Available online at www.sciencedirect.com

ScienceDirect

British Journal of Oral and Maxillofacial Surgery 60 (2022) 1184–1191

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Systematic review

Virtual and traditional surgical planning in orthognathic surgery – systematic review and meta-analysis

S. Alkaabi [a,b,*], Melvin Maningky [d], Marco N Helder [b], G. Alsabri [b,c]

[a] Oral & Maxillofacial surgeon, Dept. of Oral and Maxillofacial Surgery, Fujairah Hospital, Emirates Health Services, United Arab Emirates
[b] Dept. of Oral and Maxillofacial Surgery/Oral Pathology, Amsterdam University Medical Centers and Academic Centre for Dentistry Amsterdam (ACTA), Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, the Netherlands
[c] Oral & Maxillofacial surgeon, Private practitioner, United Arab Emirates
[d] Oral & Maxillofacial surgeon, Dept. of Oral and Maxillofacial Surgery, Fujairah Hospital, Emirates Health Services, United Arab Emirates

Accepted 18 July 2022
Available online 29 July 2022

Abstract

Traditional surgical planning (TSP) and virtual surgical planning (VSP) have been used in bimaxillary osteotomy planning. The time is taken in the planning and operating stages, and the working/doctor/total time of either approach are useful determinants of the efficiency of the operating method and quality of care. This systematic review and meta-analysis examined if VSP has a comparative advantage over TSP in the bimaxillary osteotomy. Cochrane Library, PubMed, EMBASE, and Google Scholar were used as databases to collect studies that met the outlined inclusion criteria based on PRISMA. Eight of 759 studies were considered to meet the eligibility criteria, and six fit for meta-analysis. The findings demonstrated significant VSP advantage over TSP in planning time (Z = 3.97 ($p < 0.00001$), WMD = −5.29 (CI −7.90 to −2.68)). While more time-efficient than TSP, the difference with VSP was not significant during surgery (Z = 0.44 ($p = 0.66$), WMD = −0.10 (CI −0.51 to 0.34)). The study used random effects due to the high I^2 of the planning mean differences. The continued evolution of VSP and improved application knowledge will be important in reducing the time of planning and surgery, thus improving the outcomes of the complex bimaxillary osteotomy. The current evidence shows that VSP significantly performs better than TSP in reducing the bimaxillary osteotomy planning time, but the timing difference is not significant during surgery. Future analysis will benefit from using studies with standard research and reporting metrics and procedures, thus improving evidence-based clinical practice.

Keywords: Orthognathic Surgery; Traditional surgical planning; Virtual surgical planning

Introduction

Orthognathic surgery is a delicate process that relies on rigorous preoperative planning, accurate implementation of the selected operative plan, and postoperative care to be successful.[1] Over six decades, orthognathic surgery has evolved to become safer, faster, less costly, and more successful.[2,3] Traditional surgical planning (TSP) such as manual model surgery, the use of photographs, and two-dimensional radiographs have been conventionally used at the preoperative stage of orthognathic surgery.[4] Virtual surgical planning (VSP) approaches have increasingly been used as an alternative to TSP. The computer-aided surgical simulations used in VSP have offered surgeons a three-dimensional (3D) facial skeleton, soft tissue, and dentition representation to facilitate virtual diagnosis and surgery.[2,5]

The comparison between VSP and TSP is not straightforward across different outcomes. While VSP has been presented as a superior alternative to TSP, researchers have questioned whether the VSP technique's accuracy is higher than TSP.[3] TSP has, however, been identified to be superior from a cost perspective. However, the TSP cost advantage was present after the initial fixed cost investment in VSP.[1] In their systematic review and meta-analysis, Chen et al[1]

* Corresponding author at: Oral & Maxillofacial surgeon, Dept. of Oral and Maxillofacial Surgery, Fujairah Hospital, Emirates Health Services, United Arab Emirates.
E-mail address: al_kaabi33@hotmail.com (S. Alkaabi).

https://doi.org/10.1016/j.bjoms.2022.07.007
0266-4356/

found that VSP and TSP are comparable in accuracy prediction in the sagittal plane. The findings emphasise the need to evaluate specific outcomes of VSP and TSP when used in a specific osteotomy.

