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Systematic Review
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Hierarchy of surgical stability in orthognathic surgery: overview of systematic reviews

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Abstract. The purpose was to perform an overview of systematic reviews in order to create a hierarchical scale of stability in orthognathic surgery with the aid of the highest level of scientific evidence. The systematic search was conducted in the PubMed, Embase, and Cochrane Library databases. The grey literature was investigated in Google Scholar and a manual search was done of the references lists of included studies. Fifteen studies were included in the final sample, of which eight were systematic reviews and seven were meta-analyses. These were assessed for methodological quality using the AMSTAR 2 tool and all were considered to be of medium to high methodological quality. The clinical studies included in the 15 reviews and meta-analyses were classified by the review authors as having a moderate to high potential for risk of bias. The hierarchical pyramid of stability in orthognathic surgery was established, with two surgical procedures considered highly unstable: (1) maxillary expansion with semi-rigid internal fixation evaluated at the dental level in the posterior region, and (2) clockwise rotation of the mandible with rigid internal fixation of bicortical screws in the sagittal direction.

Key words: orthognathic surgery; stability; recurrence; systematic review; overview of systematic reviews.

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Orthognathic surgery combined with orthodontic treatment is the most predictable approach for the treatment of dentofacial deformity and to achieve satisfactory outcomes with long-term bone stability[1,2]. However, masticatory muscle activity, deficient preoperative and postoperative orthodontics, surgical complications, inefficient fixation of bone segments, and the extent of the surgical movement can lead to bone instability and hence treatment relapse[3].

In recent years, this wide range of factors that may influence the stability of orthognathic surgery has been investigated in a series of systematic reviews – each with a specific objective for a particular variable. These reviews summarized and analyzed the methodology of the primary studies, but the peculiarities of each sur-

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gical intervention precluded a more educational and understandable analysis of the multiple factors that lead to bone instability[4–8].

In the current literature, the most comprehensible description of stability in orthognathic surgery in the general context is provided in two articles reporting clinical studies performed by Proffit et al. (1996 and 2007)[1,2]. In these papers, the authors report a hierarchical scale of this outcome based on their clinical experience in a sample compiled over the course of more than 30 years. Although these are considered landmark articles in the orthognathic surgery literature, little scientific evidence is provided, since no clear methodological criteria or statistical analysis are present[1,2]. Despite this lack of methodological rigor, these studies do provide a valuable demonstration of the experience of experts.

There is an unmet educational need to evaluate stability in orthognathic surgery according to the technique and surgical movement(s), and to create an evidence-based hierarchical scale of stability. In this context, an overview of systematic reviews could play an invaluable role in summarizing results and organizing existing data, in addition to analyzing the risk of bias of secondary studies that have quantified surgical stability[9].

The overviews of systematic reviews, introduced by specialists in systematic reviews, are the newest and highest level of scientific evidence. The overview is considered a 'friendly front-end' study for decision-making in health. The creation of an 'overview of systematic reviews' article-type became necessary in response to the appearance of several systematic reviews published in a wide variety of indexed journals, and the main purpose is to facilitate the subsequent complexity of the clinician's decision-making process based on such a large number of studies. Thus, the objective is to categorize and summarize secondary studies responding to the same clinical question or that complement each other in outcomes that may aid in decision-making[9].

This overview of systematic reviews was thus designed to evaluate the stability of different techniques and surgical movements used in orthognathic surgery and to establish an evidence-based hierarchy of stability for orthognathic procedures.

Methods

Three searches for systematic reviews and/or meta-analyses were conducted: the main search, which covered the PubMed, Embase, and Cochrane Library databases; a search of the grey literature, conducted through Google Scholar; and a hand-search of the references of the articles retrieved by the two aforementioned strategies. The search strategy was devised in accordance with the PICOS process: P (patient population): dentofacial deformity; I (intervention): orthognathic surgery; C (comparison): different types of surgical procedures; O (outcome): stability; S (study design): systematic review or meta-analysis. There were no restrictions on language or year of publication, and Boolean operators (OR and AND) were used to combine subject headings related to dentofacial deformity, orthognathic surgery, stability, and systematic review and/or meta-analysis.

Search strategy

For the main search, the medical subject heading (MeSH) terms (and their entry terms) and non-MeSH terms used to search PubMed were the following: [(''Dentofacial Deformities'' [MeSH term] OR (All ''Dentofacial Deformities'' entry terms) OR ''Orthognathic Surgery'' [MeSH term] OR (All ''Orthognathic Surgery'' entry terms)) AND (''Recurrence'' [MeSH term] OR (All ''Recurrence'' entry terms) OR ''Stability'' OR ''Surgical Stability'' OR ''Instability'' OR ''Surgical Instability'' OR ''Surgically Stable'' OR ''Surgically Unstable'') AND (''Review'' [MeSH term] OR (All ''Review'' entry terms) OR ''Meta-Analysis'' [MeSH term])].

To search Embase, Emtree terms and their synonyms were selected using the 'PICO search' tool. Some additional non-Emtree terms were also included to yield the following strategy: ''stability'', ''surgical stability'', ''instability'', ''surgical instability'', ''surgically stable'', and ''surgically unstable''. Thus, the systematic search was conducted as follows: [('dentofacial deformity'/syn OR All synonymous OR 'orthognathic surgery'/syn OR All synonymous) AND ('relapse'/syn OR All synonymous OR 'recurrence risk'/syn OR All synonymous OR 'stability'/syn OR 'surgical stability'/syn OR 'instability'/syn OR 'surgical instability'/syn OR 'surgically stable'/syn OR 'surgically unstable'/syn) AND ('systematic review'/syn OR All synonymous OR 'meta analysis'/syn OR All synonymous)].

The Cochrane Library search strategy was based on the PubMed query, without entry terms: [(''Dentofacial Deformities'' OR ''Orthognathic Surgery'') AND (''Recurrence'' OR ''Stability'' OR ''Surgical Stability'' OR ''Instability'' OR ''Surgical Instability'' OR ''Surgically Stable'' OR ''Surgically Unstable'') AND (''Review'' OR ''Meta-Analysis'')].

A search of the grey literature was also performed. The so-called 'grey literature' search strategy was designed to increase the scope of study retrieval, to include articles published in non-indexed journals or which, for any other reason, were not retrieved by the main search strategy. The following query was designed: (''Dentofacial Deformities'' OR ''Orthognathic Surgery'') AND (''Recurrence'' OR ''Relapse'' OR ''Stability'' OR ''Surgical Stability'') AND (''Systematic Review'' OR ''Meta-Analysis'').

In addition, a hand-search was conducted. Once the main search and grey literature searches were complete, a detailed hand-search of the references of articles retrieved by these strategies was conducted to find studies not available electronically.

Study selection

All three searches were performed by one author (OLHJ), while study selection was conducted independently by two authors (OLHJ and APSG). After an analysis of titles and abstracts, studies that met the following criteria were selected for full-text reading: (1) is not a narrative review of the literature; (2) is a systematic review or meta-analysis on the stability of surgical treatment for dentofacial deformity.

Articles that were deemed not to meet these prerequisites by the two authors were excluded. When one or both of the authors selected a study, the full text was read. The eligibility of the selected articles was then assessed. The kappa statistic (κ) was used to evaluate the level of agreement between the two authors.

Study eligibility

To achieve consistency in the analysis of articles after full-text reading by the two independent authors, a standardized form was created and used to check studies against the following inclusion criteria: (1) is not a systematic review or meta-analysis with a sample consisting exclusively of patients undergoing distraction osteogenesis; (2) is not a systematic review or meta-analysis with a sample consisting exclusively of patients with cleft lip and palate or other syndromes; (3) reports a summary of the results of primary studies on stability in orthognathic surgery without a temporomandibular joint pathology, including magnitude of surgical movement (T1) and rate of relapse during postoperative follow-up (T2); (4) includes more than one primary study reporting stability in orthognathic surgery as an outcome; and (5) is an original study.

At this stage, in the case of disagreement between the two independent investigators (OLHJ and APSG), the eligibility of the study was discussed with the other authors. Articles that did not meet the eligibility criteria were excluded from further analysis and the reason for exclusion reported. Again, the kappa statistic (κ) was used to evaluate the level of agreement between OLHJ and APSG.

Data extraction

The extraction of demographic and methodological data, analysis of methodological quality, and assessment of reported surgical stability outcomes from the systematic reviews included in this overview were performed by the same two independent authors. In the event of disagreement, the article was discussed with the other authors; if doubts persisted, the primary study to which the article in question referred was retrieved for the analysis of crude results or the corresponding author of the article was contacted via e-mail.

Analysis of surgical stability

The stability of the surgical procedure was evaluated by the percentage of dental and/or skeletal relapse in the maxilla and mandible, taking into account the mean magnitude of surgical movement (T1) in relation to the magnitude of relapse at last sample follow-up (mean postoperative relapse, T2). Results were expressed in millimetres (mm), and surgical movement in the sagittal, vertical, and transverse planes was taken into account.

Crude data from the secondary studies were converted to percentages according to the magnitude of surgical movement and magnitude of relapse during postoperative follow-up. The percentage relapse was categorized according to susceptibility as 'highly unstable' (relapse between 75% and 100%), 'unstable' (relapse between 50% and 74.9%), 'stable' (relapse between 25% and 49.9%), or 'highly stable' (relapse between 0% and 24.9%).

Analysis of methodological quality

The criteria used in the systematic reviews or meta-analyses to assess the potential risk of bias of clinical trials were evaluated.

