

Virtual surgical planning in orthognathic surgery with the use of patient-specific plates compared with conventional plates. A systematic review focusing on complications, financial expenses, professional and patient-reported outcome measures

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Abstract

Background: Orthognathic surgery is a well-known surgical procedure for correction of facial deformities. The surgical procedure is performed by the use of conventional plates and by patient-specific osteosynthesis plates (PSOPs). The aim of this study is to investigate any differences in complications, financial expenses, professional and patient-reported outcome measures (PROM) in orthognathic surgery performed by conventional plates and by PSOPs.

Material and Methods: A MEDLINE (PubMed), Embase, and Cochrane Library search was conducted. Human studies published in English through August 27, 2020 were included. Grey literature, unpublished literature as well as other databases like Scopus, Google Scholar, or Research Gate were also included in the search strategy of the present systematic review. Randomized and controlled clinical trials were included. Risk of bias was assessed by Cochrane risk of bias tool and Newcastle-Ottawa Scale.

Results: Five studies with unclear risk of bias and moderate quality were included. Meta-analysis was not applicable due to considerable heterogeneity. There was no significant difference in intra- and postoperative complications or professional and PROM with the two treatment modalities, although higher tendencies to reoperations were observed with conventional plates. Financial expenses were significantly higher with PSOP, but treatment planning and intraoperative time were shortened by approximately one third compared with mock surgery and conventional plates.

Conclusions: No significant differences were observed in complications, professional and PROM. Higher financial expenses were recorded in orthognathic surgery performed with PSOP. Treatment planning and intraoperative time were shortened with the use of conventional plates. Although further randomized trials are needed before definite conclusions can be provided about beneficial use of PSOPs in orthognathic surgery from a professional and patient perspective.

Key words: *Orthognathic surgery, systematic review, virtual planning.*

Introduction

Predictable transmission of the treatment plan and accurate intraoperative repositioning of the bone segments are essential to obtain optimal aesthetic and functional outcome in orthognathic surgery (1-2). Traditional preoperative treatment planning of dentofacial deformities involves reproduction of the occlusal discrepancy on a semi-adjustable articulator through facebow transfer of cast model, two-dimensional cephalometric analysis, mock surgery, and manual fabricated acrylic occlusal splints (3-5). However, this treatment planning approach contain potential errors and inaccuracies related to the impression, facebow transfer, simulation of the surgical plan, and intraoperative repositioning of the bone segments (6-8). Cone beam computed tomography (CBCT) and computer-assisted technologies enable acquisition of three-dimensional images of the craniofacial complex and fabrication of computer-generated occlusal splints. Novel treatment strategies have therefore been explored to improve the accuracy in orthognathic surgery including three-dimensional virtual planning, surgical guided navigation, customized surgical drill guides, and milled or laser sintered patient-specific osteosynthesis plates (PSOP) (1-5). Three-dimensional virtual surgical planning with individually designed customized surgical drill guides and PSOP poses several advantages including surgical guide-oriented osteotomies, obviate intraoperative measurements, accurate three-dimensional repositioning of the bone segments without an occlusal splint, elimination of intraoperative plate bending, precise placement of screws, and shortened time in the operating theatre (1-5). Previous systematic reviews have demonstrated comparable or higher accuracy with the use of three-dimensional virtual planning involving PSOP compared with two-dimensional planning and conventional plates in orthognathic surgery (4). However, the use of PSOP are claimed to be associated with higher cost, longer treatment planning time since designing and manufacturing of patient-specific supportive materials are time-consuming, risk of screw placement in fragile maxillary bone, and inability of modifying the surgical plan intraoperatively as the treatment are predetermined by the PSOP (9-11).

Moreover, the configuration and design of PSOP are often bulky and rough, which requires a wider surgical field, which needs further subperiosteal dissection and consequently increases the risk of contamination, infection, wound dehiscence, and postoperative plate exposure (12). Consequently, these disadvantages seem to restrict routine use of PSOP in orthognathic surgery. On the contrary, reduced time in the operating theatre could potentially lead to a better outcome for the patient including diminished blood loss and shortened hospitalization, which could justify the additional preoperative costs that come with three-dimensional virtual surgical planning and individually designed PSOP (13-14). Thus, the objective of the present systematic review is to test the hypothesis of no difference in complications, financial expenses, professional and patient-reported outcome measures (PROM) following virtual surgical planning in orthognathic surgery with PSOP compared with conventional plates.

Material and Methods

- Protocol and registration

Review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews (15). The PRISMA checklist is illustrated in Fig. 1. Methods of the analysis and inclusion criteria were specified in advance and documented in a protocol and registered in PROSPERO, an international prospective register of systematic reviews.

Registration number: CRD42020207539.

The protocol can be accessed at:

https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020207539.

- Focus question

Focus question was developed according to the Patient, Intervention, Comparison and Outcome (PICO) framework as described in Table 1.

