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Systematic Review
Orthognathic Surgery

Computer-aided planning in orthognathic surgery—systematic review

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Abstract. The aim of this study was to conduct a systematic review to evaluate the accuracy and benefits of computer-aided planning in orthognathic surgery. The search was performed in PubMed, EMBASE, Cochrane Library, LILACS, and SciELO. The articles identified were assessed independently and in a blinded manner by two authors using selection criteria and eligibility criteria. The database search yielded 375 studies. Following the application of search and eligibility criteria, a final nine studies were included in the systematic review. The level of agreement between the authors in the study selection process was substantial ($\kappa = 0.767$) and study eligibility was considered excellent ($\kappa = 0.863$). The accuracy of translation was <1.2 mm in the maxilla (vertical) and <1.1 mm in the mandible (sagittal), and for rotation was <1.5° in the maxilla (pitch) and <1.8° in the mandible (pitch). Two studies showed a medium potential risk of bias and six studies showed a high potential risk of bias. Computer-aided planning in orthognathic surgery was considered accurate for the studies included in this systematic review. However, the low quality of these studies means that randomized clinical trials are needed to compare computer-aided planning to conventional planning in orthognathic surgery.

Key words: systematic review; orthognathic surgery; CAD–CAM.

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Orthognathic surgery is a surgical procedure to treat facial deformities and involves osteotomy of the jaw bones to correct dentofacial disharmony and misalignment. Surgical planning to obtain the desired stability and harmony is complex and accuracy is essential.[1]

Planning in orthognathic surgery has evolved over the past decades. This started with 'classic' surgical planning using cephalometric analysis of lateral radiographs, facial analysis, and plaster casts of the patient's dental arches mounted on an articulator and surgical splints made from acrylic resin. Planning then evolved into the use of two-dimensional (2D) computer programs for cephalometric analysis of lateral radiographs and the more modern technique of computer-aided planning.[2,3]

Computer-aided orthognathic surgery integrates planning and the surgical intervention using software, with three-dimensional (3D) cephalometric analysis of bone and soft tissue, performance of the surgical movements to achieve the ideal dento-skeletal harmony, and transfer of the virtual planning to the surgical setting using a surgical splint. However, although surgical planning is computer-aided, the facial analysis of patients must be performed clinically.[4,5]

Some authors have reported that computer-aided planning increases the effectiveness of orthognathic surgery, with more accurate osteotomy than with the classic planning of surgery.[1,5]

In order to ensure accurate results, the computer programs used for orthognathic surgery planning require experienced operators and quality computed tomography (CT) scans.[2] It is important to note that the same anatomical points are used for cephalometric analysis in both classic and computer-aided planning. As such, the chances of error are the same for the two types of analysis, since these points are assigned by the surgeon and not the computer. However, computer-aided planning results in fewer preoperative steps for the surgeon, which lowers the number of systematic errors in the placement of osteotomies.[2,3,6]

Randomized controlled clinical trials offer the best scientific evidence to assess the effectiveness and accuracy of computer-assisted planning for orthognathic surgery. However, if studies of this nature are not available in the literature, other types of research can be used to evaluate an intervention or generate hypotheses on it.[7] A systematic review of intervention studies is therefore an important tool in helping to understand and quantify the accuracy of computer-aided planning in orthognathic surgery, as well as evaluating the need for new research on the subject.[7,8]

The aim of this systematic review was to assess the accuracy of computer-aided planning in orthognathic surgery and to determine whether it provides greater benefits to the patient and surgical procedure than classic planning, as well as to ascertain the quality of the available literature.

Materials and methods

A systematic search was conducted of electronic and printed media (annals from conferences) on computer-aided planning for orthognathic surgery. The databases used were PubMed, EMBASE, the Cochrane Library, LILACS, and SciELO. There were no restrictions in the search strategy regarding language or year of publication. Key words and Boolean operators (‘OR’ and ‘AND’) were used to join terms (thesaurus or words) related to orthognathic surgery and computer-aided planning.

Search strategy

Main search

The search of PubMed was conducted using the following medical subject heading (MeSH) terms: [(‘Orthognathic Surgery’ OR ‘Orthognathic Surgery’ OR ‘Orthognathic Surgeries’ OR ‘Surgeries, Orthognathic’ OR ‘Surgery, Orthognathic’ OR ‘Maxillofacial Orthognathic Surgery’ OR ‘Maxillofacial Orthognathic Surgeries’ OR ‘Orthognathic Surgeries, Maxillofacial’ OR ‘Orthognathic Surgery, Maxillofacial’ OR ‘Surgeries, Maxillofacial Orthognathic’ OR ‘Surgery, Maxillofacial Orthognathic’ OR ‘Orthognathic Surgical Procedures’ OR ‘Orthognathic Surgical Procedure’ OR ‘Procedure, Orthognathic Surgical’ OR ‘Procedures, Orthognathic Surgical’ OR ‘Surgical Procedure, Orthognathic’ OR ‘Surgical Procedures, Orthognathic’) AND (‘Surgery, Computer-Assisted’ OR ‘Surgery, Computer-Assisted’ OR ‘Computer-Assisted Surgeries’ OR ‘Surgeries, Computer-Assisted’ OR ‘Surgery, Computer Assisted’ OR ‘Computer-Assisted Surgery’ OR ‘Computer Assisted Surgery’ OR ‘Computer-Aided Surgery’ OR ‘Computer Aided Surgery’ OR ‘Computer-Aided Surgeries’ OR ‘Surgeries, Computer-Aided’ OR ‘Surgery, Computer-Aided’ OR ‘Surgery, Image-Guided’ OR ‘Image-Guided Surgeries’ OR ‘Surgeries, Image-Guided’ OR ‘Surgery, Image Guided’ OR ‘Image-Guided Surgery’ OR ‘Image Guided Surgery’ OR ‘Computer-Aided Design’ OR ‘Computer Aided Design’ OR ‘Computer-Aided Designs’ OR ‘Design, Computer-Aided’ OR ‘Designs, Computer-Aided’ OR ‘Computer-Assisted Design’ OR ‘Computer Assisted Design’ OR ‘Computer-Assisted Designs’ OR ‘Design, Computer-Assisted’ OR ‘Designs, Computer-Assisted’ OR ‘Computer-Aided Manufacturing’ OR ‘Computer Aided Manufacturing’ OR ‘Manufacturing, Computer-Aided’ OR ‘Computer-Assisted Manufacturing’ OR ‘Computer Assisted Manufacturing’ OR ‘Manufacturing, Computer-Assisted’ OR ‘CAD-CAM’)].

The same search strategy was applied to the Cochrane Library, since this also uses MeSH terms.

For the search of EMBASE, the Emtree terms ‘orthognathic surgery’, ‘computer assisted surgery’ and ‘computer aided design’ were used to carry out a specific search: ‘orthognathic surgery’/syn AND (‘computer assisted surgery’/syn OR ‘computer aided design’/syn).

Health sciences descriptors (Descritores em Ciências da Saúde—DeCS) in the English language were used to search the LILACS and SciELO databases; the following searches were performed: LILACS (tw:(‘orthognathic surgery’)) AND (tw:(‘computer-aided design’)) and SciELO ‘orthognathic surgery’ AND ‘computer-aided design’.