The AMSTAR 2 tool was used to ascertain the potential for risk of bias in the secondary studies included[10]. The analysis of methodological quality was performed on the basis of 16 evaluation criteria for meta-analyses and 13 evaluation criteria for systematic reviews. The 16 (or 13) criteria for evaluation of the methodological quality of the included secondary studies were marked as follows: 'yes' (Y) when the criterion was included in the study methodology; 'no' (N) when not included in the study methodology; 'partial yes' (PY) when partially included in the study methodology; or 'no meta-analysis conducted' (NM) when the study was only a systematic review and thus the item was not applicable.

These criteria used to evaluate the potential risk of bias are not intended to yield a general score or quantify the results of the studies, but rather seek to enable a careful, individualized evaluation of each study.

Results

Without restrictions on language or year of publication and according to the protocols described in the Methods section, the main search was performed on July 1, 2018, the grey literature search was performed on July 8, 2018, and the hand-search of references of the included articles was performed on July 8, 2018. The protocol of this overview of systematic reviews is summarized in the flowchart in Fig. 1.

Search strategy

The main search retrieved 150 studies from PubMed, 40 from Embase, and 14 from the Cochrane Library. After eliminating duplicate records, 168 articles remained for title and abstract screening.

With regard to the grey literature search, a wide-ranging search of Google Scholar for articles published in non-indexed journals, designed to locate as many studies as possible, retrieved 3980 items.

The hand-search of references of the included articles did not yield any studies deemed worthy of inclusion in the sample.

Study selection

Screening of titles and abstracts by the two independent authors resulted in an excellent level of agreement (κ = 0.83, 95% confidence interval 0.67 to 0.98) during study selection. Overall, 35 articles from the main search and 11 from the grey literature search were included. In the case of disagreement between the authors, the article was nonetheless selected for full-text reading.

Study eligibility

The same authors independently evaluated the full texts of all articles selected in the preceding stage. After this step, the final sample included 15 articles: 13 retrieved by the main search[4,6–8,11–19] and two by the grey literature search[20,21]. Agreement between the two authors during the eligibility assessment process was excellent (κ = 0.86, 95% confidence interval 0.57 to 1.00).

Thirty-one articles were excluded because they did not meet the predetermined eligibility criteria. Of these, six evaluated only stability in patients undergoing distraction osteogenesis[22–27], seven analyzed stability in patients with cleft lip and palate[28–34], 15 did not report sufficient data to quantify surgical stability[35–49], two included only one primary study[5,50], and one was not considered an original study because it was an early version of a Cochrane review[51].

Data extraction

This study was designed as an 'overview' of secondary studies. Fifteen articles were included: seven meta-analyses[6,12,14,15,17–19] and eight systematic reviews[4,7,8,11,13,16,20,21]. All reported various variables involved in the evaluation of stability after orthognathic surgery. A total of 148 studies reporting surgical stability outcomes were included in the 15 review articles, with the number of studies included in each review article ranging from two[7] to 24[8]; these were mostly uncontrolled and retrospective clinical trials. There were only 11 randomized clinical trials (RCTs) and one multicentre RCT (Table 1).

Analysis of the patient profile in the primary studies revealed a total of 6278 participants, aged 20–30 years, of whom 66% were female. They had different diagnoses of dentofacial deformity and were evaluated for stability after orthognathic surgery. In most studies, stability was evaluated by superimposition of cephalometric radiographs at a few weeks of follow-up[17] up to 15 years of follow-up[12] (Table 1).

Analysis of surgical stability

Sagittal stability

When performing anteroposterior movements, i.e., setback or advancement, data

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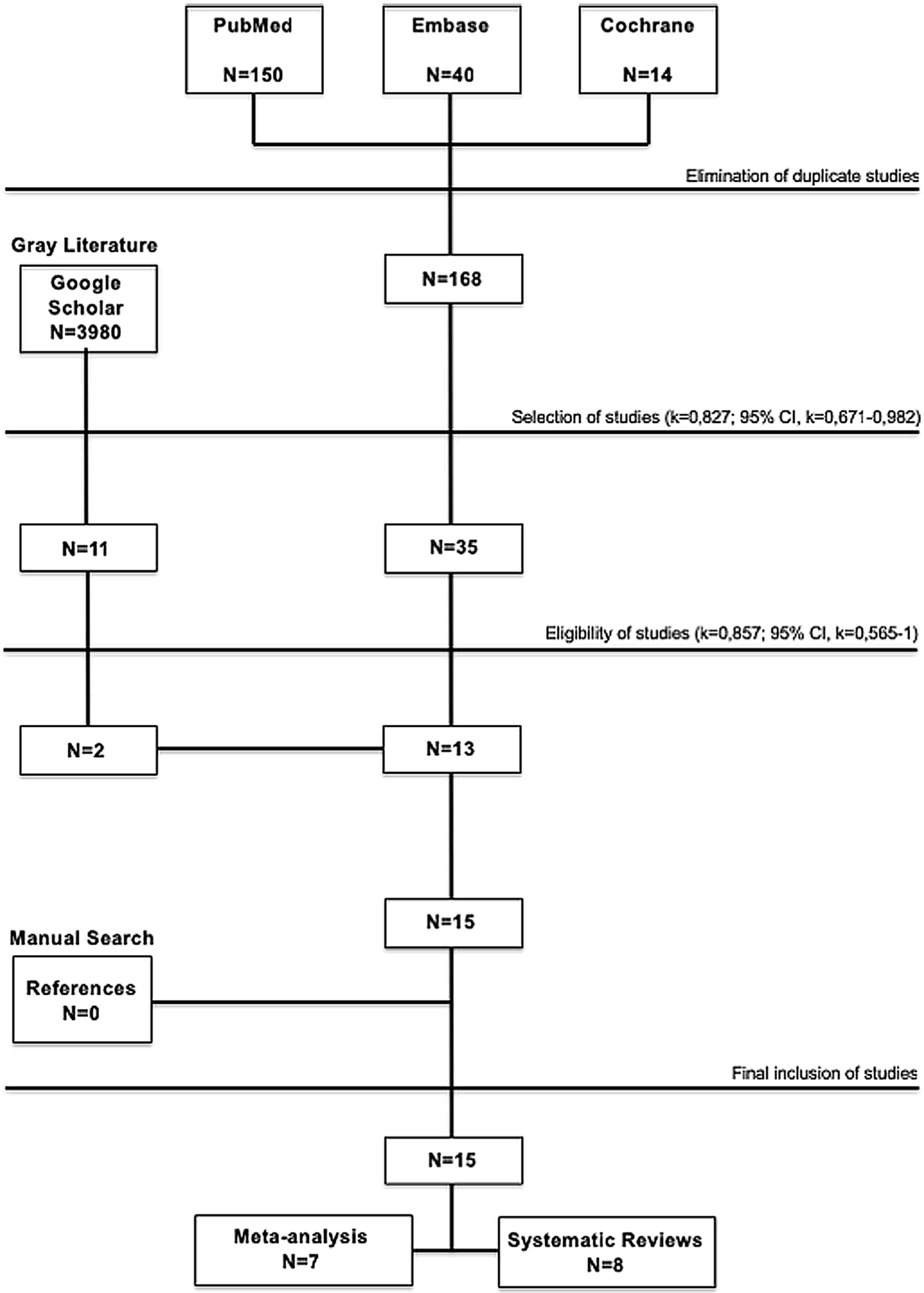

Fig. 1. Flowchart of the systematic review.

analyses for mandibular surgery revealed similar and 'highly stable' outcomes when performing bilateral sagittal split ramus osteotomy (BSSO), regardless of the method used for rigid internal fixation (RIF); the exceptions were mandibular setback with bioresorbable fixation, which was considered merely 'stable' (31%[13], 37.2%[19]), and clockwise rotation of the maxillomandibular complex with RIF by means of bicortical screws, which was 'highly unstable' for small surgical movements (>100%[6]). In mandibular surgery, large surgical movements are not less stable than small surgical movements.

When the intraoral vertical ramus osteotomy (IVRO) technique was used for mandibular setback, the percentage relapse was somewhat higher with the conventional three-stage method (33.8%) as compared to the surgery-first approach (18.3%)[18].

Stability was lower in the maxilla than in the mandible, regardless of the RIF method employed. When evaluating the different types of surgical movement of the maxilla, advancement seemed to be the most stable. Data were consistent with increased surgical relapse after maxillary setback with titanium RIF (55.7%[19]), and highly consistent with instability when resorbable RIF was used (44.56%[19]).

When the segmented Le Fort I technique was used for maxillary advancement with titanium RIF, results were considered 'highly stable' (relapse range <0% to 18.06%[4]), and similar to those of maxil-

Table 1. Demographic and study characteristics of the included studies.