- Study design eligibility criteria

Randomized controlled trials and controlled trials in humans assessing complications, financial expenses, professional and PROM following virtual planning in orthognathic surgery with the use of PSOP compared with conventional plates.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	4-5
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	4-5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	7-8
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	8
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	9-10
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	9-10
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	10
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	9-10
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	9-10
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	9-10
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	8-9
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	7-8
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	7
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	8
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	9-10
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	9-10
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	9-10
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	15
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	10
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	10-12
Study characteristics	17	Cite each included study and present its characteristics.	11-12
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	11-12
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	11-12
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	13-14
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	10-14
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	13-14
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	10-12
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	13-14
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	13-14
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	14-18
	23b	Discuss any limitations of the evidence included in the review.	15
	23c	Discuss any limitations of the review processes used.	15
	23d	Discuss implications of the results for practice, policy, and future research.	15-18
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	5
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	19
Competing interests	26	Declare any competing interests of review authors.	19
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	7

Fig. 1: PRISMA checklist.

Table 1: PICOS criteria.

PICO	
Patient and population (P)	Healthy patients undergoing orthognathic surgery involving customized surgical guides and patient-specific plates compared with conventional plates.
Intervention (I)	The use of customized surgical guides and patient-specific plates (test group)
Comparator or control group (C)	The use of conventional plates (control group).
Outcomes (O)	Intra- and postoperative complications, financial expenses, intraoperative blood loss and patient-reported outcome measures.
Study design (S)	Randomized controlled trials and controlled trials.
Focused question	Are there any differences in complications, financial expenses, professional and patient-reported outcome measures following orthognathic treatment with the use of customized surgical drill guides and patient-specific plates compared with conventional plates?

- Types of outcome measures

- 1) Intra- and postoperative complications including failures related to the patient-specific material such as improper fixation, misfit, breakage or deformation as well as dental and periodontal injuries, infection, mucosal dehiscence, soft tissue problems, bone necrosis, non-union of bone segments, limited mouth opening, fixation material failure, removal of screw and plates, maxillary sinusitis, severe swelling, fistula, and reoperation with the two treatment modalities.
- 2) Financial expenses including cost-effectiveness as well as length of treatment planning, time in the operating theatre, and hospitalization.
- 3) Intraoperative blood loss.
- 4) PROM as evaluated by interview, questionnaire, and visual analogue scale.
- 5) Professional assessment as evaluated by surgeon's satisfaction with handling of the PSOP or the surgical outcome.

- Information sources

The search strategy incorporated examinations of electronic databases, supplemented by a thorough hand-search page by page of relevant journals including "British Journal of Oral and Maxillofacial Surgery", "International Journal of Oral and Maxillofacial Surgery", "Journal of Dental Research", "Journal of Oral & Maxillofacial Research", "Journal of Craniofacial Surgery", "Journal of Cranio-Maxillo-Facial Surgery", "Journal of Oral and Maxillofacial Surgery", "Oral and Maxillofacial Surgery" and "Oral Surgery Oral Medicine Oral Pathology Oral Radiology". The manual search also included bibliographies of all articles selected for full-text screening as well as previously published reviews. Two reviewers (ÖK, TSJ) independently performed the search. In the event of disagreement between the reviewers, another reviewer was consulted (AVO).

- Search strategy for identification of studies

A MEDLINE (PubMed), Embase, Cochrane Library search was conducted. Human studies published in English through August 27, 2020 were included. Grey liter-

ature, unpublished literature as well as other databases like Scopus, Google Scholar, or Research Gate were also included in the search strategy of the present systematic review. The search strategy was performed in collaboration with a librarian and utilized a combination of Medical subject heading (MeSH) and free text terms.

- Selection of studies

In PubMed, Embase, Cochrane Library, and web of science a total of 825 titles were identified by the 27th of August 2020. After duplicate removal using EndNote a total of 620 titles were identified. PRISMA flow diagram presents an overview of the selection process (Fig. 2). Abstracts were assessed when titles indicated that the study was relevant. Full-text analysis was obtained for those with apparent relevance or when the abstract was unavailable. References of papers identified and previously published systematic reviews assessing complications, financial expenses, professional and PROM were cross-checked for unidentified articles. Study selection was performed by two reviewers (ÖK and TSJ). In the event of disagreement between the reviewers, another reviewer was consulted (AVO). The level of agreement between the authors was tested using Cohen's kappa coefficient (k).

- Inclusion criteria

Human studies assessing three-dimensional virtual planning and computer-assisted technologies in orthognathic surgery with the use of PSOP compared with conventional plates in conjunction with two- or three-dimensional planning were included, if they reported the previously described outcome measures. In addition, at least five patients had to be included in the study and the surgical procedure should be clearly specified.

- Exclusion criteria

Following exclusion criteria were applied: letters, editorials, PhD theses, letters to the editor, case reports, abstracts, technical reports, conference proceedings, cadaveric studies, animal or in vitro studies, and literature review papers were excluded. Moreover, studies using prebent osteosynthesis plates or wires as internal fixation method were also excluded.