Grey literature

A search for unpublished studies and research published in journals not indexed in major databases was conducted: (1) annals of the last three editions of the International Conference on Oral and Maxillofacial Surgery (ICOMS), promoted by the International Association of Oral and Maxillofacial Surgery, and the last three annual meetings of the American Association of Oral and Maxillofacial Surgery (AAOMS Annual Meeting). (2) Google Scholar, using MeSH terms (‘orthognathic surgery’, ‘computer aided design’, ‘computer assisted surgery’) and Boolean operators (‘AND’ and ‘OR’): ‘orthognathic surgery’ AND (‘computer aided design’ OR ‘computer assisted surgery’).

The authors of the abstracts found in the annals were contacted by e-mail for information on the results or to determine whether the study had been published.

Manual search

The references of papers identified were analyzed for further studies not located in the above-mentioned searches.

Study selection

The systematic search was conducted by one of the authors (O.L.H.J.), and articles were selected independently by two authors (O.L.H.J., O.E.B.) based on the title and abstract. Studies with the following characteristics were chosen for full-text reading: (1) intervention studies; (2) creation of a virtual surgical splint; (3) investigations assessing the accuracy of orthognathic surgery with a virtual surgical splint. Papers that did not meet these criteria were excluded from the analysis. When the authors disagreed on the selection of a paper, the study was read in full.

Studies for which the titles and abstracts were evaluated and that were accepted in the first selection process were submitted to an eligibility assessment.

The level of agreement between the authors was tested using Cohen’s kappa coefficient (κ).

Eligibility of the studies

The eligibility of the studies was checked by two authors (O.L.H.J., O.E.B.) who were blinded to the title, abstract, authorship, and origin of the papers. The following eligibility criteria were used: (1) the main theme of the paper had to centre on computer-aided planning for orthognathic surgery; (2) the trial had to be original and an intervention study; (3) the surgical procedure had to be computer-aided with virtual planning and with the design of a virtual surgical splint; (4) accuracy measures had to be presented for the surgical procedure. In the event of disagreement between the two authors, the study in question was discussed with the third, more experienced author (R.B.O.).

Investigations that did not meet the eligibility criteria were excluded from the analysis and the reason for their exclusion was reported.

When questions arose regarding the methodology or results of a paper, the author was contacted by e-mail to obtain the necessary answers.

The level of agreement between the authors was tested using Cohen's kappa coefficient (κ).

Data extraction

Demographic and methodological data, as well as the accuracy results, were extracted from the studies that met the eligibility requirements by the two blinded authors (O.L.H.J., O.E.B). In the event of disagreement between the two authors, the study was discussed with the third author (R.B.O.). When doubts persisted, the author of the study in question was contacted by

Analysis of the methodological quality of the studies included

The quality of the papers was assessed using an adaptation of the bias analysis proposed by Clementini et al.[9] The criteria used by these authors are related to the randomization of the sample, validation of measurements, statistical analysis, the definition of inclusion and exclusion criteria, and whether sample loss was reported in the postoperative period. In addition to these items, analysis of comparison data between interventions and blinding of the rater were included as criteria.

With respect to the risk of bias for each study analyzed, papers containing all the above-mentioned items were considered low risk, those for which one or two items were missing were deemed medium risk, and investigations that did not include three or more items were considered high risk.

Results

Search strategy

The strategies used for the main search and grey literature search were applied for the last time on 13 January 2014. The manual search was conducted after papers had been included, with no need for updating. A flowchart showing the studies included at each stage of the systematic review is given in Fig. 1.

Main search

Three hundred and fifty-seven articles were found in PubMed, 93 in EMBASE, and 28 in LILACS; no studies were found in the Cochrane Library or SciELO. Duplicate papers were removed, leaving a total of 375 possible studies. The oldest of these papers was published in 1984, with studies on computer-aided planning in orthognathic surgery increasing in subsequent years to a total of 157 publications in the last 3 years (2011–2013) (Fig. 2).

Grey literature

With regard to the grey literature search, four studies were selected from Google Scholar, one from the ICOMS annals, and four from the annals of the AAOMS Annual Meeting. The authors of the studies found in these annals were contacted by e-mail regarding the results and to determine whether the research had been published in the form of a scientific paper. Those studies for which an author reply was not received were excluded.[10–14] As a result, only the four studies found in the Google Scholar search were included in the sample submitted for eligibility assessment.

Manual search

One study[15] was found and included in the final sample for systematic review.

Study selection

The titles and abstracts of the 375 selected studies were read and 34 of these were chosen for full-text reading. Whenever the two authors differed as to the selection of a paper, disagreement was resolved by choosing the broadest possible study. The level of agreement between the two authors in selecting studies to be read in full was measured at $\kappa = 0.767$.

Eligibility of the studies

As part of the eligibility assessment, 38 studies were read in full, 34 from the main search and four from the grey literature search. At the end of this analysis, eight papers were included in the sample for systematic review. The other 30 studies were excluded for the following reasons: computer-aided planning for orthognathic surgery was not the main theme of the paper ($n = 7$ studies[16–22]), the paper was not an intervention study ($n = 14$ studies[12,14,1,23–33]) or was not original ($n = 1$[34]), the surgical procedure did not involve a computer-assisted virtual surgical splint ($n = 3$[35–37]), and accuracy measures for the surgical procedure were not provided ($n = 5$[38–42]).

The level of agreement between the two authors for the eligibility assessment was measured at $\kappa = 0.863$.

Data extraction

The sample used in the systematic review consisted of nine studies,[15,43–50] of which seven were found in the main search,[43–48,50] one in the grey literature,[49] and one in the manual search.[15]

The research groups on computer-aided planning in orthognathic surgery were from different countries; however, two papers by a group from the USA[15,46] and two by a research group in Spain[44,47] were included in the systematic review. All of the studies were prospective and only one paper was a randomized controlled clinical trial.[50] Six[43–46,48,49] were published in 2013, and the largest sample (65 patients) was part of a multi-centre trial.[46] The total sample from the studies included, in which CAD/CAM was used in orthognathic surgery, comprised 137 individuals; their mean age was 20–30 years and the gender (male/female) and facial deformity (class II/class III) proportions were approximately 50% (Table 1).