Author Year Country of origin Study design	PICO[a]	Sample[b]	Type of primary study[c]	Total patients (range)[d]	Age (years)	Sex	Dentofacial deformity	Method of analysis	Follow-up (years)
Greenlee et al.[12] 2011 USA/Taiwan Meta-analysis	P: Anterior open bite I: Orthognathic surgery or orthodontics C: NR O: Dental stability	$N = 16$ $n = 11$	11 CS (NR)	$n = 466$ (10–259)	21.4–25.8	M (132) F (334)	AOB	Superimposition of cephalometric radiographs ($n = 7$) Plaster models and clinical measurements ($n = 1$) NR ($n = 3$)	1–15
Al-Moraissi and Ellis III[14] 2015 Yemen/USA Meta-analysis	P: Class III and asymmetries I: IVRO for mandibular setback C: BSSO for mandibular setback O: Skeletal changes in the postoperative period	$N = 13$ $n = 9$	3 RCT (3 P) 1 CCT (1 P) 5 CT (5 R)	$n = 277$ (11–46)	19.4–25	M (55) F (176)	Class III and asymmetries	Superimposition of cephalometric radiographs ($n = 9$)	0.5 to >1
Al-Moraissi and Ellis III[15] 2016 Yemen/USA Meta-analysis	P: BSSO for mandibular setback at 15–50 years I: RIF with bicortical screw osteosynthesis C: RIF with plate osteosynthesis O: Skeletal relapse in the postoperative period	$N = 7$ $n = 7$	1 RCT (1 P) 4 CCT (4 P) 2 CT (2 R)	$n = 290$	20.4–29	M (103) F (120)	Class III and asymmetries	NR	0.1 to >1
Al-Moraissi and Al-Hendi[17] 2016 Yemen Meta-analysis	P: BSSO for mandibular advancement at 15–50 years I: RIF with bicortical screw osteosynthesis C: RIF with plate osteosynthesis O: Skeletal relapse in the postoperative period	$N = 5$ $n = 5$	2 RCT (2 P) 2 CCT (2 R) 1 CT (R)	$n = 203$	23–34.6	M (70) F (117)	Mandibular retrognathism and asymmetries	Superimposition of cephalometric radiographs ($n = 5$)	0.02–1.5
Al-Moraissi and Wolford[6] 2016 Yemen/USA Meta-analysis	P: Dentofacial deformity requiring counterclockwise rotation of the MMC I: Counterclockwise rotation of the MMC C: Clockwise rotation of the MMC O: Skeletal stability in the postoperative period	$N = 3$ $n = 3$	1 CCT (1 P) 2 CT (2 R)	$n = 155$ (26–88)	20.6–44.6	M (42) F (96)	All possible diagnoses	Superimposition of cephalometric radiographs ($n = 3$)	1–1.75

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Table 1 (*Continued*)

Author Year Country of origin Study design	PICO[a]	Sample[b]	Type of primary study[c]	Total patients (range)[d]	Age (years)	Sex	Dentofacial deformity	Method of analysis	Follow-up (years)
Luo et al.[19] 2018 China Meta-analysis	P: Orthognathic surgery at 16–45 years I: RIF with resorbable osteosynthesis C: RIF with titanium osteosynthesis O: Surgical relapse	*N* = 10 *n* = 10	10 longitudinal (4 P/6 R)	*n* = 420 (18–84)	19.7–32	M (155) F (203)	All possible diagnoses	Superimposition of cephalometric radiographs (*n* = 10)	0.5–3.2
Yang et al.[18] 2017 China Meta-analysis	P: Orthognathic surgery I: 'Surgery-first' approach C: Conventional surgical approach O: Skeletal stability in the postoperative period	*N* = 10 *n* = 10	10 CT (3 P/7 R)	*n* = 513 (26–97)	NR	M (NR) F (NR)	Class III	Superimposition of cephalometric radiographs (*n* = 10)	0.1–3
Joss and Vassalli[11] 2008 Switzerland Systematic review	P: Class III I: BSSO for mandibular setback with RIF C: NR O: Stability/relapse	*N* = 14 *n* = 14	1 MCT (1 P) 13 CT (4 P/9 R)	*n* = 484 (11–86)	20–32.1	M (NR) F (NR)	Class III	Superimposition of cephalometric radiographs (*n* = 14)	0.1–12.7
Joss and Vassalli[8] 2009 Switzerland Systematic review	P: Class III I: BSSO for mandibular advancement with RIF C: NR O: Stability/relapse	*N* = 24 *n = 24*	1 MRCT (1 P) 1 MCT (1 P) 22 CT (4 P/18 R)	*n* = 1034 (15–222)	19.3–34	M (300) F (734)	Class II	Superimposition of cephalometric radiographs (*n* = 24)	0.5–12.7
Medeiros et al.[20] 2012 Brazil Systematic review	P: Anterior open bite in adults I: Orthognathic surgery C: Various orthodontic treatment modalities O: Dental stability	*N* = 14 *n* = 10	10 CS (10 R)	*n* = 532 (10–234)	NR	M (NR) F (NR)	AOB	NR	1–15
Yang et al.[13] 2014 China Systematic review	P: Dentofacial deformity I: Orthognathic surgery with resorbable RIF C: Orthognathic surgery with titanium RIF O: Stability	*N* = 20 *n* = 20	5 RCT (5 P) 15 CT (15 P)	*n* = 1092 (20–230)	NR	M (NR) F (NR)	Multiple surgical procedures	Superimposition of cephalometric radiographs (*n* = NR) Superimposition of CT scans (*n* = NR)	0.2–6.3

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Convens et al.[7] 2015 Switzerland Systematic review	P: Vertical maxillary deficiency in adults I: Le Fort I osteotomy with RIF for maxillary disimpaction C: NR O: Stability	$N = 2$ $n = 2$	2 CT (2 R)	$n = 22$ (10–12)	NR	M (NR) F (NR)	Vertical maxillary deficiency	Superimposition of cephalometric radiographs ($n = 2$)	>0.5 to >1
Starch-Jensen and Blaehr[16] 2016 Denmark Systematic review	P: Transverse maxillary deficiency in adults I: Segmental Le Fort I osteotomy C: SARME O: Skeletal and dental relapse in the postoperative period	$N = 4$ $n = 4$	1 longitudinal (1 P) 3 CS (3 R)	$n = 97$ (4–20)	NR	M (NR) F (NR)	Transverse maxillary deficiency	Superimposition of CBCT scans ($n = 2$) Plaster models ($n = 2$)	0.6–3
Haas Junior et al.[4] 2017 Brazil/Spain Systematic review	P: Dentofacial deformity or orthognathic surgery I: Segmental Le Fort I osteotomy C: Le Fort I osteotomy and/ or multisegmental Le Fort I osteotomy O: Surgical stability	$N = 23$ $n = 14$	2 MCT (2 R) 8 CT (2 P/6 R) 4 CS (4 R)	$n = 516$	19.5–28.4	M (154) F (178)	Maxillary deformity in all three planes	Superimposition of CBCT scans ($n = 1$) Superimposition of cephalometric radiographs ($n = 7$) Superimposition of cephalometric radiographs and plaster models ($n = 2$) Plaster models and clinical measurements ($n = 1$)Plaster models ($n = 3$)	0.2–8.8
Al-Thomali et al.[21] 2017 Saudi Arabia Systematic review	P: Anterior open bite in adults I: Orthognathic surgery or orthodontics C: Various treatment modalities O: Dental stability	$N = 14$ $n = 5$	5 CS (5 R)	$n = 177$ (24–49)	20.9–30.8	M (50) F (103)	AOB	Superimposition of cephalometric radiographs ($n = 4$) Superimposition of cephalometric radiographs and plaster models ($n = 1$)	0.5–2.3

AOB, anterior open bite; BSSO, bilateral sagittal split osteotomy; CBCT, cone beam computed tomography; CT, computed tomography; F, female; IVRO, intraoral vertical ramus osteotomy; M, male; MMC, maxillomandibular complex; NR, not reported; RIF, rigid internal fixation; SARME, surgically assisted rapid maxillary expansion.

[a] PICO: population (P), intervention (I), comparison (C), outcome (O).

[b] *N*: sample of studies included in the systematic review; *n*: sample of studies reporting a surgical stability outcome.

[c] CS, case series; CCT, controlled clinical trial; CT, clinical trial; MCT, multicentre clinical trial; MRCT, multicentre randomized clinical trial; RCT, randomized clinical trial. P, prospective; R, retrospective.

[d] Number of patients evaluated for surgical stability.

Table 2. Stability in orthognathic surgery: sagittal surgical movements of the maxilla and mandible (negative values indicate negative movement, i.e. setback).

Authors Year Number of studies Number of patients	Surgical movement	Surgical techniques[a]	Sagittal Mean, mm (%) T1; T2	Sagittal Min/max[b], mm (%) T1; T2	Meta-analysis Forest plot
Joss and Vassalli[11]	Mandibular	BSSO (mono)			–
2008	setback	BS	−6.79; 1.22 (18.78%)	−7.5/−4.87; 0.1/2.13 (1.3/43.7%)	
14 studies		P/BS	NR; NR (NR)	NR; NR (NR)	
484 patients		P	−7.95; 1.04 (12.86%)	−8.2/−4.7; 0.5/1.1 (6.1/23.4%)	
		RBS	−6.6; 1.56 (23.6%)	−6.6/−6.6; 1.5/1.6 (22.7/24.5%)	
		PR	NR; NR (NR)	NR; NR (NR)	
Joss and Vassalli[8]	Mandibular	BSSO (mono)			–
2009	advancement	BS	5.46; −0.79 (14.70%)	4.44/5.33; −0.07/−3.21 (1.6/ 60.2%)	
24 studies		P/BS	NR; NR (NR)	NR; NR (NR)	
1034 patients		P	5.37; −0.48 (4.14%)	4.9/5.39; −0.1/−1.01 (1.4/18.7%)	
		RBS	5.07; −0.54 (12.5%)	6.19/4.6; −0.26/−0.8 (4.2/17.4%)	
		PR	NR; NR (NR)	NR; NR (NR)	
Yang et al.[13]	Mandibular	BSSO (bimax)			–
2014	setback	RRIF	−4.29; 1.33 (31%)	−4.29; 1.33 (31%)	
20 studies		TRIF	−7; 3.15 (45%)	−7; 3.15 (45%)	
1092 patients	Mandibular	BSSO (bimax)			
	advancement	RRIF	5.5; 0.8 (<0%)	5.5; 0.8 (<0%)	
		TRIF	6.3; −4.2 (66.7%)	6.3; −4.2 (66.7%)	
	Maxillary	LFI (bimax)			
	advancement	RRIF	3.02; −0.68 (26.25%)	3.54/2.5; −0.16/−1.2 (4.51/48%)	
		TRIF	4.45; −1.15 (25.8%)	3.5/5.4; 0.9/−1.4 (<0/26.55%)	
		LFI (mono)			
		RRIF	2.76; 0.2 (<0%)	3.5/2.02; 0.2/0.2 (<0/<0%)	
		TRIF	3.92; −0.3 (<0%)	2.45/5.4; 0.8/−1.4 (<0/25.9%)	
Al-Moraissi and Ellis III[14]	Mandibular setback	BSSO			Both forest plots (sagittal and vertical linear stability) favoured BSSO (sagittal SMD: −0.47; vertical SMD: −1.09)
2015		TRIF	−7.11; 1.57 (26.65%)	−8.9/−5.33; 0.74/2.4 (8.3/45%)	BSSO was associated with relapse, while IVRO was associated with instability, as the mandible tended to class II
9 studies		SRIF	−6.16; 0.01 (0%)	−6.16/−6.16; 0.01/0.01 (0/0%)	In IVRO, there was less instability with the longer MMF period (10 weeks)
277 patients		IVRO			
		MMF	−6.00; −1.22 (<0%)	−5.44/−5.04; −0.21/−2.3 (<0/ <0%)	
Al-Moraissi and Ellis III[15]	Mandibular setback	BSSO			The forest plot for sagittal linear stability revealed a small difference in favour of RIF with BS (SMD: 0.13)
2016		BS	−7.01; 0.8 (11.86%)	−7.5/−7.3; −0.1/1.2 (<0/16.4%)	
7 studies		P	−7.22; 0.66 (10.96%)	−8.2/−8.2; −0.5/1.9 (<0/23.1%)	The forest plot for vertical linear stability showed no difference between the two RIF methods
290 patients					