Bimaxillary osteotomy is a common yet complex surgical procedure that requires rigorous planning and accurate operation. Accuracy, time, and cost are key considerations when evaluating the treatment procedure in bimaxillary osteotomy.[6,7] The time that has to be considered in comparing the effectiveness of VSP and TSP includes the planning time, operating time, and the working/doctor/total time.[2,7,8] Ideally, shorter operating times are preferred as they ensure lower risk and less anaesthesia and blood loss, while shorter planning time ensures that necessary or urgent care is not delayed.[1] The total time helps determine the efficiency and cost of the approach used in bimaxillary osteotomy.[2,9,10,11]

The purpose of this study is to systematically review and perform meta-analysis on orthognathic surgery literature to determine if VSP is superior to TSP in terms of time-consumption in bimaxillary orthognathic surgery.

Material and methods

Protocol

The Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) was the protocol of this systematic review and meta-analysis. The guidelines provided on PRISMA were followed in defining the inclusion criteria for this systematic review and meta-analysis. Two independent reviewers searched, reviewed, and extracted eligible articles based on the inclusion criteria. The author, however, had the final decision-making responsibility in the areas that had contention or disagreement.

Search strategy

The articles considered and used in the systematic review and meta-analysis were extracted from Cochrane Library, PubMed, EMBASE, and Google Scholar. The bias standards outlined in PRISMA were adhered to in the search to ensure the credibility of the sources. The medical subject heading (MesSH) terms that were used as search keywords include “virtual surgery planning,” “VSP,” “traditional surgical planning,” “conventional surgical planning,” “computer-, “three-dimensional surgical planning,” “3D surgical planning”, “two-dimensional surgical planning,” “2D surgical planning”, “bimaxillary osteotomy,” “bimaxillary orthognathic surgery,” “double jaw surgery,” “surgical time,” “operating time,” “total time,” and “doctor time.” These keywords were used in different combinations across all databases.

The search was limited to studies published between 2014 and 2021. Non-English, editorial perspective, editorial letter, and literature reviews were excluded from the study. The studies that focused solely on single jaw osteotomy were also excluded. A summary of the selected studies was provided with the author’s name, year of publication, topic, location, sample size, nature and focus of study, primary outcomes, and secondary outcomes is presented as descriptive data.

Eligibility criteria

The inclusion criteria focused on the studies that compared VSP and TSP the planning, operating, and total time in the bimaxillary osteotomy. The studies that explicitly mentioned bimaxillary osteotomy or double-jaw surgery were included. The studies that focused on single jaw osteotomy were excluded. The studies solely focused on the ischaemia time were also excluded due to scarcity and inability to meet the earlier set bimaxillary osteotomy criteria. The studies with history of previous osteotomy were also excluded.

While the study prioritised random control trials (RTCs), retrospective cohort studies and other cohort studies were included in the search. The full-text analysis was used to determine consistency in meta-analysis’s measured outcomes and metrics.

Data extraction

The selected studies were assessed for risk bias based on the Cochrane Handbook of Systematic Reviews of Interventions.[10] The studies were assigned equal weight and assessed based on the randomisation process, missing outcome data, deviations from intended intervention, selection of the reported result, and the measurement of the outcome. The extraction identified the primary and secondary outcomes of each included study. The study’s sample sizes, mean, median, standard deviations (SD), and interquartile ranges were extracted for analysis. This systematic review and meta-analysis use Hozo et al[11] to convert interquartile ranges (IQR) to standard deviation with the median held as the mean. The other extracted information includes demographics, interventions, and the study groups.

Data analysis

The collected data were analysed to compare the planning, operation, and total time for bimaxillary orthognathic surgery in VSP and TSP. Additionally, statistical analysis was performed by pooling the studies and examining the two groups (VSP and TSP) for the surgical and planning time outcomes. Only one paper studied the difference in total time,[2] thus making the statistical analysis through forest plots ineffective. Review Manager Software version 5.4 (RevMan 5.4) was used in the statistical analysis. The I^2 statistic in the generated forest plots was used to examine the heterogeneity among the selected studies, and accordingly either fixed or random-effects approach was applied. The forest plot was used to determine the distribution of the studies.

Results

Study selection

A total of 759 studies were screened and considered for inclusion in the systematic review and meta-analysis. Of these, 74 were excluded for duplication. An additional 299 were excluded for being case reports (51), literature analysis (31), reviews (44), literature reviews (17), systematic reviews and meta-analysis (89), and commentaries (67). Of the remaining studies, 207 were excluded for using the intervention that was not targeted, measuring other outcomes, or including patients in only the single jaw osteotomy. The full-text screening was performed on the remaining sources leading to the exclusion of another 103 studies for the lack of full-text publications. Additional, 67 studies were excluded for lacking control groups and incomplete reporting of critical measures. A total of 6 studies were left after the screening to be used in the statistical meta-analysis section, and another 2 used in the narrative analysis section of this study (Table 1). The PRISMA diagram below (Fig. 1) summarises the selection, screening, elimination, and inclusion of studies for this systematic review and meta-analysis. The eight studies included in this systematic review and meta-analysis investigated the bimaxillary osteotomy surgery. All studies had one experimental and control group of VSP (N = 161) or TSP (N = 171). The other characteristics of the included studies are presented in (Table 1). (Table 2) provides the statistical measures of the targeted outcomes.