All of the studies used clinical analysis and 3D imaging in computer-aided planning, of which three[43,47,50] used cone beam computed tomography (CBCT) for 3D analysis, four[15,45,46,49] used conventional computed tomography (CT), and two[44,48] employed both techniques. Fusion of the dental arch images with facial CTs was performed in five studies[15,44,46–48]; three trials[45,49,50] used only CT and one[43] scanned the bite registration and bite mark impression so that CT could be performed with stable occlusion. Most of the surgeries planned were bimaxillary procedures and only two papers[44,50] reported patients for whom surgical planning began with the mandible. The software used in six of the studies[15,44,46–48,50] performed surgical planning and designed the virtual splint. The time dedicated to planning was assessed in two trials[43,45] (one recorded an average of 255 min and the other between 115 and 155 min), and only one study[48] reported

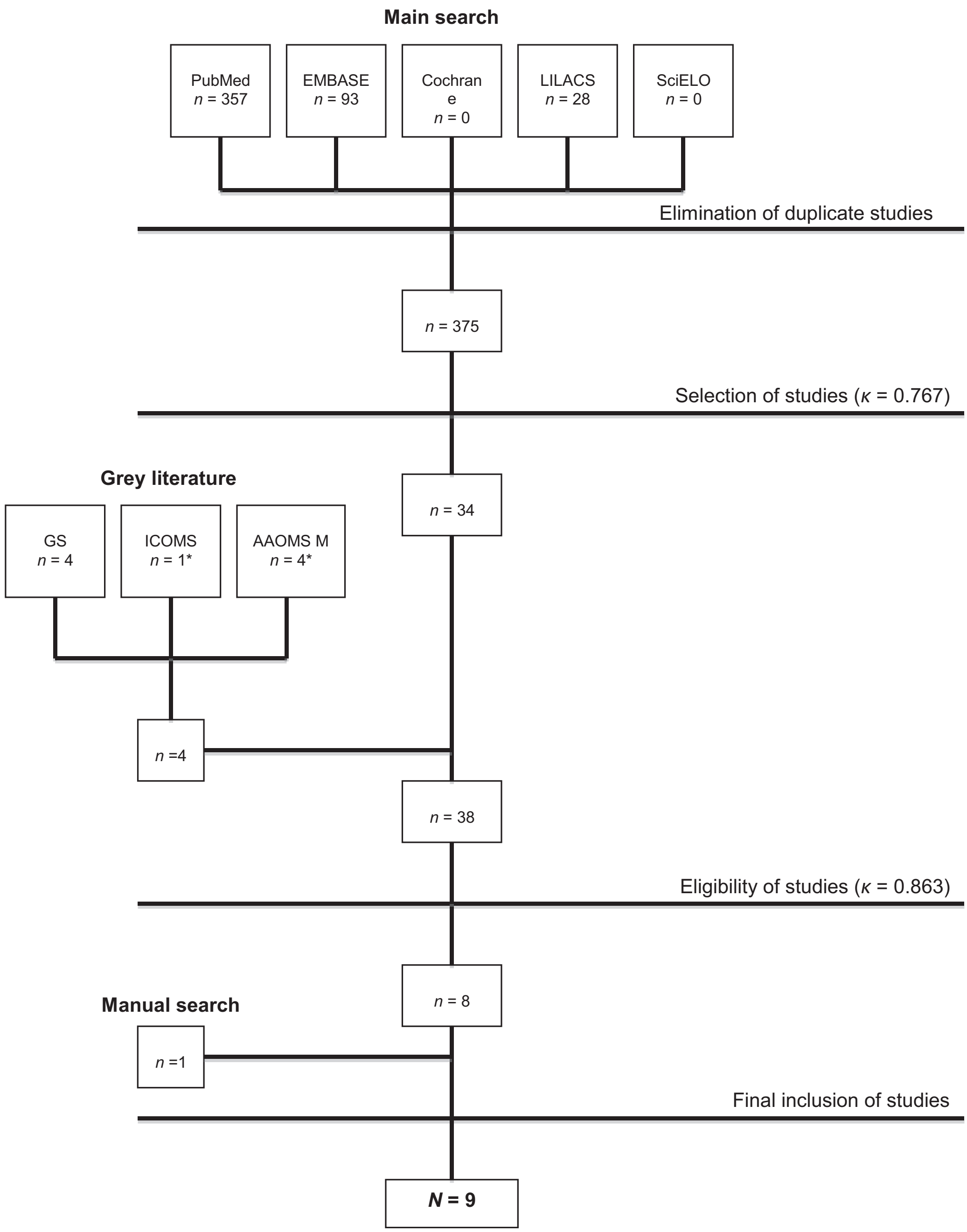

Fig. 1. Systematic review flowchart. GS, Google Scholar; ICOMS, International Conference on Oral and Maxillofacial Surgery; AAOMS M, American Association of Oral and Maxillofacial Surgery Annual Meeting; κ, measure of inter-rater agreement according to the kappa coefficient. *Abstracts found in the annals of the last three conferences; the authors were contacted by email, but no response was received and these were excluded.

intraoperative complications due to planning problems (Table 2).

The studies assessed the accuracy of computer-aided planning at specific times and only one paper[49] did not use 3D imaging of CT scans. Anatomical points and planes were used as reference to assess the study results; five papers[5,46–48,50] analyzed the accuracy of the surgical movements translation and rotation and another four[43–45,49] evaluated only translation. With regard to the measurement method, the difference between surgical planning and surgical results was evaluated in seven trials,[15,43–46,48,49] one study[50] examined the concordance in percentage terms, and another study[47] used the intra-class correlation coefficient (ICC) to assess the level of agreement between surgical planning and the surgical outcome. The accuracy for the maxilla was measured in all of the studies,[15,43–50] of the mandible in six studies,[15,44,46–48,50] the chin in three,[15,46,50] and the mandibular condyle in one.[48] In addition to these assessments, the accuracy for soft tissue was evaluated in three studies[47,48,50] (Table 3).

In summarizing the results found by all of the studies in the systematic review sample, the accuracy of computer-aided planning in orthognathic surgery was as follows: maxilla: sagittal <1 mm (0.14–1), vertical <1.2 mm (0.23–1.2),

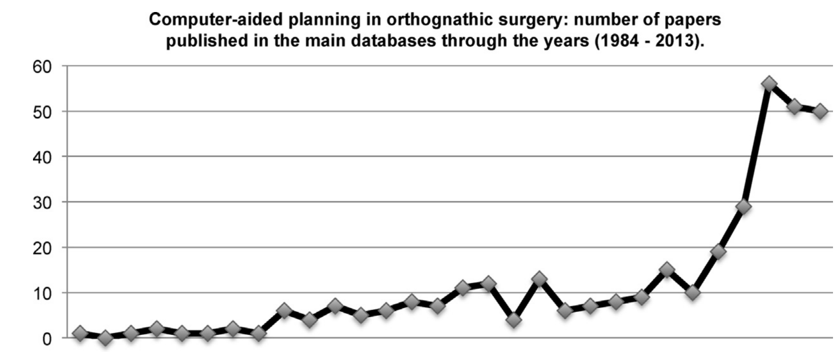

Fig. 2. Numbers of papers published through the years, 1984–2013.

transversal <0.8 mm (0.04–0.8); mandible: sagittal <1.1 mm (0.13–1.1), vertical <0.6 mm (0.33–0.6), transversal <0.8 mm (0.17–0.8); chin: sagittal <1 mm (0.3–1), vertical <0.6 mm (0.25–0.6), transversal <0.8 mm (0.76–0.8); mandibular condyle: sagittal 0.18 mm, vertical 0.13 mm, transversal 0.07 mm (Table 4).