Al-Moraissi and Al-Hendi[17]	Mandibular advancement	BSSO			The forest plot for sagittal linear stability revealed a small difference in favour of RIF with BS (SMD: −0.25)
2016		BS	6.61; −0.78 (12.13%)	7.8/6; −0.7/−1.06 (8.9/17.6%)	The forest plot for vertical linear stability showed no difference between the two RIF methods
5 studies 203 patients		P	6; −0.71 (12.06%)	6.4/6; −0.1/−1.23 (1.5/20.5%)	
Al-Moraissi and Wolford[6]	CCW rotation of the mandible	BSSO			The forest plot showed a significant difference only for postoperative rotation of the occlusal plane (WMD: −1.33°), in favour of CW rotation
2016		BS	9.2; −1.07 (10.5%)	7.6/10.81; −0.3/−1.85 (3.9/17.1%)	
3 studies		P/BS	−7.88; 1.59 (20.2%)	−7.88; 1.59 (20.2%)	
155 patients	CW rotation of the mandible	BSSO			
		BS	−0.81; 0.4 (>100%)	−2/−0.24; 0.5/−0.61 (25/>100%)	
		P/BS	−10.03; 0.6 (5.9%)	−10.03; 0.6 (5.9%)	
	Mandibular advancement	BSSO			
		BS	7.26; −0.99 (13.6%)	7.26; −0.99 (13.6%)	
		P/BS	NR; NR (NR)	NR; NR (NR)	
	Maxillary advancement	LFI			
		TRIF	2.61; −0.46 (19.74%)	3.22/1.3; −0.19/−0.5 (5.9/38.4%)	
Luo et al.[19]	Mandibular advancement	BSSO			The forest plot showed a significant difference only for mandibular setback (SMD: 0.97), in favour of titanium RIF
2018		RRIF	4.75; −1.65 (34.7%)	5.5/4.89; 0/−3.65 (<0/74.6%)	
10 studies		TRIF	5.42; −3.75 (54.42%)	4/7.3; 0/−8.72 (<0/>100%)	
420 patients	Mandibular setback	BSSO			
		RRIF	−9.25; 2.3 (37.2%)	−6.7/−5.1; 0.51/6.08 (7.6/>100%)	
		TRIF	−8.86; 1.85 (20.71%)	−7.2/−8.36; 0.7/3.28 (9.7/39.2%)	
	Maxillary advancement	LFI			
		RRIF	3.48; −1.67 (45.35%)	2.02/4.56; −0.2/−3.82 (9.9/83.7%)	
		TRIF	4.79; −1.48 (29.8%)	3.54/6.04; −0.16/−3.84 (4.5/63.5%)	
	Maxillary setback	LFI			
		RRIF	−3.86; 2.16 (44.56%)	−2.2/−5.93; <0/4.48 (<0/75.4%)	
		TRIF	−3.65; 2.36 (55.7%)	−1.9/−5.35; 0.6/4.8 (31.5/89.7%)	
Yang et al.[18]	Mandibular setback	Surgery-first			The forest plot showed no significant difference for mandibular and maxillary stability (WMD: 0.35 mm Md/0.13 mm Mx), slightly in favour of the conventional surgical method
2017		BSSO (bimax)			
10 studies		RIF	−10.1; 1.76 (17.55%)	−12.6/−9.7; 1.8/2.5 (14.2/25.7%)	
513 patients		IVRO (bimax)			
		MMF	−7.1; 1.3 (18.3%)	−7.1; 1.3 (18.3%)	
		Conventional			
		BSSO (bimax)			
		TRIF	−10.12; 1.61 (15.52%)	−7.7/−10.3; 0.86/1.78 (11.2/17.3%)	
		IVRO (bimax)			
		MMF	−7.7; 2.6 (33.8%)	−7.7; 2.6 (33.8%)	
	Maxillary advancement	Surgery-first			
		LFI (bimax)			
		TRIF	1.42; −0.47 (27.1%)	2/0.1; −0.04/−0.2 (1.9/>100%)	
		Conventional			
		LFI (bimax)			
		TRIF	1.5; −0.47 (26.37%)	3.4/0.1; −0.19/−0.42 (5.5/>100%)	

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Table 2 (*Continued*)

Authors Year Number of studies Number of patients	Surgical movement	Surgical techniques[a]	Sagittal Mean, mm (%) T1; T2	Sagittal Min/max[b], mm (%) T1; T2	Meta-analysis Forest plot
Haas Junior et al.[4] 2017	Maxillary surgical correction in all three planes	Segmental LFI TRIF[c]	Anterior T1; anterior T2D: 2.17; −0.2 (9.37%)	D: 0.5/1.3; 2/−0.3 (<0/23.1%)	–
14 studies			Posterior T1; posterior T2D: 2.3; <0 (<0%)	D: 2.4/2.2; <0/<0 (<0/<0%)	
516 patients			Anterior T1; anterior T2S: 3.82; −0.42 (10.6%)	S: 2.6/3.7; 0.1/−1 (<0/27%)	
			Posterior T1; posterior T2S: 3.43; −0.5 (18.06%)	S: 4.1/2; −0.3/−0.7 (7.3/35%)	
		SRIF[c]	Anterior T1; anterior T2D: −3.3; 1 (30.3%)	D: −3.3; 1 (30.3%)	
			Posterior T1; posterior T2D: NR; NR (NR)	D: NR; NR (NR)	
			Anterior T1; anterior T2S: NR; NR (NR)	S: NR; NR (NR)	
			Posterior T1; posterior T2S: NR; NR (NR)	S: NR; NR (NR)	

CW, clockwise; CCW, counterclockwise; Md, mandible; Mx, maxilla; NR, not reported; RIF, rigid internal fixation; SMD, standardized mean difference; T1, magnitude of surgical movement; T2, magnitude of relapse; WMD, weighted mean difference.

[a] BSSO, bilateral sagittal split osteotomy (BS, bicortical screw for rigid internal fixation; P/BS, miniplate and bicortical screw for rigid internal fixation; P, miniplate for rigid internal fixation; RBS, resorbable bicortical screw for rigid internal fixation; RP, resorbable miniplate for rigid internal fixation); RRIF, resorbable rigid internal fixation; TRIF, titanium rigid internal fixation; LFI, Le Fort I osteotomy; IVRO, intraoral vertical ramus osteotomy; SRIF, semi-rigid internal fixation; MMF, maxillomandibular fixation.

[b] Min/max from the primary studies.

[c] D, dental relapse; S, skeletal relapse.

lary advancement in monomaxillary procedures (Table 2.

Vertical stability

Surgical procedures to correct vertical dentofacial deformities are less stable than those used to correct sagittal ones. This is true to such an extent that maxillary downward (52.2%[19]) and upward (50.97%[19]) movement with resorbable RIF are considered 'unstable'. Maxillary downward movement with semi-rigid fixation showed a trend towards instability (45.3%[6]). However, maxillary upward movement with titanium RIF (19.7%[6]) and with semi-rigid fixation (22.9%[6]) yielded 'highly stable' results, as did small downward movement in the anterior and posterior maxilla with titanium RIF (17.5% and 8.3%)[7].

Vertical correction by means of segmented Le Fort I osteotomy was 'unstable' in small posterior skeletal upward movements with titanium fixation (50.82%[4]) and 'stable' in anterior downward movements with titanium fixation, in terms of both dental (35.12%[4]) and skeletal (37.84%[4]) stability. The only movement considered 'highly stable' with this surgical technique was posterior upward movement with titanium fixation (23.75%[4]) and semi-rigid fixation (17.4%[4]), both at the dental level.

Clockwise and counterclockwise mandibular rotation were both 'highly stable' (<0%[6]) when secured with bicortical plates and screws, but when using bicortical screws alone, clockwise rotation was merely 'stable' for small surgical movements (28.95%[6]) (Table 3).

Transverse stability

Posterior maxillary expansion with semi-rigid fixation had the highest relapse rate at the dental level, exceeding 100% even in small surgical movements[4], which makes it 'highly unstable'. Instability was also found in anterior expansion with RIF (71% dental relapse[4]). Conversely, from a skeletal standpoint, posterior maxillary expansion with rigid fixation can be considered to range from 'highly stable' to 'stable' (13.72%[4], 25.1%[16]) (Table 4).