Quality of studies

The included studies were evaluated for their usefulness in this systematic analysis and meta-analysis. Only one was reviewed by an independent data monitoring committee of the included studies. None of the studies included an enrolment flow diagram, though they all described their eligibility criteria and included and excluded patients. The Cochrane Library Risk of Bias (RoB) tool evaluated the studies. The risk of bias was classified as either high, low, or uncertain. Overall, most studies were of low risk, with data and methodological concerns used only in the narrative analysis. The RoB tool used the measures of the randomisation process, missing outcome data, deviations from intended intervention, selection of the reported result, and the measurement of the outcome to evaluate the risks (Fig. 2).

Statistical results for the planning time

Six studies discussed the planning time, however only four of them have sufficient data for meta-analysis.[6,7,9,12] One of the four studies have measured the planning time in three different groups and were included as three different measures. The diamond shape on the forest plot in (Fig. 3) does not touch the line of no effect and is on the left side. This implies that VSP is significantly favoured for its time-saving ability in the planning phase compared to TSP. Individually, all statistically analysed studies[6,7,9,12] reported a significant advantage of VSP compared to TSP in saving planning time.

A low heterogenicity could have been achieved by excluding Wrzosek et al (2016) and Park et al (2021) (I^2 of 0%). However, these two studies included anyway (Heterogeneity: $Tau^2 = 8.30$; $Chi^2 = 53.46$, df = 5 ($p < 0.00001$) I^2 of 91%) since the overall results didn't differ (Fig. 3). Hence, the random effects rather than fixed effects treatment are applied to the analysis.

The meta-analysis showed that the planning time in VSP is significantly shorter than TSP ($p < 0.00001$). The weighted mean difference (WMD) was −5.29 (CI −7.90 to −2.68).

Statistical results for the surgical time

The sample results of the included two studies with regards to surgical time were used in the meta-analysis since they were highly homogenous given their low level of heterogeneity. The I^2 of 0% is evidence of the high homogeneity. In the case of the comparison for the surgical time, the $I^2 = 0\%$ Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.58$, df = 1 (P = 0.44). At 95% confidence level, the overall effect of Z = 0.44 (P = 0.66) with a WMD of −0.10 (CI −0.51 to 0.34) for surgical timing. The diamond shape on the forest plot in (Fig. 4) touches the line of no effect. This implies that the difference between the groups that went through surgery after VSP and those in the TSP condition was insignificant (P = 0.66). These statistics demonstrate the forest plots' fit in comparing the surgical times for VSP and TSP (Fig. 4).

Discussion

In this systematic review, eight studies were reviewed to compare VSP and TSP as methods of planning bimaxillary orthognathic surgery. Despite articles covering other areas such as soft tissue or hard tissue accuracy and precision, this analysis narrowed to three aspects: planning time, surgery time, and total time.

CT scan data in the reconstruction of 3D maxillofacial images has been in place since the 1980s.[1] The improved quality of VSP has followed over the last two decades as technology has advanced. The slow practical application of these technological advancements has been identified to contribute to the slight differences in the time advantage of VSP over TSP in some studies. Wrzosek et al (2016)[12] demonstrated that other variables might determine the planning time. With the study using post-graduate trainees, the time was significantly prolonged given limited experience using these technologies. The time in both VSP and TSP conditions was long in the study when compared to other studies. This could be explained by the fact that most of the planning steps in the TSP were performed by residents under supervision of their surgeon, and in VSP the planning was performed through an online discussion between the clinician and a software engineer.

Table 1
Studies Characteristics.