Zinser et al.[48] compared computer-aided planning and classic planning and obtained the following differences in accuracy between the two intervention techniques: (1) Difference for bone: (a) maxilla, sagittal 0.47 mm, vertical 1.07 mm, transversal 0.39 mm, maxillary plane 0.28° FHP/0.43° MFP (FHP in relation to the Frankfort plane; MFP in relation to the midfacial projection), occlusal plane 0.93° FHP/0.33° MFP; (b) mandible, sagittal 0.77 mm, vertical 1.47 mm, transversal 0.41 mm, mandibular plane 9.67° FHP/0.49° MFP; (c) mandibular condyle, sagittal 0.43 mm, vertical 0.37 mm, transversal 0.43 mm, condylar angle 0.46°. (2) Difference for soft tissue: (a) maxilla, sagittal 0.71 mm, vertical 1.78 mm, transversal 1.3 mm; (b) mandible, sagittal 0.65 mm, vertical 1.02 mm, transversal 0.2 mm. Hsu et al.[46] compared the accuracy of the two interventions for the chin and recorded the following differences: sagittal 2.5 mm/roll 1.2°, vertical

Table 1. Demographic data for the studies included.

Author, year, and country of origin	Type of study	Sample	Age, years, mean ± SD (variation)	Gender	Type of facial deformity
Xia et al., 2007[15] USA	Prospective case series/pilot study	*n* = 5	NA	2 M, 3 F[a]	3 class II, 2 class III, all asymmetrical[a]
Centenero and Hernández-Alfaro, 2012[47] Spain	Prospective case series	*n* = 16	NA	NA	9 class II, 7 class III
Sun et al., 2013[43] Belgium	Prospective case series	*n* = 15	NA	NA	NA
Li et al., 2013[45] China	Prospective case series	*n* = 6	(19–30)	4 M, 2 F	NA
Hsu et al., 2013[46] USA	Prospective case series/ multi-centre	*n* = 65 Houston: 41 Portland: 11 New York: 13	25 (15–51) Houston: 26.7 (15–51) Portland: 26.7 (16–46) New York: 21.7 (16–51)	31 M, 34 F Houston: 23 M, 18 F Portland: 3 M, 8 F New York: 5 M, 8 F	NA
Hernández-Alfaro and Guijarro-Martínez, 2013[44] Spain	Prospective case series/proof of concept study	*n* = 6	23.7 (19–37)	3 M, 3 F	5 class II, 1 class III
Shehab et al., 2013[49] Egypt	Prospective case series/pilot study	*n* = 6	23.5 (18–30)	6 F	6 class II with vertical maxillary excess
Zinser et al., 2013[48] Germany	Non-randomized clinical trial	*n* = 28 Virtual splint: 8 Surgical navigation: 10 Classic splint: 10	20.8 ± 4.9 (18–35) Virtual splint: 21.6 ± 5.45 (19–35) Surgical navigation: 20.5 ± 4.1 (18–32) Classic splint: 20.6 ± 2.6 (18–26)	15 M, 13 F Virtual splint: 4 M, 4 F Surgical navigation: 5 M, 5 F Classic splint: 6 M, 4 F	5 class II, 23 class III Virtual splint: 8 class III Surgical navigation: 1 class II, 9 class III Classic splint: 4 class II, 6 class III
De Riu et al., 2014[50] Italy	Randomized controlled clinical trial	*n* = 20 Virtual splint: 10 Classic splint: 10	Virtual splint: (21–54) Classic splint: (24–47)	10 M, 10 F Virtual splint: 3 M, 7 F Classic splint: 7 M, 3 F	Class II/class III: NA All asymmetrical

SD, standard deviation; NA, no information provided by the authors; M, male; F, female.
[a] Data obtained from the article by Gateno et al., 2007[51], which used the same sample as Xia et al., 2007.[15]

Table 2. Computer-aided planning data for the studies included.

Author and year	Imaging method	Imaging of dental arches	Surgical planning	Software used for virtual planning	Surgical splint	Planning time	Complications and duration of surgery
Xia et al., 2007[15]	CT	Scan of plaster models with reference points	Clinical and 3D analysis Bimaxillary surgery (5), planning through maxilla	CASS—virtual planning and manufacturing of virtual splint	Occlusal splint	NA	No complications Duration NA
Centenero and Hernández-Alfaro, 2012[47]	CT (10) CBCT (6)	Scan of plaster models	Clinical and 3D analysis Bimaxillary surgery (15), planning through maxilla Single maxillary surgery (1)—mandible	SimPlant Pro OMS 10.1 (Materialise Dental, Belgium)—virtual planning and manufacturing of virtual splint	Occlusal splint	NA	NA
Sun et al., 2013[43]	CBCT	Scan of bite registration with reference points for image fusion with CT	Clinical and 3D analysis Bimaxillary surgery (15), planning through maxilla	Amira (Visage Imaging, Germany)—virtual planning VisCAM (Marcam Engineering GmbH, Germany)—manufacturing of virtual splint	Occlusal splint	255 min	No complications Duration NA
Li et al., 2013[45]	CT	CT with bite registration	Clinical and 3D analysis Bimaxillary surgery (6), planning through maxilla	SurgiCase CMF 5.0 (Materialise, Belgium)—virtual planning Unigraphics NX 7.5 (Siemens PLM Software, USA)—manufacturing of virtual splint	Occlusal splint Bone splint (maxilla)	145 min[a] (115–155)	No complications 160 min[a] (120–180)
Hsu et al., 2013[46]	CT	Scan of plaster models with reference points	Clinical and 3D analysis Bimaxillary surgery (65), planning through maxilla	CASS—virtual planning and manufacturing of virtual splint	Occlusal splint Bone splint (chin)	NA	NA
Hernández-Alfaro and Guijarro-Martínez, 2013[44]	CBCT	Intraoral scanning	Clinical and 3D analysis Bimaxillary surgery (6), planning through maxilla (3) and mandible (3)	SimPlant Pro OMS 10.1 (Materialise Dental, Belgium)—virtual planning and manufacturing of virtual splint	Occlusal splint	NA	No complications 136 min (110–156) surgery and intraoral scanning 19 min 45 s—scanning
Shehab et al., 2013[49]	CT	CT without braces and restoration of amalgam fillings	Clinical and 3D analysis Bimaxillary surgery (6), planning through maxilla	VoXim (IVS Solutions, Germany)—virtual planning 3 days Max 2009 (Autodesk Inc., USA)—manufacturing of virtual splint	Occlusal splint Bone splint (maxilla)	NA	No complications Duration NA
Zinser et al., 2013[48]	CT (12) CBCT (16)	Scan of plaster models	Clinical and 3D analysis Bimaxillary surgery (28), planning through maxilla	SimPlant Pro OMS 10.1 (Materialise Dental, Belgium)—virtual planning and manufacturing of virtual splint	Occlusal splint Bone splint (maxilla and mandibular condyle)	NA	Complications in surgery with a virtual splint Classic splint: 258 ± 35 min Virtual splint: 278 min
De Riu et al., 2014[50]	CBCT (10)	CBCT triple scan procedure	Clinical and 3D analysis Bimaxillary surgery (20), planning through maxilla (NA) and mandible (NA)	Maxilim (Medicim Nobel Biocare Group, Belgium)—virtual planning and manufacturing of virtual splint	Occlusal splint	NA	NA

CT, computed tomography; 3D, three-dimensional; CASS, computer-aided surgical simulation; NA, data not provided by the authors; CBCT, cone beam computed tomography.

[a] Used the median as a measure of central tendency.

Table 3. Methods for evaluating the postoperative accuracy of the studies included.