Anterior open bite stability

This study found surgical treatment of anterior open bite to be the most stable procedure when overbite was evaluated as a parameter of stability, regardless of the fixation method or type of surgery. All systematic reviews

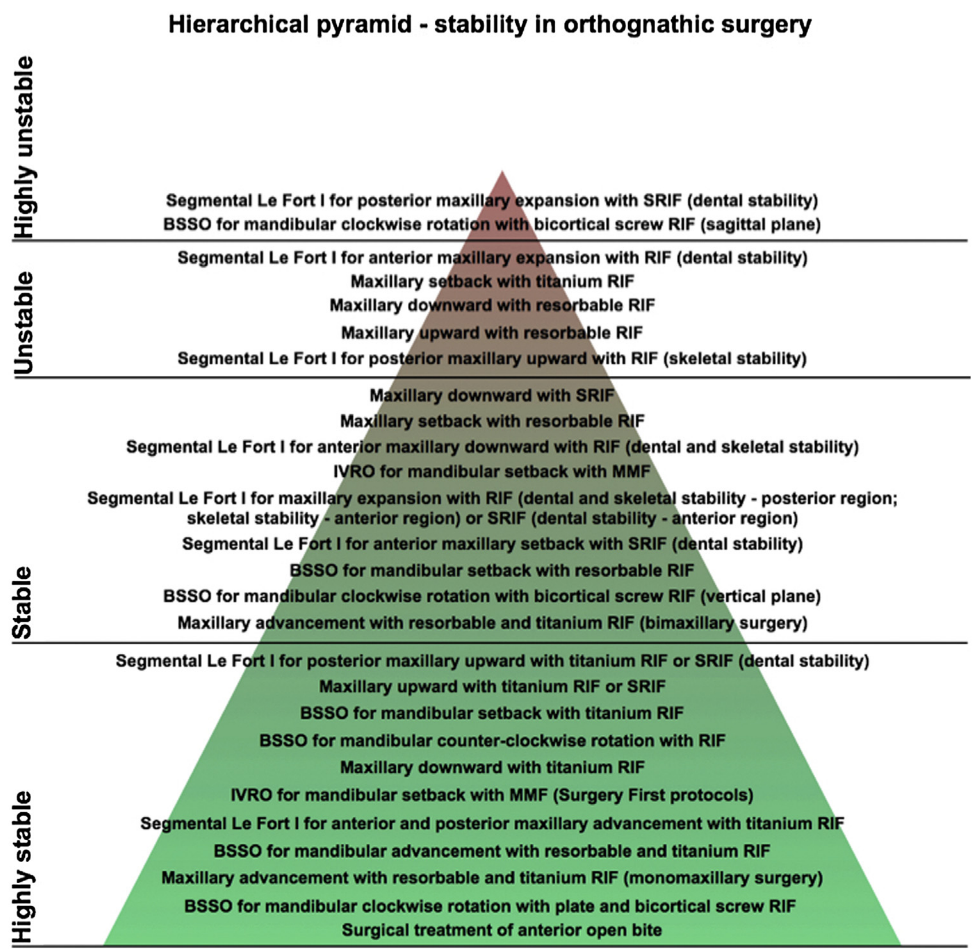

Fig. 2. Hierarchical pyramid—stability in orthognathic surgery.

reported relapse rates ranging from <0%[12,21] to 13.9%[21] (Table 5).

Analysis of methodological quality

Methodological quality of clinical studies

Two systematic reviews did not analyze the methodological quality of the primary studies included[11,13]. Only three used tools developed specifically by expert groups to evaluate the methodological quality of primary studies: two used the Newcastle–Ottawa scale[18,19], and one used the Quality Assessment Tool for Quantitative Studies[21]. The rest evaluated methodological quality using custom scales developed by the authors themselves.

The potential risk of bias in clinical trials was generally considered moderate to high, as some important criteria were neglected by analyses of methodological quality, such as assessor blinding[6,14–17] (in customized scales) and sample randomization[16,18,19,21] (in specific scales). In the vast majority of primary studies, there was no random sample allocation, a condition that increases the potential risk of bias (Table 6).

Methodological quality of the systematic reviews and meta-analyses

None of the secondary studies reported all of the criteria evaluated by the AMSTAR 2 tool[10]. Among systematic reviews, the greatest methodological rigor was found in the review performed by Haas Junior et al. (2017)[4], where 11 out of 13 possible items were evaluated in the methodology section. Among meta-analyses, Luo et al.[19] (2018) reported 10 of 16 possible criteria.

Individual analysis of the items used to verify potential risk of bias in systematic reviews revealed that none of the articles took into account conflicts of interest in primary studies and only three papers had a written protocol established prior to the execution of the review[7,16,21]. All articles reported the inclusion and exclusion criteria of the primary clinical trials (Table 7).

Discussion

Overviews of systematic reviews are designed to pool the outcomes of secondary studies and synthesize data such that the effect of an intervention can be evaluated more clearly and educationally. This provides decision-makers in health with the most robust scientific evidence available in an accessible manner[9]. So, a summary of stability in orthognathic surgery from this overview is given in Table 8 and Fig. 2.

A major step when conducting this type of project is to search the literature for published secondary studies with similar or complementary outcomes; furthermore, the authors must be experienced in the design of systematic reviews[9,52,53]. Regarding the design and execution of an overview of systematic reviews on surgical stability in orthognathic surgery, 46 articles on this topic were selected for full-text reading; among these, eight systematic reviews[4,7,8,11,13,16,20,21] and seven meta-analyses[6,12,14,15,17–19] were included for the extraction of data on a wide range

Table 3. Stability in orthognathic surgery: vertical surgical movements of the maxilla and mandible (negative values indicate upward movement).

Authors Year Number of studies Number of patients	Surgical movement	Surgical techniques[a]	Vertical Mean, mm (%) T1; T2	Vertical Min/max[b], mm (%) T1; T2	Meta-analysis Forest plot
Convens et al.[7]	Maxillary downward	LFI			–
2015		RIF[c]	Anterior T1; anterior T2S: 3.85; −0.8 (17.5%)	S: 3.2/4; <0/−1.6 (<0/35%)	
2 studies			Posterior T1; posterior T2S: 0.95; −0.3 (8.3%)	S: 0.1/1.8; <0/−0.3 (<0/16.6%)	
22 patients					
Haas Junior et al.[4]	Maxillary surgical correction in all three planes	Segmental LFI			–
2017		RIF[c]	Anterior T1; anterior T2D: 3.07; −0.45 (35.12%)	D: 0.5/−0.6; <0/0.6 (<0/100%)	
14 studies			Posterior T1; posterior T2D: −0.85; 0.15 (23.75%)	D: −1.4/−0.3; 0.2/0.1 (14.2/33.3%)	
516 patients			Anterior T1; anterior T2S: 1.56; −0.44 (37.84%)	S: 0.1/0.2; <0/>100% (<0/>100%)	
			Posterior T1; posterior T2S: −0.7; 0.34 (50.82%)	S: −0.3/−0.4; −0.7/0.7 (<0/>100%)	
		SRIF[c]	Anterior T1; anterior T2D: 0.1; <0 (<0%)	D: 0.1; <0 (<0%)	
			Posterior T1; posterior T2D: −2.9; 0.5 (17.24%)	D: −2.9; 0.5 (17.24%)	
			Anterior T1; anterior T2S: NR; NR (NR)	S: NR; NR (NR)	
			Posterior T1; posterior T2S: NR; NR (NR)	S: NR; NR (NR)	
Luo et al.[19]	Maxillary upward	LFI			–
2018		RRIF	−2.91; 1.32 (50.97%)	−2.46/−3.13; 0.12/2.67 (4.8/85.3%)	
10 studies		TRIF	−4.15; 2.21 (49.45%)	−2.14/−3.3; 0.66/2.2 (29.9/66.6%)	
420 patients	Maxillary downward	LFI			
		RRIF	4.68; −1.98 (52.2%)	6.5/2.32; −1.3/−1.98 (20/85.3%)	
		TRIF	3.29; −2.45 (73.1%)	2.92/3.25; −1.39/−2.88 (47/88.6%)	
Al-Moraissi and Wolford[6]	Maxillary upward	LFI			–
2016		RIF	−2.36; 0.35 (19.7%)	−3.1/−0.6; 0.2/0.2 (6.4/33.3%)	
3 studies		SRIF	−2.87; 0.6 (22.9%)	−3.84/−1.91; 0.66/0.55 (17.1/28.7%)	
155 patients	Maxillary downward	LFI			
		RIF	1.11; −0.08 (7.2%)	1.11; −0.08 (7.2%)	
		SRIF	1.17; −0.53 (45.3%)	1.17; −0.53 (45.3%)	
	CCW rotation of the mandible	BSSO			
		BS	−2.36; 0.35 (19.7%)	−2.82; 0.06 (2.1%)	
		P/BS	−7.79; <0 (<0%)	−7.79; <0 (<0%)	
	CW rotation of the mandible	BSSO			
		BS	0.3; 0.35 (28.95%)	−2/2.6; 0.5/−0.86 (25/32.9%)	
		P/BS	−2.86; <0 (<0%)	−2.86; <0 (<0%)	

CW, clockwise; CCW, counterclockwise; NR, not reported; T1, magnitude of surgical movement; T2, magnitude of relapse.

[a] LFI, Le Fort I osteotomy; RIF, rigid internal fixation; SRIF, semi-rigid internal fixation; RRIF, resorbable rigid internal fixation; TRIF, titanium rigid internal fixation; BSSO, bilateral sagittal split osteotomy (BS, bicortical screw for rigid internal fixation; P/BS, miniplate and bicortical screw for rigid internal fixation).