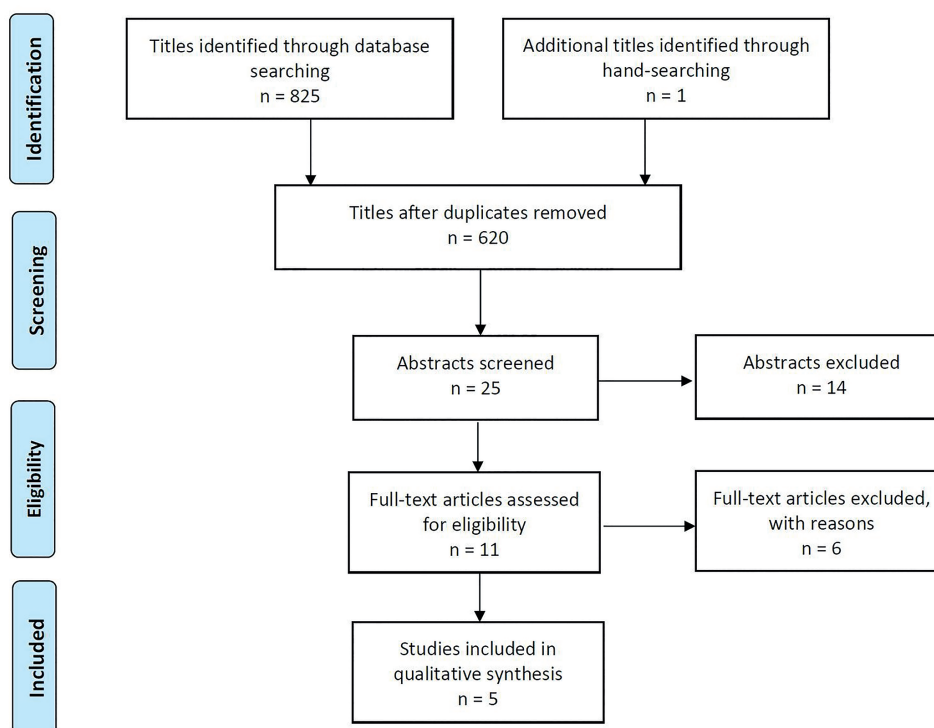


Fig. 2: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram demonstrating the first hit retrieved a total of 825 records. The distribution of the searched records and the number of studies finally selected are shown in the flow diagram.

- Data extraction

Data were extracted by one reviewer (TSJ) according to a data-collection form ensuring systematic recording of the outcome measures. In addition, relevant characteristics of the study were recorded. Corresponding authors were contacted by e-mail in the absence of important information or ambiguities.

- Data items

Following items were collected and arranged in following fields: source, study design, number of patients, surgical procedure, material, observation period, complications, financial expenses, professional and PROM.

- Quality and risk-of-bias assessment

Quality assessment was undertaken by one review author (TSJ) as part of the data extraction process. Cochrane Collaboration's tool for assessing risk of bias suggested in the Cochrane Handbook for Systematic Reviews of Interventions was used for included randomized controlled trials (version 5.1.0) (16). Following items were evaluated: random sequence generation, allocation concealment, patient blinding, outcome blinding, incomplete outcome data addressed and selective reporting. Publications were grouped into the following categories: low risk of bias (possible bias not seriously affecting results) if all criteria were met; high risk of bias (possible bias seriously weakening reliability of re-

sults) if one or more criteria were not met; or unclear risk of bias when too few details were available for classification as high or low risk.

Newcastle-Ottawa scale (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp) was applied for non-randomized studies. Following items were evaluated: selection of studies, comparability of cohorts, and ascertainment of either the exposure or outcome of interest. Stars were awarded with highest quality studies awarded up to nine stars. Included non-randomized studies were categorized as: low-quality (0 - 3 stars), moderate quality (4 - 6 stars) or high quality (7 - 9 stars).

Results

- Study selection

Search results are outlined in Fig. 2. Electronic search resulted in 825 entries. One article was identified through hand-searching. Of these 826 articles, 206 were excluded due to being retrieved in more than one search. A total of 25 abstracts were reviewed and full-text analysis included 11 articles. Finally, five comparative clinical trials were included (17-21).

The level of agreement between the two authors (ÖK and TSJ) in selecting studies to be read in full was measured at $k = 0.682$ (95% confidence interval: 0.501-0.863), while level of agreement between the two au-

thors (ÖK and TSJ) for eligibility assessment was measured at $k = 1.00$.

- Exclusion of studies

Reasons for excluding six studies after full-text assessment were: none of the outcome measures were reported ($n = 1$) (22), prebent osteosynthesis plates were used (23-24), PSOP were not used (25-26), and case-serie (27).