Author and year	Postoperative period	Anatomical region	Methods of evaluating accuracy
Xia et al., 2007[15]	6 weeks	Maxilla Mandible Chin	Linear and angular distance between reference points on the *x* (pitch), *y* (roll), and *z* (yaw) planes 3D imaging (surface-best-fit), software (NA)
Centenero and Hernández-Alfaro, 2012[47]	3 months	Maxilla Mandible (Bone and soft tissues)	Intra-class correlation coefficient (ICC) of the reference lines and angles; concordance level 3D imaging (NA), SimPlant Pro OMS 10.1 (Materialise Dental, Belgium)
Sun et al., 2013[43]	6 weeks	Maxilla	Linear distance between the reference points for the *x*, *y*, and *z* planes 3D imaging (voxel-based), Amira (Visage Imaging, Germany)
Li et al., 2013[45]	3 days	Maxilla	Linear distance between the reference points for FHP, CP, and MFP 3D imaging (NA), software (NA)
Hsu et al., 2013[46]	6 weeks	Maxilla Mandible Chin	Linear and angular distance between reference points on the *x* (pitch), *y* (roll), and *z* (yaw) planes 3D imaging (surface-best-fit), 3ds Max (Autodesk Inc., USA)
Hernández-Alfaro and Guijarro-Martínez, 2013[44]	Transoperative	Maxilla Mandible	Colour scale through interactive proximity between points during the intermediate split; iterative closest point (ICP) 3D imaging (best-fit), Mimics (Materialise Dental, Belgium) and Math Works Inc. (Natick, USA)
Shehab et al., 2013[49]	1 week	Maxilla	Linear distance between the reference points in relation to the vertical line going through the N point and the true horizontal line Cephalometric analysis of the lateral cephalogram, OnyxCeph 2.6.24 (Image Instruments GmbH, Germany)
Zinser et al., 2013[48]	6 months	Maxilla Mandible (Bone and soft tissues) Mandibular condyle	Linear and angular distance between the reference points and the reference lines in relation to FHP, CP, MFP, and the frontal process of the zygomatic bone 3D imaging (voxel-based), SimPlant Pro OMS 10.1 (Materialise Dental, Belgium)
De Riu et al., 2014[50]	NA	Maxilla Mandible Chin	Percentage rate of alignment in linear and angular distance between the reference points and the reference points in relation to the facial midline and midsagittal plane Classic splint: cephalometric analysis of the posteroanterior cephalogram Virtual splint: 3D imaging (Swennen modified 3D cephalometry[52]), software (NA)

3D, three-dimensional; NA, no information provided by the authors; FHP, Frankfort horizontal plane; CP, coronal plane; MFP, midfacial plane; N, nasion point.

1.9 mm/yaw 2°, transversal 0.9 mm/pitch 3.6°. All measurements favoured computer-aided planning (Table 4).

Analysis of the methodological quality of the papers included

The risk of bias was considered high in seven studies[15,43–45,47,49,50] and medium in two.[46,48] Papers deemed medium risk were those by Zinser et al.[48] and Hsu et al.[46]; the quality criteria not present in these studies were related to the sample randomization and blinding, and sample randomization and comparison between treatments, respectively (Table 5).

Discussion

In recent decades, the use of computerized methods to aid diagnosis and treatment in oral and maxillofacial surgery has evolved substantially.[48] This is confirmed by the 375 papers pertaining to its use in orthognathic surgery in major databases. Research has increased steadily since the publication of the first study in 1984,[53] with 157 papers on computer-assisted planning published in the last 3 years (2011–2013) (Fig. 2). In addition, seven papers included in the present study were published during this period,[43–50] demonstrating that the theme of this systematic review is highly relevant to current scientific evidence on orthognathic surgery.

An investigation by Zinser et al. (2012)[34] was excluded because it was not considered original, given that the sample of patients operated on using a virtual surgical splint was the same as that analyzed in the non-randomized clinical trial by Zinser et al. published in 2013.[48] Another noteworthy study that was excluded is that conducted by Xia et al. published in 2011.[39] The authors did not present accuracy measurements for the intervention using a virtual surgical splint, but compared computer-aided and classic planning in virtual surgeries using a visual analogue scale (VAS). The results for skeletal harmony and symmetry and mandible positioning were significantly better for computer-assisted planning. Moreover, the investigation by Xia et al.[39] showed the greatest methodological rigour among the papers selected to be read in full, since, of the quality assessment criteria applied for the systematic review, only sample randomization was not present in that study.[39]

Inter-rater agreement was assessed using Cohen's kappa coefficient based on the index proposed by Landis and Koch.[54] Thus, the kappa value between the two review authors was considered significant for study selection ($\kappa = 0.767$) and excellent for study eligibility ($\kappa = 0.863$). These data are highly relevant with regard to the quality of the systematic review, since they indicate that the methodological rigour of the inclusion and exclusion criteria can be reproduced by the reader. We believe that the level of agreement in study selection was significant and not excellent because the titles and abstracts of the papers did not clearly demonstrate their methodology and because the authors were as inclusive as possible during the selection process. Moreover, when doubts arose as to a

Table 4. Orthognathic surgery accuracy of the studies included.

Author and year	General Mean ± SD (variation)	Maxilla Mean ± SD (variation)	Mandible Mean ± SD (variation)	Chin Mean ± SD (variation)	Mandibular condyle Mean ± SD (variation)
Xia et al., 2007[15]	NA	Sagittal: <0.45 mm (−0.57 to 1.17) Roll: 0.08° ± 1.14° (−1.64° to 1.41°) Vertical: <0.44 mm (−1.98 to 1.65) Yaw: 0.56° ± 0.48° (0.18° to 1.17°) Transversal: <0.64 mm (−1.19 to 1.88) Pitch: 1.08° ± 2.33° (−2.53° to 3.48°)	Sagittal: <0.81 mm (−0.84 to 1.99) Roll: 0.05° ± 1.53° (−1.36° to 2.11°) Vertical: <0.38 mm (−1.88 to 1.01) Yaw: 0.05° ± 0.69° (−0.78° to 0.86°) Transversal: <0.49 mm (−1.51 to 1.71) Pitch: 0.55° ± 1.83° (−3.05° to 1.71°)	Sagittal: <0.3 mm (−0.83 to 1.65) Roll: 0.74° ± 1.36° (−0.70° to 1.99°) Vertical: <0.25 mm (−0.99 to 1.16) Yaw: 0.45° ± 0.91° (−1.33° to 0.48°) Transversal: <0.76 mm (−1.93 to 1.5) Pitch: 0.74° ± 1.29° (−0.38° to 2.15°)	NA
Centenero and Hernández-Alfaro, 2012[47]	*Soft tissue* 0.724 ± 0.310 (0.053–0.970) ICC[a] Angles: 0.867 ± 0.164 (0.624–0.970) ICC[a] Lines: 0.608 ± 0.368 (0.053–0.947) ICC[a] *Bone tissue* 0.722 ± 0.246 (0.350–0.964) ICC[a] Angles: 0.655 ± 0.249 (0.350–0.910) ICC[a] Lines: 0.922 ± 0.059 (0.880–0.964) ICC[a]	OcPl: 0.375 (−0.178 to 0.739) ICC[a] (FHP)	MdPl: 0.608 (0.162 to 0.849) ICC[a] (FHP)	NA	NA
Sun et al., 2013[43]	NA	Sagittal: 0.5 ± 0.22 mm (0 to 0.9) Vertical: 0.57 ± 0.35 mm (0.2 to 1.4) Transversal: 0.38 ± 0.35 mm (0 to 1.3)	NA	NA	NA
Li et al., 2013[45]	<1 mm (0.03–1.7)	Sagittal: 0.7 mm (0.04 to 1.7) Vertical: 0.8 mm (0.03 to 1.6) Transversal: 0.6 mm (0.03 to 1.6)			