[b] Min/max from the primary studies.

[c] D, dental relapse; S, skeletal relapse.

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Table 4. Stability in orthognathic surgery: transverse surgical movements of the maxilla (negative values indicate narrowing).

Authors Year Number of studies Number of patients	Surgical movement	Surgical techniques[a]	Transverse Mean, mm (%) T1; T2	Transverse Min/max[b], mm (%)	Meta-analysis Forest plot
Starch-Jensen and Blaehr[16] 2016 4 studies 97 patients	Maxillary expansion	Segmental LFI			–
		RIF[c]	Anterior T1; anterior T2D: 1.88; −0.32 (23.85%)	D: 2.75/1; −0.25/−0.4 (9.1/38.6%)	
			Posterior T1; posterior T2D: 2.96; −0.76 (27.75%)	D: 3.75/2.2; −0.75/−0.8 (20/35.5%)	
			Anterior T1; anterior T2S: 1.94; −0.55 (28.35%)	S: 1.94; −0.55 (28.35%)	
			Posterior T1; posterior T2S: 3.43; −0.86 (25.1%)	S: 3.4; −0.86 (25.1%)	
Haas Junior et al.[4] 2017 14 studies 516 patients	Maxillary surgical correction in all three planes	Segmental LFI			–
		RIF[c]	Anterior T1; anterior T2D: 1.15; −0.46 (71%)	D: 1.8/0.3; −0.2/−0.4 (11.1/>100%)	
			Posterior T1; posterior T2D: 3.23; −1.5 (49.4%)	D: 4.1/1.7; −1.1/−1.4 (26.8/82.3%)	
			Anterior T1; anterior T2S: 1.94; −0.55 (28.35%)	S: 1.94; −0.55 (28.35%)	
			Posterior T1; posterior T2S: 2.45; −0.37 (13.72%)	S: 2.2/3.4; 0/−0.86 (0/25.3%)	
		SRIF[c]	Anterior T1; anterior T2D: 1.7; −0.53 (29.7%)	D: 1.3/2.2; −0.3/−0.9 (23.1/40.9%)	
			Posterior T1; posterior T2D: 0.57; −1.1 (>100%)	D: 2.9/−0.1; −2.1/−0.8 (72.4/>100%)	
			Anterior T1; anterior T2S: NR; NR (NR)	S: NR; NR (NR)	
			Posterior T1; posterior T2S: NR; NR (NR)	S: NR; NR (NR)	

NR, not reported; T1, magnitude of surgical movement; T2, magnitude of relapse.
[a] LFI, Le Fort I osteotomy; RIF, rigid internal fixation; SRIF, semi-rigid internal fixation.
[b] Min/max from the primary studies.
[c] D, dental relapse; S, skeletal relapse.

of surgical techniques analyzed for the outcome of interest. The results of these studies could be synthesized to more easily understand stability in orthognathic surgery.

In addition to the evident methodological plausibility of conducting an overview of systematic reviews on stability in orthognathic surgery, the authors who designed and conducted this overview have broad experience in conducting secondary studies; in fact, one of the articles with the greatest methodological rigor included in the sample was authored by our team[4]. In addition, the level of agreement between the authors was considered excellent both during the study selection process ($\kappa = 0.83$) and during the assessment of study eligibility ($\kappa = 0.86$)[54], demonstrating their homogeneity in generating scientific evidence.

Important criteria such as assessor blinding were often neglected by the studies included in the systematic reviews[4,7,8,17], and the vast majority of primary studies considered as having a low risk of bias in the secondary studies were actually evaluated using a customized methodological quality scale that did not include a specific item for assessor blinding[6,14,15] or for random allocation of the sample[19,21], because they were better suited for observational studies. Therefore, the data summarized in this overview are derived from systematic reviews that did not collate clinical studies of the highest level of scientific evidence.

Although the primary studies were classified as having a generally moderate to high potential for risk of bias, the systematic reviews that included them were deemed to be of medium to high methodological quality, as most had a greater number of AMSTAR 2 items present ('yes') than absent ('no') (Table 7)[10]. However, none of the secondary studies included took into account conflicts of interest in the original intervention studies, which could be a cause for concern in studies comparing two surgical procedures that involve financial issues.

Taking into account that the secondary studies were considered as having a medium to low risk of bias, i.e., they followed adequate protocols for quality scientific output, and that data from the primary studies are available in the literature, it is believed that this overview of systematic reviews synthesizes the current scientific evidence on stability in orthognathic surgery as best as possible, and that the hierarchical pyramid proposed is a useful tool to help practitioners choose the sur-

Table 5. Surgical stability of treatment of anterior open bite.

Authors Year Number of studies Number of patients	Surgical movement	Surgical techniques[a]	Overbite Mean, mm (%) T1; T2	Overbite Min/max[b], mm (%) T1; T2	Meta-analysis Forest plot
Greenlee et al.[12]	Maxillary upward	LFI + BSSO			82% (57–100%) of surgical patients were considered stable
2011	Mandibular setback/	RIF	2.6; 0 (0%)	2.6; 0 (0%)	Meta-analysis – random-effects
11 studies	advancement	SRIF	3.6; −0.06 (<0%)	4.42/2.1; 0.82/−0.5 (<0/23.8%)	for overbite: −2.8 pre/1.5 post/1.3
466 patients		LFI			long-term/7% relapse
		RIF	4.1; −0.4 (9.8%)	4.1; −0.4 (9.8%)	
		SRIF	6.3; −0.3 (4.8%)	6.3; −0.3 (4.8%)	
Medeiros et al.[20]	NR	LFI + BSSO			–
2012		RIF	4.03; −0.41 (13%)	9.1/3.52; −0.7/−0.97 (7.7/27.5%)	
10 studies		SRIF	3.26; −0.44 (13.5%)	3.26; −0.44 (13.5%)	
532 patients		LFI			
		RIF	4; −0.2 (4.85%)	3.9/4.11; −0.02/−0.38 (0.5/9.2%)	
		SRIF	NR; NR (NR)	NR; NR (NR)	
Al-Thomali et al.[21]	Maxillary upward/	LFI + BSSO			–
2017	downwardMandibular	RIF	3.68; 0.07 (<0%)	3.2/4.2; 0.4/−0.2 (<0/5.9%)	
5 studies	setback/advancement	SRIF	NR; NR (NR)	NR; NR (NR)	
177 patients		LFI			
		RIF	3.04; 0.32 (<0%)	3.8/4.1; 0.4/−0.4 (<0/9.7%)	
		SRIF	6.9; −0.95 (13.9%)	6.9; −0.95 (13.7%)	

NR, not reported; T1, magnitude of surgical movement; T2, magnitude of relapse.
[a] LFI, Le Fort I osteotomy; BSSO, bilateral sagittal split osteotomy; RIF, rigid internal fixation; SRIF, semi-rigid internal fixation.
[b] Min/max from the primary studies.

gical technique that provides the most satisfactory stability outcomes.

At the top of the hierarchical pyramid of stability are two procedures considered 'highly unstable': (1) BSSO for clockwise rotation of the mandible with bicortical screw RIF, and (2) posterior maxillary expansion with semi-rigid internal fixation (assessed in terms of dental stability). (Table 8; Fig. 2)

The highly relapse-prone nature of clockwise mandibular rotation can be explained in two ways: first, through the difficulty in passive positioning of the proximal segment for fixation by means of bicortical screws, as these tend to exert a compressive force that favours the greatest anatomical reduction possible, which is often suboptimal for condylar positioning; and second, through the small bone movements to which patients in the primary studies were subjected, which may have easily readapted to a new position in the postoperative period in response to orthodontic movement – in other words, the mandible will always be subject to instability secondary to the patient's dental occlusion, because it is a mobile bone structure. However, the surgical technique of miniplate and bicortical screw fixation was 'highly stable' in the vertical and sagittal planes, as was counterclockwise mandibular rotation (regardless of the method of RIF used). (Table 8; Fig. 2)

When analyzed for posterior dental stability, maxillary expansion through segmental Le Fort I osteotomy with semi-rigid internal fixation was 'highly unstable' (>100%[4]), and 'unstable' when assessed for anterior dental relapse with RIF (71%[4]). However, the combination of plates and screws, often further combined with bone grafts and palatal fixation[4,16], enhanced stability and yielded results that were considered 'highly stable' (13.72%)[4] or at least 'stable' (28.35%)[4,16] (Table 8; Fig. 2). The data found for maxillary expansion, at least those regarding skeletal stability, contradict the landmark studies of Proffit et al. (1996 and 2007), which deemed it the surgical intervention with the lowest possible stability within a hierarchical scale[1,2].

Some factors may have influenced this disparity in findings, especially regarding the methods of evaluation. Proffit et al. (1996 and 2007) reported the use of lateral X-rays to evaluate surgical stability[1,2]. This method is known to be inappropriate for transverse analyses. Conversely, the systematic reviews reported analyses of plaster models and/or cone beam computed tomography scans[4,16], methods that are believed to be more reliable. However, if

Table 6. Methodological quality analyses used in the systematic reviews.