- Characteristics of the studies included

Three randomized controlled trials (18,20-21), and two controlled trials were included in the present systematic review (17,19). Randomization was conducted by computer software (18,20), or blocked randomization using the Sealed Envelope online tool (21). Power calculation of the sample size was performed in one study (21). Age and gender distribution were clearly specified in all the included studies (17-21). Defined inclusion and exclusion criteria were clearly described in three studies (28, 22-21). Image acquisition, three-dimensional virtual planning, surgical simulation, as well as designing and manufacturing of PSOP was performed using dissimilar software systems including Planmeca ProModel System (Planmeca Ltd, Helsinki, Finland) (17,19), Mimics 19.0 (Materialise NV, Leuven, Belgium) (20), 3-matic 11.0 (Materialise NV, Leuven, Belgium) (20), Maxilim v2.3 (Medicim NV, Mechelen, Belgium) (21), or no information was provided about the used software program (18). Customized surgical drill guides were manufactured in white polyamide using fused deposition modelling technology (20), three-dimensional printing in resin-based material (21), or no information was provided about the used technique (17-19). PSOP was manufactured in titanium using laser sintering (20), milling (19,21), or no information was provided about the used technique. (17-18). Conventional plates included

MatrixORTHOGNATHIC (DePuy Synthes, Oberdorf, Switzerland) (17-19), or no information was provided about the brand (18,20-21). The intermediate acrylic resin splint fabricated on a semi-adjustable articulator (17-18,20). The surgical procedure was planned and performed by one surgeon (17), two surgeons (21), or by an unknown number of surgeons (18-20). Experience of the surgeon was not described in any of the included studies. The maxilla-first approach without a splint for maxillary positioning was used in three studies (17,20-21), while no information was provided about the surgical sequence or use of splint (18). In bilateral sagittal split osteotomy or bimaxillary surgery, positioning of the mandible was guided by a computer-assisted printed splint (19,21), or an acrylic splint fabricated on a hinge articulator (20). Blinded assessment was conducted in one study (20). Complications were assessed by clinical examination (17). PROM were reported by self-administrated orthognathic quality of life questionnaire (18), or no information's was provided about the assessment method (20). Information about drops-out was reported in one study (21). Methods for examiner training or calibration was not reported in any of the included studies.

- Data synthesis

Meta-analysis can only be conducted for continuous data if both the mean and standard deviation are available for similar comparison with identical outcome measures. However, the included studies of the present systematic review solely reported mean values with or without standard deviation. Thus, meta-analysis was not applicable.

- Methodological quality

Quality of the included studies is summarized in Table 2 and Table 3.

Table 2: Cochrane Collaboration's tool for assessing risk of bias for randomized controlled trials.

Author	Year of publication	Random sequence generation	Allocation concealment	Patient blinding	Outcome blinding	Incomplete outcome data addressed	Selective reporting
Hanafy <i>et al.</i> (18)	2019	+	+	?	?	?	+
Hanafy <i>et al.</i> (20)	2020	+	+	+	+	?	+
Kraeima <i>et al.</i> (21)	2020	+	+	?	?	?	+

+ = low risk of bias; ÷ = high risk of bias; ? = unclear risk of bias.

Table 3: Newcastle-Ottawa scale for assessing quality of non-randomized studies.

Study	Year of publication	Selection (maximum 4 stars)	Comparability (maximum 2 stars)	Outcome (maximum 3 stars)	Total score/ quality
Suojanen <i>et al.</i> (17)	2018	☆☆★★	★★	☆☆★	5 stars/ moderate quality
Suojanen <i>et al.</i> (19)	2019	☆☆★★	★★	☆☆★	5 stars/ moderate quality

low-quality (0 - 3 stars), moderate quality (4 - 6 stars), and high quality (7 - 9 stars).

- Outcome measures

Results of each outcome measures are presented below and outlined in Table 4. Amount of intraoperative blood loss was not reported in any of the included studies. Hence, this outcome measure is not described. Reported numerical values are presented as mean values with standard deviation.

- Complications

The frequency of intra- and postoperative complications was reported in four studies (17-20). Infection, mucosal dehiscence, and plate exposure were the most commonly reported complications. There was no significant difference between the two treatment modalities, although there seems to be a higher tendency for reopera-

Table 4: Intra- and postoperative complications, financial expenses, professional and patient-reported outcome measures.

Source	Material and methods					Outcome measures					
	SD	NOP	Surgical procedure	Material	OP (M)	Complications	Financial expenses			Professional assessment	PROM
Suojanen <i>et al.</i> 2018 (17)	RCS	31	Le Fort I osteotomy & Bimaxillary osteotomy	CSDG & PSOP	26 (14-37)	Palatal fistula: 1 Maxillary sinusitis: 1 Plate removal: 1 Septum deviation: 2 Swelling of cheek: 1	NR	NR	NR	NR	
		37		CMP							49 (38-62)
Hanafy <i>et al.</i> 2019 (18)	RCT	16	Bimaxillary osteotomy	CSDG & PSOP	6	Uneventful healing	NR	NR	NR	Questionnaire (0-88): Base-line: 6 M 46.1 ± 8.7 21.8 ± 8.4	
		16		CMP							Mucosal dehiscence and plate exposure: 1
Suojanen <i>et al.</i> 2019 (19)	RCS	28	BSSO	CSDG & PSOP	30 (24-38)	Infection: 7 Mucosal dehiscence: 1 Plate removal: 8 Reoperation: 1	NR	NR	NR	NR	
		48		CMP							50 (12-63)
Hanafy <i>et al.</i> 2020 (20)	RCT	9	Bimaxillary osteotomy	CSDG & PSOP	4	No infection or mucosal dehiscence	Cost	PT (m)	ST (m)	NR	Satisfied with outcome
		9		CMP							
							\$280	192	72		
Kraeima <i>et al.</i> 2020 (21)	RCT	27	Le Fort I osteotomy	CSDG & PSOP		NR	NR	NR	Satisfaction: 7.8 (0-10) vs. CMP	NR	
		31		CMP							