No	Author	Country	Journal	Centre	Total Patient			Age		Procedure	Design Study	Outcome parameter	
					VSP	**TSP**	**Total**	**VSP**	**TSP**			**Primary**	**Secondary**
1	Resnick et al 2016[7]	USA	J Oral Maxillofac Surg	1	20	23	43	-	-	bimaxillary orthognathic surgery	Retrospective cohort study	• Average planning times	• Average cost
2	Van et al 2015[13]	Belgium	Journal of Cranio-Maxillo-Facial Surgery	1	38	31	69	19.78		bimaxillary orthognathic surgery	RCT	• Soft tissue accuracy	• Planning time • Postoperation patient satisfaction
3	Park et al 2021[6]	Korea	Maxillofacial Plastic and Reconstructive Surgery	1	10	10	20	-	-	Le Fort I osteotomy + bilateral sagittal split osteotomy [LFI+BSSO]	Retrospective cohort study	• Average planning times	• Average cost
4	Schwartz 2014[2]	USA	Int. J. Oral Maxillofac. Surg	1	30	30	60	28.3 (16–54)	25.6 (16–49)	bimaxillary orthognathic surgery	RCT	• Doctor time • Surgical time	• Visit count
5	Schneider et al 2019[8]	Germany	Clin Oral Investig	1	9	12	21	Average (31.1) Median (32.6, 23–52.1)		two-jaw orthognathic surgery	RCT	• Accuracy of defined angles.	• Accuracy of the splints • Time required for surgery • Costs
6	Steinhuber et al 2018[9]	Austria	Journal of Oral and Maxillofacial Surgery	1	11	11	22	24.6 ± 7.9		bimaxillary orthognathic surgery	Prospective cohort study	• Working time	• Profession • Location • Surgeon time
7	Wrzosek et al 2016[12]	USA	Journal of Oral and Maxillofacial Surgery	1	41	41	82	-		bimaxillary orthognathic surgery	Prospective cohort study	• Planning time in Traditional vs. VSP	• Planning time in simple, complex, and multi-piece operations
8	Hanafy et al 2020[14]	Egypt	Journal of Oral and Maxillofacial Surgery	1	9	9	18	21.22(19–24)		bimaxillary orthognathic surgery	Double-blind, randomized controlled clinical study	• Angular measurements	• Wound healing*Deviation from plan*Planning time*Operative time