Hsu et al., 2013[46]	NA	Sagittal: 1 mm (−0.7 to 1.6) Roll: 0.9° (−1.8° to 1.8°) Vertical: 0.6 mm (−0.8 to 0.9) Yaw: 1.3° (−2.7° to 2.3°) Transversal: 0.8 mm (−1.7 to 1.4) Pitch: 1.5° (−2.3° to 3.4°)	Sagittal: 1.1 mm (−0.9 to 1.5) Roll: 1° (−2° to 1.8°) Vertical: 0.6 mm (−0.8 to 0.7) Yaw: 1.7° (−3.3° to 3.3°) Transversal: 0.8 mm (−1.4 to 1) Pitch: 1.8° (−3.7° to 3.6°)	Sagittal: 1 mm (−2.1 to 2) (VS) Sagittal: 3.5 mm (−6.2 to 7.8) (NS) Roll: 1.8° (−4° to 3.7°) (VS) Roll: 3° (−5.8° to 6.3°) (NS) Vertical: 0.6 mm (−1.4 to 1) (VS) Vertical: 2.5 mm (−5.3 to 4.6) (VS) Yaw: 1.9° (−4° to 4.1°) (VS) Yaw: 3.9° (−7.1° to 8.4°) (NS) Transversal: 0.8 mm (−1.7 to 1.8) (VS) Transversal: 1.7 mm (−2.9 to 3.9) (NS) Pitch: 2.2° (−4.1° to 4.9°) (VS) Pitch: 5.8° (−9.4° to 12.9°) (NS)	NA
Hernández-Alfaro and Guijarro-Martínez, 2013[44]	Sagittal: 0.15 ± 0.15 mm (0–0.4) Vertical: 0.5 ± 0.35 mm (0.1–0.9) Transversal: 0.25 ± 0.16 mm (0–0.5)	Sagittal: 0.17 ± 0.2 mm (0–0.4) Vertical: 0.6 ± 0.43 mm (0.1–0.9) Transversal: 0.13 ± 0.11 mm (0–0.2)	Sagittal: 0.13 ± 0.11 mm (0–0.2) Vertical: 0.4 ± 0.3 mm (0.1–0.7) Transversal: 0.37 ± 0.11 mm (0.3–0.5)	NA	NA
Shehab et al., 2013[49]	NA	Sagittal: 0.8 ± 0.9 mm Vertical: 1.2 ± 1.3 mm	NA	NA	NA
Zinser et al., 2013[48]	NA	*Bone tissue* Sagittal: <0.14 mm (VS) Sagittal: <0.61 mm (CS) Vertical: <0.23 mm (VS) Vertical: <1.3 mm (CS) Transversal: <0.04 mm (VS) Transversal: <0.43 mm (CS) MxPl: 0.35° (FHP)—0.03° (MFP) (VS) MxPl: 0.63° (FHP)—0.46° (MFP) (CS) OcPl: 0.02° (FHP)—0.03° (MFP) (VS) OcPl: 0.95° (FHP)—0.36° (MFP) (CS) *Soft tissue* Sagittal: <1.39 mm (VS) Sagittal: <2.1 mm (CS) Vertical: <2.52 mm (VS) Vertical: <4.3 mm (CS) Transversal: <1.2 mm (VS) Transversal: <2.5 mm (CS)	*Bone tissue* Sagittal: <0.17 mm (VS) Sagittal: <0.94 mm (CS) Vertical: <0.33 mm (VS) Vertical: <1.8 mm (CS) Transversal: <0.17 mm (VS) Transversal: <0.58 mm (CS) MdPl: 0.58° (FHP)—0.61° (MFP) (VS) MdPl: 10.25° (FHP)—1.1° (MFP) (CS) *Soft tissue* Sagittal: 0.09 mm (VS) Sagittal: 0.74 mm (CS) Vertical: <0.48 mm (VS) Vertical: 1.5 mm (CS) Transversal: 1.1 mm (VS) Transversal: 1.3 mm (CS)	NA	Sagittal: 0.18 mm (VS) Sagittal: 0.61 mm (CS) Vertical: 0.13 mm (VS) Vertical: 0.5 mm (CS) Transversal: 0.07 mm (VS) Transversal: 0.5 mm (CS) CoL–ZFS: 0.05° (VS) CoL–ZFS: 0.51° (CS)

Table 4 (*Continued*)

Author and year	General Mean ± SD (variation)	Maxilla Mean ± SD (variation)	Mandible Mean ± SD (variation)	Chin Mean ± SD (variation)	Mandibular condyle Mean ± SD (variation)
De Riu et al., 2014[50]		*Bone tissue*	*Bone tissue*	*Bone tissue*	NA
		Vertical: 92.59% (VS)	Vertical: 92.59% (VS)	Transversal: 85.77% (VS)	
		Vertical: 58.5% (CS)	Vertical: 58.5% (CS)	Transversal: 79.67% (CS)	
		Transversal: <88.1% (VS)	Transversal: <88.17% (VS)	Transversal: 76.67% (VS)	
		Transversal: <76.25% (CS)	Transversal: <50.82% (CS)	Transversal: 79.67% (CS)	

SD, standard deviation; NA, information not provided by the authors; ICC, intra-class correlation coefficient; OcPl, occlusal plane; FHP, Frankfort horizontal plane; MdPl, mandibular plane; VS, virtual splint; NS, no splint; CS, classic splint; MxPl, maxillary plane; MFP, midfacial plane; CoL, condylar line; ZFS, zygomaticofrontal suture.

[a]ICC index: low correlation, ICC < 0.4; good correlation, ICC 0.4–0.75; excellent correlation, ICC > 0.75.

study's eligibility, it was read in full regardless of whether one of the authors had rejected it.

The protocol for computer-aided planning in orthognathic surgery varied substantially between studies, with the following methods used most widely in each planning phase: CT (six studies[15,45–49]), scanning plaster casts (four studies[15,46–48]), clinical analysis and 3D imaging (nine studies[15,43–50]), planning beginning with the maxilla (nine studies[15,43–50]), and using software that carries out the planning and designs the virtual surgical splint (six studies[15,44,46–48,50]) (Table 2). The preference for CT over CBCT presents disadvantages in terms of image quality, the supine position of the patient during the test, and larger radiation doses, while advantages include better identification of soft tissue and less image distortion where metallic elements are present.[55,56] Mandible retrusion in the supine position during CT image capture was attenuated using central occlusal registration in five studies[15,45–48] and the head's natural position was corrected in trials that used a gyroscope[15,46]; however, the effect of gravity on soft tissues cannot be corrected. The major disadvantage of CBCT is in relation to the metallic elements of dental braces, which was diminished in the next phase of the protocol by scanning the plaster casts,[47,48] using intraoral scans of the dental arches,[44] scanning occlusal registration with reference points,[43] or by triple scan procedure.[50] Two other important aspects of capturing dental arch images are the greater need for accuracy in tooth segmentation[57] and the tactile sensitivity of the surgeon in identifying the best final occlusion.[48] Thus, the fusion of facial CT images and dental arch scans is important in computer-aided planning. This is evident in the protocols of the studies included in the systematic review, because two[45,49] of the three studies[45,49,50] that used a splint for fixation of the maxilla and did not scan the dental arches[45,49] had to create a classic splint for mandibular fixation in final occlusion.