BSSO, bilateral sagittal split osteotomy; CAD, computer-aided design; CAM, computer-aided manufacturing; CMP, conventional mini-plates; CSDG, customized surgical drill guides; M, months; m, minutes; NOP, number of patients; NR, not reported; OP, observation period; PROM, patient-reported outcome measures; PSOP, patient-specific osteosynthesis plates; PT, planning time; RCT, randomized controlled trial; RCS, retrospective cohort study; SD, study design; ST, surgical time.

tion with conventional plates compared with PSOP (17).
- Financial expenses

Financial expenses were reported in one study (20). The approximated cost was significantly higher with customized surgical drill guides and PSOP (USD \$780) compared with conventional plates (USD \$280) (20). However, the treatment planning time from the end of the virtual plan to export of the stereolithography file was shortened with computer-aided surgery (113 minutes) compared with mock surgery on a semi-adjustable articulator using facebow record (192 minutes). Moreover, the intraoperative time from maxillary incision to fixation was shortened with customized surgical drill guides and PSOP (49 minutes) compared with conventional plates (72 minutes) (20). The actual financial expenses therefore seem to be increased with the use of customized surgical drill guides and PSOP compared with conventional plates, but treatment planning time as well as intraoperative time were shortened by approximately one third.

- Professional reported outcome measures

Professional reported outcome measures were reported in one study (21). The surgeon's overall satisfaction with the user-friendliness as well as the position of the maxilla was 7.8 on a scale from zero to ten with customized surgical drill guides and PSOP compared with previous experience using conventional plates (21). The drilled screw holes [8.1], screw placement [8.1], position of the maxilla [8.4], placement of the guide [7.5], and indication of screw holes [7.1] were also evaluated (20).

- Patient-reported outcome measures

PROM were reported in two studies (18,20). Verbal response and self-administrated orthognathic quality of life questionnaire revealed no significant differences between the two treatment modalities (18,20). The overall baseline score containing four domains (facial aesthetics, oral function, awareness of deformity, and social aspect) decreases from 46.1 (SD: 8.7) to 21.8 (SD: 8.4) on a scale ranging from zero to 88 with customized surgical drill guides and PSOP ($P < 0.001$), after six months. Corresponding measurements with conventional plates were 46.2 (SD: 10.5) to 23.2 (SD: 9.5) ($P < 0.001$) (18).

Discussion

The objective of the present systematic review was to test the hypothesis of no difference in complications, financial expenses, professional and PROM following virtual surgical planning in orthognathic surgery with the use of PSOP compared with conventional plates. Three randomized controlled trials with unclear risk of bias and two controlled trials of moderate quality were included in the present systematic review (17-21). There was no significant difference in the frequency of intra- and postoperative complications or professional

and PROM with the two treatment modalities, although a higher tendency to reoperations were reported with the use of conventional plates. The financial expenses were significantly higher with customized surgical drill guides and PSOP, but treatment planning time and intraoperative time were shortened by approximately one third compared with mock surgery on a semi-adjustable articulator using facebow record and conventional plates (20). Consequently, customized surgical drill guides and POSP are currently associated with higher cost, but the shortened treatment planning and time in operating theatre may compensate for the higher financial expenses.

The strength of evidence from a systematic review and meta-analysis is related to the quality of the included studies. Quality and risk-of-bias assessment revealed some methodological confounding factors among the included studies of the present systematic review and considerable heterogeneity prevented meta-analysis from being performed. The current level of evidence is therefore inadequate to propose specified implications for evidence based clinical guidelines according to the focus question of the present systematic review. Further randomized controlled trials with larger patient samples assessing accurate transmission of the treatment plan, complications, economic perspectives as well as professional and PROM with the two treatment modalities are therefore needed before definite conclusions can be provided about the beneficial use of customized surgical drill guides and PSOP in orthognathic surgery according to the focus question of the present systematic review.