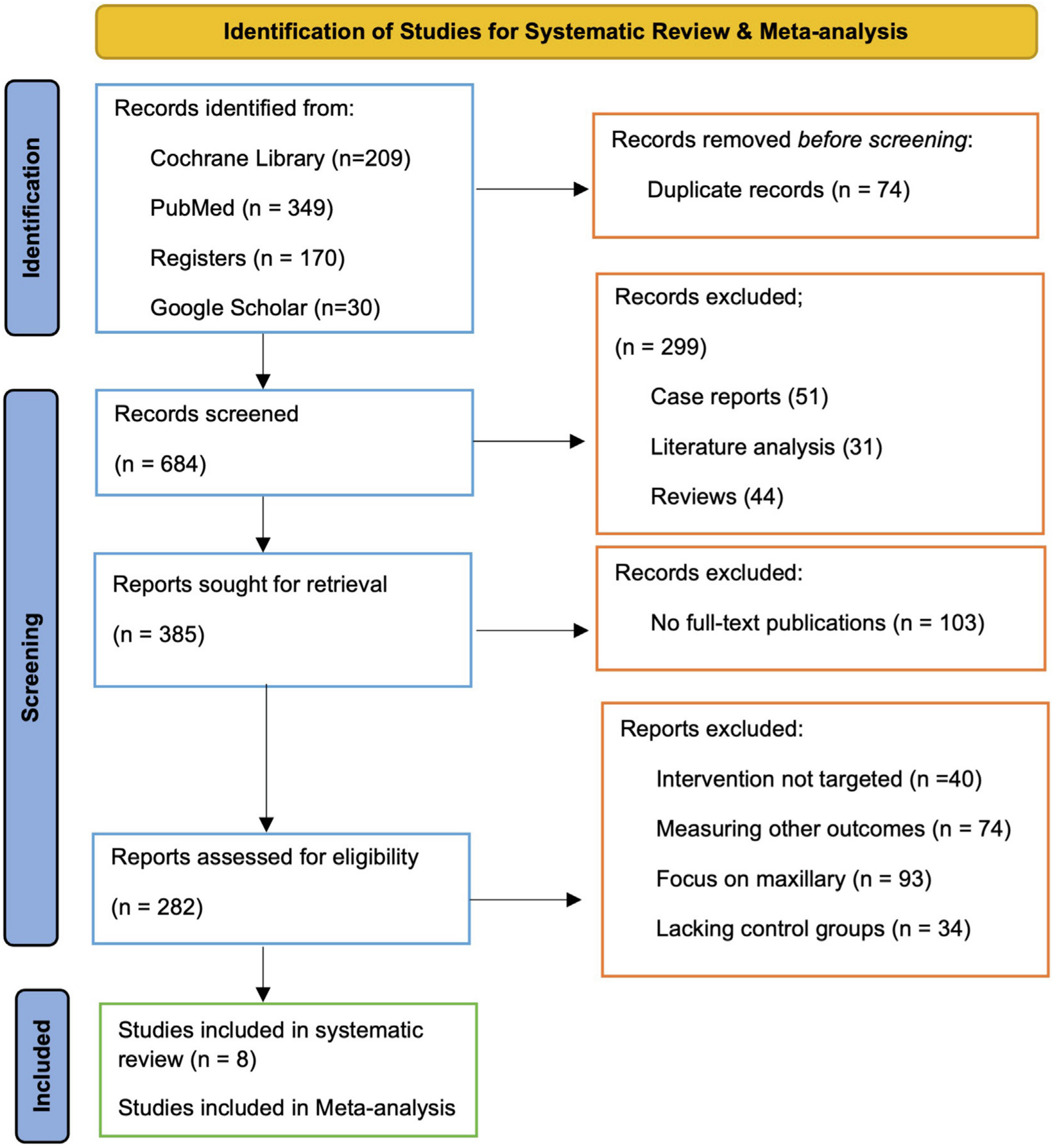

Fig. 1. PRISMA Flow Diagram.

Table 2
Studies outcomes.

		VSP			TSP		
Unique ID		Mean	SD	Total	Mean	SD	Total
Schwartz 2014[2]	Surgical	250	11.2	30	250	11.2	30
Schwartz 2014[2]	Total	805	134.1	30	865	134.1	30
Park et al 2021[6]	Planning	143.2	7.6	10	385	7.8	10
Resnick et al 2016[7]	Planning - symmetric, nonsegmental (Group 1)	188	17.8	9	524.4	86.1	10
Resnick et al 2016[7]	Planning – asymmetric (Group 2)	187.4	10.9	8	556.1	94.1	9
Resnick et al 2016[7]	Planning – segmental (Group 3)	208.8	13.5	3	542.3	118.4	4
Schneider et al 2019[8]	Surgical	162	88.1	9	202	103.7	12
Steinhuber et al 2018[9]	Planning	149.6	15.3	11	224.1	11.2	11
Wrzosek et al 2016[12]	Planning	306	64.8	41	447	87.6	41
Van et al 2015[13]	Planning	38	N/A	31	20	N/A	35
Hanafy et al 2020[14]	Planning	113	N/A	9	192	N/A	9
Hanafy et al 2020[14]	Operative	49	N/A	9	72	N/A	9

