reconstruction in Orthognathic Surgery. *International Journal of Oral & Maxillofacial Surgery*, **48**, 347-354. https://doi.org/10.1016/j.ijom.2018.09.001

[15] Ho, C.-T., Lin, H.-H. and Lo, L.-J. (2019) Intraoral Scanning and Setting Up the Digital Final Occlusion in Three-Dimensional Planning of Orthognathic Surgery: Its Comparison with the Dental Model Approach. *Plastic and Reconstructive Surgery*, **143**, 1027-1036. https://doi.org/10.1097/PRS.0000000000005556

[16] Plooij, J.M., Maal, T.J.J., Haers, P., Borstlap, W.A., Kuijpers-Jagtman, A.M. and Bergé, S.J. (2011) Digital Three-Dimensional Image Fusion Processes for Planning and Evaluating Orthodontics and Orthognathic Surgery. A Systematic Review. *International Journal of Oral & Maxillofacial Surgery*, **40**, 341-352. https://doi.org/10.1016/j.ijom.2010.10.013

[17] Elshebiny, T., Morcos, S., Mohammad, A., Quereshy, F. and Valiathan, M. (2019) Accuracy of Three-Dimensional Soft Tissue Prediction in Orthognathic Cases Using Dolphin Three-Dimensional Software. *Journal of Craniofacial Surgery*, **30**, 525-528. https://doi.org/10.1097/SCS.0000000000005037

[18] Wang, P., Wang, Y., Zhang, Z., Li, X., Ye, B. and Li, J. (2018) Comprehensive Consideration and Design with the Virtual Surgical Planning-Assisted Treatment for Hemifacial Microsomia in Adult Patients. *Journal of Cranio-Maxillofacial Surgery*, **46**, 1268-1274. https://doi.org/10.1016/j.jcms.2018.05.004

[19] Rubio-Palau, J., Prieto-Gundin, A., Cazalla, A.A., Serrano, M.B., Fructuoso, G.G. and Ferrandis, F.P. (2016) Three-Dimensional Planning in Craniomaxillofacial Surgery. *Annals of Maxillofacial Surgery*, **6**, 281-286. https://doi.org/10.4103/2231-0746.200322

[20] Wang, P., Zhang, Z., Wang, Y., Li, X., Ye, B. and Li, J. (2019) The Accuracy of Virtual-Surgical-Planning-Assisted Treatment of Hemifacial Microsomia in Adult Patients: Distraction Osteogenesis vs. Orthognathic Surgery. *International Journal of Oral & Maxillofacial Surgery*, **48**, 341-346. https://doi.org/10.1016/j.ijom.2018.07.026

[21] Ying, B., Ye, N., Jiang, Y., Liu, Y., Hu, J. and Zhu, S. (2015) Correction of Facial Asymmetry Associated with Vertical Maxillary Excess and Mandibular Prognathism by Combined Orthognathic Surgery and Guiding Templates and Splints Fabricated by raPid Prototyping Technique. *International Journal of Oral & Maxillofacial Surgery*, **44**, 1330-1336. https://doi.org/10.1016/j.ijom.2015.05.012

[22] Zinser, M.J., Mischkowski, R.A., Sailer, H.F. and Zöller, J.E. (2012) Computer-Assisted Orthognathic Surgery: Feasibility Study Using Multiple CAD/CAM Surgical Splints. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, **113**, 673-687. https://doi.org/10.1016/j.oooo.2011.11.009

[23] Hong, M., Kim, M-J., Shin, H.J., Cho, H.J. and Baek, S-H. (2020) Three-Dimensional Surgical Accuracy between Virtually Planned and Actual Surgical Movements of the Maxilla in Two-Jaw Orthognathic Surgery. *The Korean Journal of Orthodontics*, **50**, 293-303. https://doi.org/10.4041/kjod.2020.50.5.293

[24] Steinbacher, D.M. (2015) Three-Dimensional Analysis and Surgical Planning in Craniomaxillofacial Surgery. *Journal of Oral and Maxillofacial Surgery*, **73**, 40-56. https://doi.org/10.1016/j.joms.2015.04.038

[25] Park, S.-Y., Hwang, D.-S., Song, J.-M. and Kim, U.-K. (2019) Comparison of Time and Cost between Conventional Surgical Planning and Virtual Surgical Planning in Orthognathic Surgery in Korea. *Maxillofacial Plastic and Reconstructive Surgery*, **41**, Article No. 35. https://doi.org/10.1186/s40902-019-0220-6

[26] Resnick, C.M., Inverso, G., Wrzosek, M., Padwa, B.L., Kaban, L.B. and Peacock, Z.S. (2016) Is There a Difference in Cost Between Standard and Virtual Surgical Planning for Orthognathic Surgery? *Journal of Oral and Maxillofacial Surgery*, **74**, 1827-1833. https://doi.org/10.1016/j.joms.2016.03.035

[27] Adolphs, N., Haberl, E-J., Liu, W., Keeve, E., Menneking, H. and Hoffmeister, B. (2014) Virtual Planning for Craniomaxillofacial Surgery—7 Years of Experience. *Journal of Cranio-Maxillofacial Surgery*, **42**, 289-295. https://doi.org/10.1016/j.jcms.2013.10.008