Fusion of facial CT images and dental arch images is more accurate when reference points are reproducible for both planning phases.[58,59] Only four studies used this method to create an accurate virtual 3D model.[15,43,46,50] As such, the other trials[44,45,47–49] (Table 2) may have made mistakes in image fusion similar to allocation errors for cephalometric points, generating surgical inaccuracies.

The use of a virtual 3D model in planning software for orthognathic surgery is beneficial for surgeons in that several 3D cephalometric analyses can be performed and shared, contact points and anatomical structures can be visualized prior to surgery, and a virtual surgical splint can be created.[2,3,5,31,60] These benefits can result in shorter surgical planning and surgery times, as well as fewer surgical complications in relation to classic planning. These data were under-evaluated and discussed in the studies included. Only Sun et al.[43] (255 min) and Li et al.[45] (from 115 to 155 min) reported results for planning times, which were significantly lower than those recorded for studies using classic planning (about 10 h).[29,61] The surgery time (between 110 and 180 min[44,45] and about 278 min[48]) and the number of surgical complications related to planning (one case reported problems establishing final occlusion) showed no apparent differences between computer-assisted and classic planning. These data were presented in the non-randomized clinical trial when comparing the two types of intervention (Table 2).[48] Therefore, the argument that computer-aided planning provides greater benefits in relation to surgery time and complications may not be valid; however, the reduction in time spent on planning is in itself an excellent advantage for surgeons.

Studies used 3D imaging[15,43–48,50] and cephalometric radiographs[49,50] to measure the accuracy of surgical planning. Image superimposition errors for lateral cephalometric radiographs using Onyx-Ceph (Image Instruments GmbH, Germany) varied from 1.24 mm to 7.55 mm, according to the results of Krey et al.[62] This variation hampered the analysis and comparison of the measurements reported by Shehab et al.[49] with those from other studies and made it impossible to determine the accuracy of transversal maxillary movement. De Riu et al.[50] used posteroanterior cephalometric radiographs to analyze the accuracy in the classic planning, but used 3D superimposition to analyze the results of the virtual planning; these different types of analysis made the comparison of results between groups unfeasible. So, it was not possible to use the results of the randomized controlled clinical trial[50] to assess the best way to intervene in orthognathic surgery.

Sun et al.[43] used voxel-based 3D imaging and observed a superimposition accuracy of 0.15 mm. Xia et al.[15] and Hsu et al.[46] applied surface-best-fit 3D imaging and obtained accuracy values lower than 0.12 mm. The other trials either did not

Table 5. Quality analysis of the studies included.

Quality criteria for studies	Xia et al., 2007[15]	Centenero and Hernández-Alfaro 2012[47]	Sun et al., 2013[43]	Li et al., 2013[45]	Hsu et al., 2013[46]	Hernández-Alfaro and Guijarro-Martínez, 2013[44]	Shehab et al., 2013[49]	Zinser et al., 2013[48]	De Riu et al., 2014[50]
Sample randomization	No	No	No	No	No	No	No	No	Yes
Comparison between treatments[a]	No	No[b]	No	No	No[c]	No	No	Yes[d]	Yes
Blind assessment	Yes	No	No	No	Yes	No	No	No	No
Validation of measurements	No[e]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Statistical analysis	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Defined inclusion and exclusion criteria	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Report of follow-up	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Risk of bias assessment[f]	High	High	High	High	Medium	High	High	Medium	High

[a] Comparison between 'gold standard' treatment (control group) and the treatment being tested (experimental group).
[b] The classic splint and the virtual splint were compared.
[c] The only treatments compared were the surgical chin procedures.
[d] The virtual splint, surgical navigation, and classic splint were compared.
[e] Validation of measurements used only for accuracy of 3D imaging superimposition.
[f] Risk of bias assessment: high = 0–5 'Yes'; medium = 5–6 'Yes'; low = 7 'Yes'.

identify the type of 3D imaging used[45,47] or provided no information on superimposition accuracy[44,48] (Table 3). Computer-aided planning showed a considerable advantage over classic planning in regard to accuracy and the ability to analyze surgical results.

The accuracy of maxilla translation in computer-assisted planning for orthognathic surgery was <1 mm (Hsu et al.,[46] sagittal) and rotation was <1.5° (Hsu et al.,[46] pitch), indicating that this type of planning is accurate for the maxilla. However, when results were analyzed using lateral radiographs in the study by Shehab et al.,[49] the accuracy of the vertical movement of the maxilla was <1.2 mm and <0.8 mm for 3D imaging. The accuracy measurement of 1.2 mm for vertical maxillary movement is similar to that recorded by Zinser et al.[48] (<1.3 mm) in the group that used a classic splint. This information must be taken into account since Shehab et al.[49] used similar splints to those employed by Li et al.[45] and Zinser et al.,[48] with vertical accuracy of the maxilla in the latter two studies of 0.8 mm and 0.23 mm, respectively. The splint used by Shehab et al.,[49] Li et al.,[45] and Zinser et al.[48] controls surgical rotation and translation movements based on the bone segment and not occlusion, avoiding the need for intraoperative verification to vertically position the maxilla. Thus, it is once again assumed that the method used to assess accuracy in lateral cephalometric radiographs compromised the results obtained by Shehab et al.[49] (Table 4).

As occurred with the maxilla, computer-aided planning in jaw surgery showed accurate translation and rotation in the mandible. The results obtained by Xia et al.,[15] Hsu et al.,[46] Hernández-Alfaro and Guijarro-Martínez,[44] and Zinser et al.[48] showed translation accuracy in the mandible of <1.1 mm (Hsu et al.,[46] sagittal) and rotation accuracy <1.8° (Hsu et al.,[46] pitch). Therefore, the initial surgical placement of the maxilla and use of the final virtual splint directly influenced the surgical accuracy, given that surgical planning for all the patients analyzed by Xia et al.,[15] Hsu et al.,[46] and Zinser et al.[48] began with the maxilla and a final virtual splint was used (Tables 2 and 4).