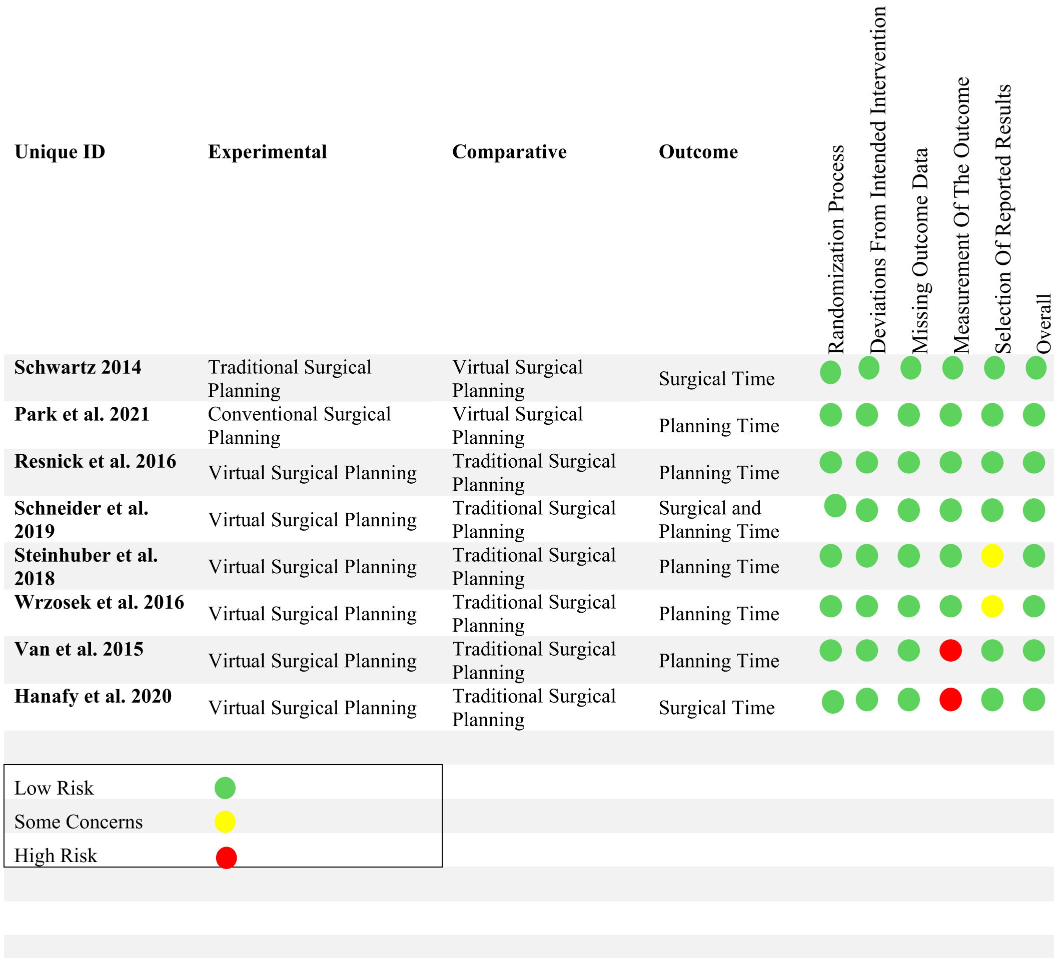

Fig. 2. RoB Diagram.

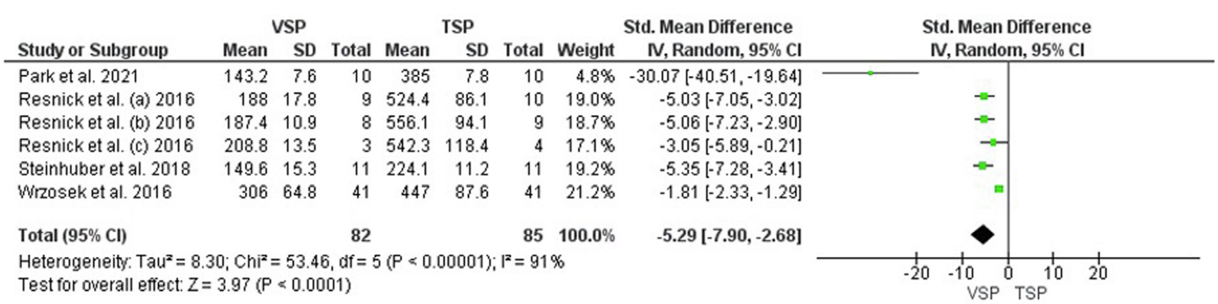

Fig. 3. The forest plot of the planning time comparison between the VSP group and the TSP group.

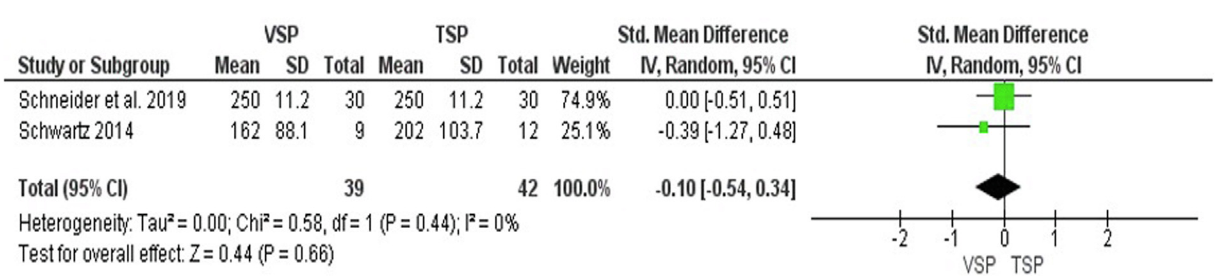

Fig. 4. The forest plot of the surgical time comparison between the VSP group and the TSP group.

VSP is not an entirely new technology, the learning curve can be instrumental in reducing the time in using it in the planning.[1,15] This systemic review and meta-analysis sought to determine the significance of the theorised advantage of VSP and evaluate if the learning curve reduces the ability to realise these gains.

The studies used in the statistical analysis of the comparative surgery timing advantage of VSP over TSP were both RCTs.[2,8] The statistical analysis showed that TSP was a significant time-consumer relative to VSP in planning. VSP outperformed TSP during surgery, the difference was not significant. The insights gained from the individual studies and pooled effects demonstrate a strong case for the preference towards VSP over TSP.