Intra- and postoperative complications are unanticipated or unfavourable outcome of a treatment. Errors related to the design and manufacturing of customized surgical drill guides and PSOP may cause intraoperative misfit, improper fixation, or deformation, which adversely affect the transmission of the treatment plan and accurate reposition of the bone segments (21,28-29). Conventional occlusal splints are therefore occasionally manufactured as a safety precaution, if the patient-specific material cannot be used (21). In the present systematic review, conversion of the treatment strategy from customized surgical drill guides and PSOP to conventional plates was reported in one study due to damaged or incomplete customized surgical drill guides or PSOP after sterilization, late change in the surgical planning, and intraoperative conversion to the control group (21). These necessary safety precautions in conjunction with the use of customized surgical drill guides and PSOP constitute a significant drawback due to prolonged treatment planning time, higher cost and risk of surgical inaccuracies. Moreover, a newly published study described increased caution and counselling with utilization of patient-specific mandibular implants in patients

with syndromic status, history of orofacial cleft, and history of previous maxillomandibular surgery due to increased risk of hardware-related complications (30). These results are in accordance with a previous study assessing bilateral sagittal split osteotomy with customized surgical drill guides and PSOP reporting total precision of the patient-specific material in solely 11 out of 30 patients (28). Further development and improvement in the manufacture of patient-specific material is therefore needed to ensure satisfying durability, strength, and accuracy in orthognathic surgery. Thus, surgical splints printing is still required.

Infection, mucosal dehiscence, severe swelling, dental and periodontal injuries, bone necrosis are well-known complications in orthognathic surgery (31-32). The prevalence of complications in the included studies of the present systematic review seems to be comparable with previous studies (30). Risk of infection, mucosal dehiscence, and soft tissue problems are commonly related to age, gender, smoking habits, duration of surgery, surgeon experience, surgical site, previous surgeries, and type of osteotomy performed (33-34). Description of duration of surgery, surgeons experience nor correlation analysis of relationship between age or gender and percentage of complications have not been performed in any of the included studies of the present systematic review.

Estimating the total financial expenses associated with a specific treatment modality is difficult to compare since the cost attributable the national health care system and dissimilar calculation methods. Operating theatres generally account for a large percentage of a hospital's total revenue and improving operating theatre efficiency can considerably affect the overall cost and improve health care outcome. In the present systematic review, the cost of customized surgical drill guides and PSOP in Egypt was significantly higher compared with conventional plates, but treatment planning time and time in the operating theatre were shortened by approximately one third compared with mock surgery on a semi-adjustable articulator using facebow record and conventional plates (20). Recent studies have reported lower cost and shorter treatment planning time with three-dimensional virtual planning and manufacturing of occlusal splints by computed technologies compared with conventional treatment planning and manual splint fabrication, although customized surgical drill guides and PSOP were not used in any of these studies (9-11,26). Patient-specific material is often manufactured in an outsourced laboratory, which significantly increases the cost. Development of low-cost technologies as well as in-house three-dimensional printer or milling device will efficiency improve the cost-effectiveness and accuracy of the process by reducing errors and extra charges from the outsourced laboratory. Further-

more, a newly published study concluded that computed technology for mandibular reconstruction will become a widely used reconstructive method and that its cost will be covered by gains in terms of surgical time, quality of reconstruction, and reduced complications (35). Reduced length of hospitalization may decrease risk of infection, medication side effects, improvement in the quality of treatment, and increased hospital profit with more efficient bed management (36). A previous study has shown a significant correlation between duration of surgery and length of hospitalization in orthognathic surgery (33), which is in accordance with the conclusions of a newly published systematic review and meta-analysis (3). In the present systematic review, time in the operating theatre were shortened by approximately one third with the use of customized surgical drill guides and PSOP compared with conventional plates (20). Consequently, customized surgical drill guides and PSOP in orthognathic surgery will shortened time in the operating theatre, which may possibly diminish risk of complications, reduce financial expenses, and shortened hospitalization.

PROM are commonly used in orthognathic surgery to assess patients' perception of the treatment outcome and views of their health status (37-39). Patient expectations and satisfaction following orthognathic surgery are generally high revealing improvement in oral-health related quality of life, psychosocial components, and facial aesthetics (37-39). However, each individual patient has different motivations and expectations, which necessitates standardized, validated, and reliable tools for assessment of PROM in orthognathic surgery (40). In the present systematic review, verbal response and self-administrated orthognathic quality of life questionnaire revealed no significantly differences between customized surgical drill guides and PSOP compared with conventional plates in orthognathic surgery (18,20).

Conclusions

The hypothesis of no difference in complications, financial expenses, professional and PROM following virtual surgical planning in orthognathic surgery with customized surgical drill guides and PSOP compared with conventional plates is rejected. No significant difference in intra- and postoperative complications or professional and PROM were revealed, though higher tendencies to reoperations were observed with conventional plates. Financial expenses were significantly higher with customized surgical drill guides and PSOP, but treatment planning and intraoperative time were shortened by approximately one third compared with mock surgery on semi-adjustable articulator using facebow record and conventional plates. Conclusions drawn from results of this systematic review should be interpreted with caution due to dissimilar evaluation methods and

various methodological confounding factors among the included studies. Further randomized trials are therefore needed before definite conclusions can be provided about beneficial use of customized surgical drill guides and PSOP in orthognathic surgery according to the focus question of the present systematic review.