Accuracy for soft tissue is considered a challenge in computer-aided planning. The study by Centenero and Hernández-Alfaro[47] recorded a mean ICC with good correlation (0.724) for soft tissue; however, an individual assessment of agreement between the reference lines in the area close to the upper and lower lips showed a substantial variation in the ICC. Zinser et al.[48] recorded contradictory results for accuracy in soft tissue, with linear analysis between the planning and postoperative phases indicating greater inaccuracy for the maxilla (<2.52 mm) and less inaccuracy for the mandible (<1.1 mm) (Table 4). Inaccuracy in the maxilla can be explained by the use of the V–Y suture, intraoperative bone recontouring in the anterior maxilla, and different Le Fort I osteotomy heights[63,64] associated with the inability of the software to reproduce these inherent surgical procedures. The authors, however, did not provide any data in this regard. Nevertheless, volumetric analysis in the study by Zinser et al.[48] showed a high level of inaccuracy for the lower lip and chin. As such, surgeons using computer-aided planning in jaw surgery should not use soft tissue analyses as a reference for planning or communication with the patient, since results indicate that this type of analysis is inaccurate.

Three studies[46,48,50] compared computer-assisted and classic planning and found favourable results for accuracy in all bone segments for computer-aided planning, but as mentioned previously the results of De Riu et al.[50] were not amenable to analysis. Zinser et al.[48] compared accuracy in the maxilla, mandible, and mandibular condyle and found a more visible difference in accuracy between the two interventions for vertical positioning of the maxilla and mandible (<1.47 mm) and for rotation of the mandibular plane in relation to the Frankfort plane (9.67°) (Table 4). The mandibular condyle maintained a central position in the temporomandibular joint, which did not occur when classic planning was used. The favourable vertical position of the maxilla and correct placement of the mandibular condyle can be attributed to the type of virtual surgical splint used by Zinser et al.[48] This splint uses holes in the maxilla and mandibular branch established by a splint prior to osteotomy as reference points, with the intermediate and final virtual splints then fixed using these holes. This enables the surgeon to overcome the major intraoperative challenges,[65] avoiding the use of external or internal references to vertically position the maxilla and ensuring that the proximal segment of the mandible is not subject to rotation. It is important to note that Xia et al.,[15] Sun et al.,[43] Hsu et al.[46] and Hernández-Alfaro and Guijarro-Martinez[44] used a virtual occlusal splint and reported accurate vertical placement for the maxilla (<0.6 mm) (Tables 2 and 4).

Hsu et al.[46] compared the two interventions in the chin and found highly favourable accuracy results for computer-aided planning in this bone segment, with the largest difference recorded for translation in the sagittal plane (2.5 mm) and rotation (pitch, 3.6°) (Table 4). The difference between the two interventions occurs because classic planning does not use surgical splints; surgeons are guided by their experience, some internal reference points, and the chin plate. As such, classic planning for chin surgery is imprecise and computer-aided planning ensures much greater accuracy (Table 4).

Classic planning for jaw surgery has been described as accurate[65–68] (sagittal 0.23 mm,[65] 0.7 mm,[66] 1.2 mm,[67,68] 1.65–1.77 mm,[69] 2.2 mm[70]; vertical 0.23 mm,[65] 1.2 mm,[67,68] 0.8–1.9 mm[66], 0.96–2.16 mm[69]; transversal 1.9 mm[67]), however variation in measurements makes it imprecise. This is primarily due to difficulty in reproducing and transferring cephalometric planning, articulator assembly, and the surgical models to the surgery itself.[66–68] These surgical stages vary significantly in accordance with the surgeon's experience and the techniques used. Comparisons were not be made between the accuracy achieved using classic planning for orthognathic surgery described in the literature and accuracy recorded with computer-aided planning in this systematic review, since the methods used to assess accuracy for these two interventions are not reproducible (overlaying radiographs and 3D imaging). Nevertheless, the literature provides strong indications that computer-assisted planning is more accurate than classic planning.

The quality assessment of the studies included in this systematic review was based on an analysis by Clementini et al.,[9] with additional criteria to evaluate the effect of comparison between classic planning and computer-aided planning, as well as blinding of the rater. These are key criteria in assessing the quality of intervention studies, particularly when the aim is to determine whether one type of treatment provides greater benefits than the other.

The papers included in this systematic review were assessed as being of low or medium quality, since the risk of bias was considered high in seven studies[15,43–45,47,49,50] and medium in only two studies.[46,48] The study by Hsu et al.[46] compared computer-aided and classic planning for chin surgery only. As a result, the quality assessment of the study concluded that it did not present this criterion, since chin surgery is secondary to orthognathic surgery and, in accordance with the primary outcomes of the study, comparison effects were not presented. The randomized controlled clinical trial done by De Riu et al.[50] did not present the blinding assessment, the validation of measurements, and the follow-up. Thus, no paper was deemed to have a low risk of bias, which means there were no well-delineated randomized controlled clinical trials on the subject available in the literature.

With respect to current scientific evidence on computer-aided planning in orthognathic surgery, meta-analysis is impossible, since as previously mentioned, no well-delineated randomized controlled clinical trials were found. However, the systematic review of smaller intervention studies can help generate hypotheses and encourage larger intervention studies.[7] This was a descriptive systematic review aimed at evaluating the scientific evidence currently available and improving estimates of the effect of computer-aided planning on the results of orthognathic surgery.

The scientific literature on computer-assisted planning in orthognathic surgery is somewhat repetitive in terms of conclusions. All of the papers selected for full-text reading indicated that this type of surgical intervention is superior to classic planning, i.e., the data found in the literature are biased. However in order to state that computer-aided planning offers greater advantages than classic planning, well-structured randomized controlled clinical trials are needed to evaluate surgical accuracy. To this porpose, the study design needs to be standardized, and preferably based on the Consolidated Standards of Reporting Trials (CONSORT 2010)[71]; this would provide credibility and make it easier to reproduce the work of other authors.

In theory, conducting a randomized controlled clinical trial on this question appears simple, but this is not the case because care must be taken in the study design to control for clinical heterogeneity. For that, the sample size and the randomization are critical, because these cares will equalize clinically the control group and the test group for the different types of dentofacial deformities to be treated. In relation to the different protocols for computer-aided planning, conducting a multi-centre study will bring greater validity to the type of protocol used by the authors of the study. However, as the main idea of computer-aided planning is that different technologies can be superior to classic planning, the ideal is that each researcher tests their protocol, but using a standardized study design and CONSORT 2010[71] as reference. Another important point to be considered is how the accuracy of the surgical procedure will be evaluated, taking into account that the two groups should be analyzed using superimposed preoperative and postoperative CBCT images. The evaluator should be blinded to the type of intervention and if possible the accuracy of the superimposed images should be measured by the software to validate the analysis.

In conclusion, the systematic summarization of the results presented in the literature suggests that computer-aided planning is accurate for orthognathic surgery of the maxilla and mandible, that the virtual surgical splints used by Hsu et al.[46] and Zinser et al.[48] are accurate in placement of the chin and mandibular condyle, respectively, and that the analysis of the soft tissues is inaccurate.

With respect to the benefits to the patient and surgical procedure, it is estimated that computer-aided planning facilitates the analysis of surgical outcomes and provides greater accuracy. When comparing this technique with classic planning, the former results in reduced preoperative planning times, both have similar intraoperative times, the number of planning-related surgical complications does not decline, and there are indications that computer-aided planning is more accurate.

Although these findings favour computer-aided planning, the quality of the scientific evidence is low and well-structured randomized controlled clinical trials are needed to clearly determine whether this type of intervention in orthognathic surgery is more accurate and provides greater benefits to the patient and the surgical procedure than classic planning.

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