Planning time

The studies defined the TSP is the process required to complete the preoperative planning (including radiographs, 2D analysing, model surgery and surgical splints) while the VSP was defined as the tool for predicting complex surgical movement in three dimensions (including radiographs, clinical photographs, production and scanning the plaster models, virtual analysis and 3D printing of the surgical splints).[6,7,12]

Our meta-analysis showed that VSP is significantly favoured for its time-saving ability in the planning phase compared to TSP. All of the included studies individually showed that less time was required when VSP method was adopted compared to TSP.[6,7,9,12] Wrzosek et al[12] found that the advantage persisted irrespective of the complexity of the case with savings of 2.19 ± 0.93 h (30.1%), 2.22 ± 1.74 h (29.0%), and 1.98 ± 0.80 h (26.3%) in simple cases, complex cases, and multisegmented cases respectively. The findings were also consistent in the studies by Resnick[7] who also showed that the advantage persisted in symmetric, nonsegmental, asymmetric, and segmental groups. Hanafy et al[14] found that the time between the virtual plan to STL export was 113 while TSP took 192 minutes from maxillary incision to fixation.

The planning timing studies agreed on the significant advantage of VSP. It is important to understand the area that accounts for the planning advantage in VSP compared to TSP. Van et al[13] found statistically significant differences in soft tissue planning, but the difference was not significant in complex tissue planning.

Surgery time

The surgery time should ideally be short to limit the loss of blood, use of anaesthesia, and risk of errors. In (Fig. 4) the forest plot showed that the difference between the groups that went through surgery after VSP and those in the TSP condition was insignificant.

Schwartz[2] found that the surgical times were the same at 250 minutes for both VSP and TSP. The researcher, however, noticed that residents were responsible for most surgeries. This finding, along with Wrzosek et al (2016),[12] provides an important caveat when evaluating the difference between VSP and TSP time. The potential impact of inexperience can account for the insignificant differences in VSP and TSP time. The findings are different from the recent study by Chen et al that reported a significant difference in surgery time with TSP taking longer than VSP.[1] The difference in the included studies contributes to this difference is significance. Including studies that looked at both maxillary and bimaxillary surgeries could explain the difference.

Hanafy et al[14] demonstrated that VSP was particularly advantageous over TSP especially for trainees and junior surgeons. This is because it can precisely detect bone/root morphology compared to TSP. The finding illustrates that both TSP and VSP are beneficial in offering the guidance necessary to complete the surgery. The finding also emphasises the need for examining VSP as an approach that might save time by reducing the errors during surgery.[16,17] Such advantage is likely to reduce for experienced practitioners who are accustomed to TSP and less prone to making errors irrespective of the method used.

Total time

Two studies[2,9] looked at the total time from planning through the surgery to the postoperative stages. While the studies could not be statistically analysed due to missing values, narrative analysis can be performed on the researchers' findings. In their study, Steinhuber[9] found that the total working time reduction was significant when moving from TSP to VSP in double-jaw surgeries. The reduced time difference in the double-jaw surgeries compared to the single jaw surgery is evidence of the complexity of bimaxillary surgeries, thus the need for efficient processes. Significant time savings in VSP emerged from the surgeon and technician laboratory work in the total time.

Limitations

The limited number of RCTs is a legitimate concern when examining the comparative advantage of VSP over TSP. With most studies being retrospective studies, there is a risk that researcher selection bias might affect the quality of the results. This study prioritised RCTs but confronted the reality of limited RCT design in the current literature focused on time. The studies used in this study had small sample sizes. Larger samples in future studies will also be necessary for performing a comparative analysis of VSP and TSP.

Conclusion

VSP significantly performs better than TSP in reducing the bimaxillary osteotomy planning time, but the timing difference is not significant during surgery. While the statistical analysis shows that bimaxillary osteotomy planning time can be improved through improved knowledge among healthcare practitioners on how to use the relatively new technologies.

Ethics statement/confirmation of patients' permission

Not required.

Conflict of interest

No conflict of interest.