Authors and year	Method of analysis	Criteria	Analysis of risk of bias	Overall potential for risk of bias	Notes
Greenlee et al., 2011[12]	Custom scale	4 domains 12 items	0 to 2 points; maximum score 20	Not categorized, assessed continuously without preset criteria	The studies, in general, were considered as having a high potential for risk of bias; mean 10.3 (range 7–16) points out of a possible 20 points
Al-Moraissi and Ellis III, 2015[14]	Custom scale	5 items	Low: All items present	Low: 3	Assessor blinding was not included as a criterion; this is most probably related to the low potential for risk of bias
			Moderate: Absence of 1 of the items	Moderate: 6	Sample randomization was the only item neglected in the 6 studies with moderate potential risk
			High: Absence of 2 of the items	High: 0	
Al-Moraissi and Ellis III, 2016[15]	Custom scale	5 items	Low: All items present	Low: 1	Assessor blinding was not included as a criterion; this is most probably related to the low potential for risk of bias
			Moderate: Absence of 1 of the items	Moderate: 6	Sample randomization was the only neglected item in the 6 studies with moderate potential risk
			High: Absence of 2 of the items	High: 0	
Al-Moraissi and Al-Hendi, 2016[17]	Custom scale	4 domains	Yes: item/domain reported – low risk of bias	Low: 0	Assessor blinding was included as a criterion; this is related to the uncertain potential for risk of bias
		4 items	Unclear: item/domain uncertain – uncertain risk of bias	Uncertain: 2	Random allocation and assessor blinding were neglected or not clearly described in all studies
			No: item/domain neglected – high risk of bias	High: 3	
Al-Moraissi and Wolford, 2016[6]	Custom scale	5 items	Low: All items present	Low: 0	Assessor blinding was not included as a criterion; this is most probably related to the moderate potential for risk of bias
			Moderate: Absence of 1 of the items	Moderate: 3	Sample randomization was the item neglected by all studies
			High: Absence of 2 of the items	High: 0	
Luo et al., 2018[19]	NOS	3 domains	Low: ≥7 items present	Low: 9	The NOS is used for observational studies; therefore, it does not include sample randomization as an item for evaluation
		8 items (0 to 9 points)	Moderate: 5–6 items present	Moderate: 1	Assessor blinding was the item neglected by all studies
			High: 0–4 items present	High: 0	
Yang et al., 2017[18]	NOS	3 domains	Low: ≥6 items present	Low: NR	The NOS is used for observational studies; therefore, it does not include sample randomization as an item for evaluation
		8 items (0 to 9 points)	Moderate: NR	Moderate: NR	Studies could not be evaluated individually, but overall quality was considered low
			High: NR	High: 794% inter-observer agreement	
Joss and Vassalli, 2008[11]	NR	NR	NR	NR	There was no analysis of the methodological quality of the included studies
Joss and Vassalli, 2009[8]	Custom scale	9 items	Low/moderate/high	Low: 0	No specific table listing the quality analysis was provided
				Moderate: 6	Sample power and assessor blinding were the criteria neglected by all studies
				High: 12	

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Table 6 (*Continued*)

Authors and year	Method of analysis	Criteria	Analysis of risk of bias	Overall potential for risk of bias	Notes
Medeiros et al., 2012[20]	Custom scale	3 domains 13 items	0 to 2 points; maximum score 16 Low: >13 Medium: 8–13 High: <8	Low: 4 Moderate: 10 High: 0	The studies, in general, were considered as having a moderate potential for risk of bias; mean 10.8 (range 8–14) points out of a possible 16 points No RCTs were included; even so, 4 studies were considered to have a low risk
Yang et al., 2014[13]	NR	NR	NR	NR	There was no analysis of the methodological quality of the included studies
Convens et al., 2015[7]	Custom scale	3 domains 15 items	Poor quality: <55% of items present Moderate quality: 55–70% of items present Good quality: >70% of items present	Poor quality: 1 Moderate quality: 1 Good quality: 0 Inter-observer agreement: κ = 0.85	Calculation of sample size, prospective design, assessor blinding, dropouts, confounding factors, and confidence interval were the criteria neglected by all studies
Starch-Jensen and Blaehr, 2016[16]	Custom scale	5 items	Low: All items present Moderate: Absence of 1 of the items High: Absence of 2 of the items	Low: 0 Moderate: 0 High: 4	Assessor blinding was not included as a criterion Sample randomization, definition of inclusion/exclusion criteria, and loss to follow-up were the items neglected by the 4 studies with a high potential risk of bias
Haas Junior et al., 2017[4]	Custom scale	7 items	Low: All items present Moderate: Absence of 2 of the items High: Absence of 3 of the items	Low: 0 Moderate: 4 High: 10	Assessor blinding was the item neglected by all studies; therefore, none of the articles was classified as having a low potential for risk of bias
Al-Thomali et al., 2017[21]	QATQS	6 items	Weak/moderate/strong Strong: no item considered weak and at least 4 items considered strong Moderate: 1 item considered weak and at least 3 considered strong Weak: 2 or more items considered weak	Strong: 3 Moderate: 10 Weak: 1	No table was provided for the evaluation of each item individually As sample randomization was not included as a criterion, the quality of the studies may have been overestimated

NOS, Newcastle–Ottawa scale; QATQS, The Quality Assessment Tool for Quantitative Studies; RCT, randomized clinical trial; NR, not reported.

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Table 7. Quality analysis of the included studies—AMSTAR-2 (A MeaSurement Tool to Assess Systematic Reviews).

	Greenlee et al., 2011[12]	Al-Moraissi and Ellis III, 2015[14]	Al-Moraissi and Ellis III, 2016[15]	Al-Moraissi and Al-Hendi, 2016[17]	Al-Moraissi and Wolford, 2016[6]	Luo et al., 2018[19]	Yang et al., 2017[18]
Did the research questions and inclusion criteria for the review include the components of PICO?	PY	Y	Y	Y	Y	Y	PY
Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	N	N	N	N	N	N	N
Did the review authors explain their selection of the study designs for inclusion in the review?	Y	Y	Y	Y	Y	Y	Y
Did the review authors use a comprehensive literature search strategy?	Y	PY	PY	PY	PY	PY	PY
Did the review authors perform study selection in duplicate?	Y	Y	N	N	Y	Y[a]	Y[a]
Did the review authors perform data extraction in duplicate?	Y	PY	N	PY	Y	Y	Y
Did the review authors provide a list of excluded studies and justify the exclusions?	Y	N	N	N	N	PY	PY
Did the review authors describe the included studies in adequate detail?	Y	Y	Y	Y	Y	Y	PY
Did the review authors use a satisfactory technique for assessing the RoB in individual studies that were included in the review?	Y	PY	PY	PY	Y	PY	PY[a]
Did the review authors report on the sources of funding for the studies included in the review?	N	N	N	N	N	N	N
If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results?	PY	PY	PY	PY	PY	Y	Y
If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	PY	Y	N	PY	Y	Y	Y
Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	Y	N	N	Y	Y	Y	Y
Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	PY	N	N	PY	Y	Y	Y
If meta-analysis was performed, did the review authors carry out an adequate investigation of publication bias and discuss its likely impact on the results of the review?	Y	PY	N	N	N	N	N
Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	N	N	Y	Y	N	Y	Y
Risk of bias	Y (9) PY (4) N (3)	Y (5) PY (5) N (6)	Y (4) PY (3) N (9)	Y (5) PY (6) N (5)	Y (9) PY (2) N (5)	Y (10) PY (3) N (3)	Y (8) PY (5) N (3)

	Joss and Vassalli, 2008[11]	Joss and Vassalli, 2009[8]	Medeiros et al., 2012[20]	Yang et al., 2014[13]	Convens et al., 2015[7]	Starch-Jensen and Blaehr, 2016[16]	Haas Junior et al., 2017[4]	Al-Thomali et al., 2017[21]
Did the research questions and inclusion criteria for the review include the components of PICO?	PY	PY	Y	PY	PY	Y	Y	PY
Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	N	N	N	N	Y	Y	N	Y
Did the review authors explain their selection of the study designs for inclusion in the review?	Y	Y	Y	Y	Y	Y	Y	Y

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Table 7 (*Continued*)

	Joss and Vassalli, 2008[11]	Joss and Vassalli, 2009[8]	Medeiros et al., 2012[20]	Yang et al., 2014[13]	Convens et al., 2015[7]	Starch-Jensen and Blaehr, 2016[16]	Haas Junior et al., 2017[4]	Al-Thomali et al., 2017[21]
Did the review authors use a comprehensive literature search strategy?	PY	PY	PY	PY	PY	PY	Y	PY
Did the review authors perform study selection in duplicate?	N	N	Y	Y	Y	Y	Y[a]	Y[a]
Did the review authors perform data extraction in duplicate?	N	N	N	N	PY	N	Y	Y
Did the review authors provide a list of excluded studies and justify the exclusions?	Y	Y	N	PY	PY	PY	Y	N
Did the review authors describe the included studies in adequate detail?	Y	Y	PY	PY	PY	PY	Y	Y
Did the review authors use a satisfactory technique for assessing the RoB in individual studies that were included in the review?	N	PY	PY	N	Y[a]	PY	Y	PY
Did the review authors report on the sources of funding for the studies included in the review?	N	N	N	N	N	N	N	N
If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results?	NM	NM	NM	NM	NM	NM	NM	NM
If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	NM	NM	NM	NM	NM	NM	NM	NM
Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	N	Y	PY	N	Y	Y	Y	PY
Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	Y	Y	N	N	Y	Y	Y	Y
If meta-analysis was performed, did the review authors carry out an adequate investigation of publication bias and discuss its likely impact on the results of the review?	NM	NM	NM	NM	NM	NM	NM	NM
Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	N	N	N	Y	Y	Y	Y	Y
Risk of bias	Y (4) PY (2) N (7)	Y (5) PY (3) N (5)	Y (3) PY (4) N (6)	Y (3) PY (4) N (6)	Y (7) PY (5) N (1)	Y (7) PY (4) N (2)	Y (11) PY (0) N (2)	Y (7) PY (4) N (2)

RoB, risk of bias; Y, yes; N, no; PY, partial yes; NM, no meta-analysis.
[a] Inter-observer agreement.