References

1. Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Virtual planning in orthognathic surgery. *Int J Oral Maxillofac Surg.* 2014;43:957-65.
2. Gaber RM, Shaheen E, Falter B, Araya S, Politis C, Swennen GRJ, *et al.* A systematic review to uncover a universal protocol for accuracy assessment of 3-dimensional virtually planned orthognathic surgery. *J Oral Maxillofac Surg.* 2017;75:2430-40.
3. Nilsson J, Hindocha N, Thor A. Time matters - Differences between computer-assisted surgery and conventional planning in craniomaxillofacial surgery: A systematic review and meta-analysis. *J Craniomaxillofac Surg.* 2020;48:132-40.
4. Van den Bempt M, Liebrechts J, Maal T, Bergé S, Xi T. Toward a higher accuracy in orthognathic surgery by using intraoperative computer navigation, 3D surgical guides, and/or customized osteosynthesis plates: A systematic review. *J Craniomaxillofac Surg.* 2018;46:2108-19.
5. Haas OL Jr, Becker OE, de Oliveira RB. Computer-aided planning in orthognathic surgery-systematic review. *Int J Oral Maxillofac Surg.* 2015;44:329-44.
6. Quast A, Santander P, Witt D, Damm A, Moser N, Schliephake H, *et al.* Traditional face-bow transfer versus three-dimensional virtual reconstruction in orthognathic surgery. *Int J Oral Maxillofac Surg.* 2019;48:347-54.
7. Zizelmann C, Hammer B, Gellrich NC, Schweska-Polly R, Rana M, Bucher P. An evaluation of face-bow transfer for the planning of orthognathic surgery. *J Oral Maxillofac Surg.* 2012;70:1944-50.
8. Sharifi A, Jones R, Ayoub A, Moos K, Walker F, Khambay B, *et al.* How accurate is model planning for orthognathic surgery? *Int J Oral Maxillofac Surg.* 2008;37:1089-93.
9. Resnick CM, Inverso G, Wrzosek M, Padwa BL, Kaban LB, Peacock ZS. Is there a difference in cost between standard and virtual surgical planning for orthognathic surgery? *J Oral Maxillofac Surg.* 2016;74:1827-33.
10. Wrzosek MK, Peacock ZS, Laviv A, Goldwasser BR, Ortiz R, Resnick CM, *et al.* Comparison of time required for traditional versus virtual orthognathic surgery treatment planning. *Int J Oral Maxillofac Surg.* 2016;45:1065-9.
11. Steinhuber T, Brunold S, Gärtner C, Offermanns V, Ulmer H, Ploder O. 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;76:397-407.
12. Stoor P, Suomalainen A, Mesimäki K, Kontio R. Rapid prototyped patient specific guiding implants in critical mandibular reconstruction. *J Craniomaxillofac Surg.* 2017;45:63-70.
13. Bao T, He J, Yu C, Zhao W, Lin Y, Wang H, Liu J, Zhu H. Utilization of a pre-bent plate-positioning surgical guide system in precise mandibular reconstruction with a free fibula flap. *Oral Oncol.* 2017;75:133-9.
14. Heufelder M, Wilde F, Pietzka S, Mascha F, Winter K, Schramm A, *et al.* Clinical accuracy of waferless maxillary positioning using customized surgical guides and patient specific osteosynthesis in bimaxillary orthognathic surgery. *J Craniomaxillofac Surg.* 2017;45:1578-85.
15. Welch V, Petticrew M, Tugwell P, Moher D, O'Neill J, Waters E, *et al.* PRISMA-Equity Bellagio group. PRISMA-Equity 2012 extension: reporting guidelines for systematic reviews with a focus on health equity. *PLoS Med.* 2012;9:e1001333.
16. Higgins JPT, Altman DG, Gotzsche PC, Jüni P, Moher D, Oxman AD, *et al.* Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ.* 2011;343:d5928.
17. Suojanen J, Järvinen S, Kotaniemi KV, Reunanen J, Palotie T, Stoor P, *et al.* Comparison between patient specific implants and conventional mini-plates in Le Fort I osteotomy with regard to infections: No differences in up to 3-year follow-up. *J Craniomaxillofac Surg.* 2018;46:1814-7.
18. Hanafy M, Abou-Elfetouh A, Mounir RM. Quality of life after different approaches of orthognathic surgery: a randomized controlled study. *Minerva Stomatol.* 2019;68:112-7.
19. Suojanen J, Järvinen S, Hodzic Z, Reunanen J, Leikola J, Stoor P. No differences in infections between patient-specific implants and conventional mini-plates in mandibular bilateral sagittal split osteotomy - Up to 3-year follow-up. *J Craniomaxillofac Surg.* 2019;47:1181-4.
20. Hanafy M, Akoush Y, Abou-Elfetouh A, Mounir RM. 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;49:62-8.
21. Kraeima J, Schepers RH, Spijkervet FKL, Maal TJJ, Baan F, Witjes MJH, *et al.* Splintless surgery using patient-specific osteosynthesis in Le Fort I osteotomies: a randomized controlled multi-centre trial. *Int J Oral Maxillofac Surg.* 2020;49:454-60.
22. Kotaniemi KVM, Heliövaara A, Kotaniemi M, Stoor P, Leikola J, Palotie T, *et al.* Comparison of postoperative skeletal stability of maxillary segments after Le Fort I osteotomy, using patient-specific implant versus mini-plate fixation. *J Craniomaxillofac Surg.* 2019;47:1020-30.
23. Hu P, Li J, Du W, Ji H, Xu C, Luo E. The drilling guiding templates and pre-bent titanium plates improves the operation accuracy of orthognathic surgery with computer-aided design and computer-aided manufacturing occlusal splints for patients with facial asymmetry. *J Craniofac Surg.* 2019;30:2144-8.
24. 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;23:3115-22.
25. 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;40:162-8.
26. Park SY, Hwang DS, Song JM, Kim UK. Comparison of time and cost between conventional surgical planning and virtual surgical planning in orthognathic surgery in Korea. *Maxillofac Plast Reconstr Surg.* 2019;41:35.
27. Kim JW, Kim JC, Jeong CG, Cheon KJ, Cho SW, Park IY, *et al.* The accuracy and stability of the maxillary position after orthognathic surgery using a novel computer-aided surgical simulation system. *BMC Oral Health.* 2019;19:18.
28. Suojanen J, Leikola J, Stoor P. The use of patient-specific implants in orthognathic surgery: A series of 30 mandible sagittal split osteotomy patients. *J Craniomaxillofac Surg.* 2017;45:990-4.
29. Huottilainen E, Jaanimets R, Valášek J, Marcián P, Salmi M, Tuomi J, *et al.* Inaccuracies in additive manufactured medical skull models caused by the DICOM to STL conversion process. *J Craniomaxillofac Surg.* 2014;42:e259-65.
30. Kalmar CL, Humphries LS, Zimmerman CE, Vu GH, Swanson JW, Bartlett SP, *et al.* Orthognathic hardware complications in the era of patient-specific implants. *Plast Reconstr Surg.* 2020;146:609e-21e.
31. Jędrzejewski M, Smektała T, Sporniak-Tutak K, Olszewski R. Preoperative, intraoperative, and postoperative complications in orthognathic surgery: a systematic review. *Clin Oral Investig.* 2015;19:969-77.
32. Haas Junior OL, Guijarro-Martínez R, de Sousa Gil AP, da Silva Meirelles L, de Oliveira RB, Hernández-Alfaro F. Stability and surgical complications in segmental Le Fort I osteotomy: a systematic