References

1. Chen Z, Mo S, Fan X, et al. A meta-analysis and systematic review comparing the effectiveness of traditional and virtual surgical planning for orthognathic surgery: based on randomized clinical trials. *J Oral Maxillofac Surg* 2021;**79**(2):471–e1.
2. Schwartz HC. Does computer-aided surgical simulation improve efficiency in bimaxillary orthognathic surgery? *Int J Oral Maxillofac Surg* 2014;**43**(5):572–576. https://doi.org/10.1016/j.ijom.2013.10.018, Epub 2013 Dec 11 PMID: 24332585.
3. Wang YY, Fan S, Zhang HQ, et al. Virtual Surgical Planning in Precise Maxillary Reconstruction With Vascularized Fibular Graft After Tumor Ablation. *J Oral Maxillofac Surg* 2016;**74**(6):1255–1264. https://doi.org/10.1016/j.joms.2016.01.010, Epub 2016 Jan 9 PMID: 26851316.
4. Brown SA, Levi B, Lequex C, et al. Basic science review on adipose tissue for clinicians. *Plast Reconstr Surg* 2010;**126**(6):1936–1946.
5. Alkhayer A, Piffkó J, Lippold C, Segatto E. Accuracy of virtual planning in orthognathic surgery: a systematic review. *Head Face Med* 2020 Dec;**16**(1):1–9.
6. Park SY, Hwang DS, Song JM, et al. Comparison of time and cost between conventional surgical planning and virtual surgical planning in orthognathic surgery in Korea. *Maxillofac Plast Reconstr Surg* 2021;**43**(1):18. https://doi.org/10.1186/s40902-021-00305-7, PMID: 34152473; PMCID: PMC8217346.
7. Resnick CM, Inverso G, Wrzosek M, et al. Is There a Difference in Cost Between Standard and Virtual Surgical Planning for Orthognathic Surgery? *J Oral Maxillofac Surg* 2016;**74**(9):1827–1833. https://doi.org/10.1016/j.joms.2016.03.035, Epub 2016 Apr 22 PMID: 27181623.
8. Schneider D, Kämmerer PW, Hennig M, et al. Customized virtual surgical planning in bimaxillary orthognathic surgery: a prospective randomized trial. *Clin Oral Investig* 2019;**23**(7):3115–3122. https://doi.org/10.1007/s00784-018-2732-3, Epub 2018 Nov 15 PMID: 30443778.
9. Steinhuber T, Brunold S, Gärtner C, et al. Is Virtual Surgical Planning in Orthognathic Surgery Faster Than Conventional Planning? A Time and Workflow Analysis of an Office-Based Workflow for Single- and Double-Jaw Surgery. *J Oral Maxillofac Surg* 2018 Feb;**76**(2):397–407. https://doi.org/10.1016/j.joms.2017.07.162, Epub 2017 Jul 25 PMID: 28826783.
10. Higgins J, Thomas J, Chandler J, et al. Cochrane Handbook for Systematic Reviews of Interventions [Internet]. 6.0. Cochrane Library; 2019. Available from: https://training.cochrane.org/handbook/archive/v6.
11. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and sample size. *BMC Med Res Methodol* 2005;**20**(5):13. https://doi.org/10.1186/1471-2288-5-13, PMID: 15840177; PMCID: PMC1097734.
12. Wrzosek MK, Peacock ZS, Laviv A, et al. Comparison of time required for traditional versus virtual orthognathic surgery treatment planning. *Int J Oral Maxillofac Surg* 2016 Sep;**45**(9):1065–1069. https://doi.org/10.1016/j.ijom.2016.03.012, Epub 2016 Apr 18 PMID: 27102289.
13. Van Hemelen G, Van Genechten M, Renier L, et al. Three-dimensional virtual planning in orthognathic surgery enhances the accuracy of soft tissue prediction. *J Craniomaxillofac Surg* 2015 Jul;**43**(6):918–925. https://doi.org/10.1016/j.jcms.2015.04.006, Epub 2015 Apr 30 PMID: 26027866.
14. Hanafy M, Akoush Y, Abou-ElFetouh A, et al. Precision of orthognathic digital plan transfer using patient-specific cutting guides and osteosynthesis versus mixed analogue-digitally planned surgery: a randomized controlled clinical trial. *Int J Oral Maxillofac Surg* 2020 Jan;**49**(1):62–68. https://doi.org/10.1016/j.ijom.2019.06.023, Epub 2019 Jun 29 PMID: 31262680.
15. Marlière DA, Demétrio MS, Schmitt AR, et al. Accuracy between virtual surgical planning and actual outcomes in orthognathic surgery by iterative closest point algorithm and color maps: A retrospective cohort study. *Med Oral Patol Oral Cir Bucal* 2019;**24**(2):e243–e253. https://doi.org/10.4317/medoral.22724, PMID: 30818318; PMCID: PMC6441591.
16. Rustemeyer J, Sari-Rieger A, Melenberg A, et al. Comparison of intraoperative time measurements between osseous reconstructions with free fibula flaps applying computer-aided designed/computer-aided manufactured and conventional techniques. *Oral Maxillofac Surg* 2015;**19**(3):293–300. https://doi.org/10.1007/s10006-015-0493-6, Epub 2015 Apr 12 PMID: 25861911.
17. Stokbro K, Aagaard E, Torkov P, et al. 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. https://doi.org/10.1016/j.ijom.2015.07.010, Epub 2015 Aug 4 PMID: 26250603.