review. *Int J Oral Maxillofac Surg.* 2017;46:1071-87.

33. Zaroni FM, Cavalcante RC, João da Costa D, Kluppel LE, Scariot R, Rebellato NLB. Complications associated with orthognathic surgery: A retrospective study of 485 cases. *J Craniomaxillofac Surg.* 2019;47:1855-60.

34. Kantar RS, Cammarata MJ, Rifkin WJ, Alfonso AR, DeMitchell-Rodriguez EM, Noel DY, *et al.* Bimaxillary orthognathic surgery is associated with an increased risk of early complications. *J Craniofac Surg.* 2019;30:352-7.

35. Tarsitano A, Battaglia S, Crimi S, Ciocca L, Scotti R, Marchetti C. Is a computer-assisted design and computer-assisted manufacturing method for mandibular reconstruction economically viable? *J Craniomaxillofac Surg.* 2016;44:795-9.

36. Baek H, Cho M, Kim S, Hwang H, Song M, Yoo S. Analysis of length of hospital stay using electronic health records: A statistical and data mining approach. *PLoS One.* 2018;13:e0195901.

37. Al-Hadi N, Chegini S, Klontzas ME, McKenny J, Heliotis M. Patient expectations and satisfaction following orthognathic surgery. *Int J Oral Maxillofac Surg.* 2019;48:211-6.

38. Al-Asfour A, Waheedi M, Koshy S. Survey of patient experiences of orthognathic surgery: health-related quality of life and satisfaction. *Int J Oral Maxillofac Surg.* 2018;47:726-31.

39. Murphy C, Kearns G, Sleeman D, Cronin M, Allen PF. The clinical relevance of orthognathic surgery on quality of life. *Int J Oral Maxillofac Surg.* 2011;40:926-30.

40. Soh CL, Narayanan V. Quality of life assessment in patients with dentofacial deformity undergoing orthognathic surgery--a systematic review. *Int J Oral Maxillofac Surg.* 2013;42:974-80.

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Authors contributions

All authors contributed to the conception of the study design, the drafting of the article, the critical revision and the final approval of the manuscript. Furthermore, Özlem Kesmez, Adaia Valls Ontañón and Thomas Starch-Jensen obtained data for this study. Analysis of data were made by Özlem Kesmez and Thomas Starch-Jensen.