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Table 8. Stability in orthognathic surgery. Relapse between 75% and 100% was considered 'highly unstable'; relapse between 50% and 74% was considered 'unstable'; relapse between 25% and 49% was considered 'stable'; relapse between 0% and 24% was considered 'highly stable'.

Highly unstable – 75% to 100% relapse
- Maxillary expansion: 100% posterior dental relapse with SRIF
- Clockwise rotation of the mandible: 100% BSSO with bicortical screw RIF (sagittal)

Unstable – 50% to 74% relapse
- Maxillary expansion: 71% anterior dental relapse with RIF
- Maxillary downward: 52.2% with resorbable RIF, 73.1% with titanium RIF
- Maxillary upward with segmental Le Fort I: 50.82% posterior skeletal relapse with RIF
- Maxillary upward: 50.97% with resorbable RIF
- Maxillary setback: 55.7% with titanium RIF
- Mandibular advancement: 66.7% with titanium RIF, 54.42% with titanium RIF

Stable – 25% to 49% relapse
- Maxillary expansion: 28.35% anterior skeletal relapse with RIF, 25.1% posterior skeletal relapse with RIF, 27.75% posterior dental relapse with RIF, 49.4% posterior dental relapse with RIF, 28.35% anterior skeletal relapse with RIF, 29.7% anterior dental relapse with SRIF
- Maxillary downward: 45.3% with SRIF
- Maxillary downward with segmental Le Fort I: 35.12% anterior dental relapse with RIF, 37.84% anterior skeletal relapse with RIF
- Maxillary upward: 49.45% with titanium RIF
- Maxillary advancement: 26.25% with resorbable RIF, 25.8% with titanium RIF, 45.35% with resorbable RIF, 29.8% with titanium RIF, 27.1% in surgery-first with titanium RIF, 26.37% in conventional treatment with titanium RIF
- Maxillary setback: 44.56% with resorbable RIF
- Maxillary setback with segmental Le Fort I: 30.3% anterior dental relapse with SRIF
- Mandibular setback: 31% BSSO with resorbable RIF, 45% BSSO with titanium RIF, 26.65% BSSO with plate RIF, 37.2% BSSO with resorbable RIF, 33.8% IVRO in conventional treatment with MMF
- Mandibular advancement: 34.7% with resorbable RIF
- Clockwise rotation of the mandible: 28.95% BSSO with bicortical screw RIF (sagittal)

Highly stable – 0% to 24% relapse
- Maxillary expansion: 23.85% anterior dental relapse with RIF, 13.72% posterior skeletal relapse with RIF
- Maxillary downward: 17.5% anterior relapse with RIF, 8.3% posterior relapse with RIF, 7.2% anterior/posterior with RIF
- Maxillary downward with segmental Le Fort I: 0% anterior dental relapse with SRIF
- Maxillary upward with segmental Le Fort I: 23.75% posterior dental relapse with RIF, 17.24% posterior skeletal relapse with SRIF
- Maxillary upward: 19.7% with titanium RIF, 22.9% with SRIF
- Maxillary advancement: 0% if monomaxillary with resorbable RIF, 0% if monomaxillary with titanium RIF, 19.74% with titanium RIF
- Maxillary advancement with segmental Le Fort I: 9.37% anterior dental relapse with resorbable RIF, 0% posterior dental relapse with titanium RIF, 10.6% anterior skeletal relapse with titanium RIF, 18.06% posterior skeletal relapse with titanium RIF
- Mandibular setback: 18.78% BSSO with bicortical screw RIF, 12.86% BSSO with plate RIF, 23.6% BSSO RIF with resorbable bicortical screw, 0% BSSO with SRIF, 0% IVRO with MMF, 11.86% BSSO with bicortical screw RIF, 10.96% with plate RIF, 20.71% BSSO with titanium RIF, 17.55% surgery-first BSSO with RIF, 18.3% surgery-first IVRO with MMF, 15.52% BSSO in conventional treatment with RIF
- Mandibular advancement: 14.70% BSSO with bicortical screw RIF, 4.14% BSSO with plate RIF, 12.5% BSSO with resorbable bicortical screw RIF, 0% BSSO with resorbable RIF, 12.13% BSSO with bicortical screw, 12.06% BSSO with plate RIF, 13.6% BSSO with bicortical screw RIF
- Clockwise rotation of the mandible: 0% BSSO with plate/bicortical screw RIF (vertical), 5.9% BSSO with plate/bicortical screw RIF (sagittal)
- Counterclockwise rotation of the mandible: 19.7% BSSO with bicortical screw RIF (vertical), 0% BSSO with plate/bicortical screw RIF (vertical), 10.5% BSSO with bicortical screw RIF (sagittal), 20.2% BSSO with plate/bicortical screw RIF (sagittal)
- Surgical treatment of anterior open bite: 0% up to 13.5% bimaxillary with RIF or SRIF, 0% up to 9.8% in Le Fort I with RIF, 4.8% to 13.9% in Le Fort I with SRIF

BSSO, bilateral sagittal split osteotomy; IVRO, intraoral vertical ramus osteotomy; MMF, maxillomandibular fixation; RIF, rigid internal fixation; SRIF, semi-rigid internal fixation.

the data provided by Proffit et al. (1996 and 2007) were based on dental analyses, their results would be very similar to the findings of this overview of systematic reviews[1,2]. Taking this into account, preoperative dental expansion should not be performed under any circumstances in order to avoid underestimating the amount of bone expansion needed and to prevent the creation of a transverse dental instability in the postoperative period.

In the same way as for maxillary expansion, maxillary downward movement is also considered in the general literature to be a problematic procedure from the stability standpoint[1,2]. This finding contradicts the data found in a systematic review by Convens et al. (2015)[7], who reported relapse rates of between <0% and 35% with the use of bone grafts in some situations. Although these data belong to a secondary study with excellent methodological quality, only two clinical studies were included for a total sample of 22 patients only. In addition, another systematic review of similar methodological quality reported a percentage relapse of 73.1% after fixation with titanium miniplates and 52.2% after fixation with resorbable miniplates[19]. Therefore, we believe that the literature does not supersede changes in some pre-established surgical concepts regarding maxillary downward movement, especially regarding the need for RIF and bone grafting.

Another type of surgical movement considered problematic in the literature is isolated mandibular setback[1,2]. However, mandibular advancement and setback were both generally 'highly stable', especially in the context of BSSO with RIF, whether with screws and/or Plates[6,8,11,15,17,18]. This discrepancy in findings may be related to the type of fixation (rigid or semi-rigid), the magnitude of rotation of the mandibular complex, and incorrect posterior positioning of the distal segment[1,2,8,11]. Therefore, mandibular stability outcomes are extremely dependent on the surgeon's experience.

Mandibular advancement and setback were considered more stable than the same movements when performed in the maxilla. This finding is closely related to the proportion that the percentage relapse represents; the absolute magnitude of relapse is very similar in both bone segments (except in maxillary setback), but as the magnitude of surgical movement is greater in the mandible than in the maxilla, relapse is relatively less in this anatomical structure. Remarkably, however, maxillary setback was characterized as 'stable' (44.56%[19]) or 'unstable' (55.7%[19]), with an absolute magnitude of relapse (2.16 mm and 2.36 mm[19]) greater than in the vast majority of secondary studies reporting ample mandibular movement[6,8,11,14,15,17].

Assessment of the influence of different osteotomy techniques on surgical stability of the mandible was limited; only mandibular setback could be compared between BSSO and IVRO. The latter technique was more unstable, with no appreciable pattern for accommodation of the condylar segment in the postoperative period. Relapse outcomes ranged from up to 33.8%[18] to overcorrections of up to 20.3%[14]. The variability of outcomes found for IVRO is closely related to non-union of the bone segments and the possibility of free accommodation of the mandibular condyle within the glenoid fossa.

Of all the surgical techniques evaluated, the treatment of anterior open bite was found to be the most stable, with relapse rates ranging from <0% to 13%[12,20,21]. A few primary studies reported rates close to 25%, which would fall outside of the 'highly stable' category. These data came from dental measurements of overbite, and no relapse-related factors such as tongue size and position, facial pattern, respiratory problems, or condylar resorption were considered[42]. Therefore, the orthodontic mechanics of the anterior teeth in the postoperative period may have masked the occurrence of some skeletal relapse. However, it is paramount to note that a combination of surgical and orthodontic treatment, regardless of the type of RIF or the number of osteotomized bone segments, is capable of treating anterior open bite and providing long-term occlusal stability.

Given the design of this overview of systematic reviews, it was possible to dilute the bias of the individual characteristics of each primary study toward the final outcome of interest (stability in orthognathic surgery). Therefore, the hierarchy of stability proposed herein is the combined result of the experience of several surgeons who have published scholarly articles on the subject, making the results of this study more comprehensive and applicable to clinical reality rather than restricted to the experience of a single specialized centre.

From an academic standpoint, this overview contains suggestions to improve the level of scientific evidence of primary studies by revealing the need for conducting well-designed clinical trials, even those that due to the ethical issues involved in some types of interventions cannot be randomized. As for secondary studies, it is also an objective of overviews to suggest new systematic reviews[9]. We believe there is a notable research gap concerning the imaging method used to evaluate the results of primary studies, as there have been no systematic reviews with inclusion criteria that have limited studies to those using three-dimensional analyses of pre- and postoperative computed tomography scans.

In conclusion, according to the hierarchy of stability in orthognathic surgery proposed by this overview of systematic reviews, two procedures are considered 'highly unstable': posterior maxillary expansion with semi-rigid internal fixation when evaluated at the dental level and clockwise rotation with bicortical screw fixation after mandibular BSSO.

Surgical procedures in the maxilla were deemed more unstable than those performed in the mandible, with the following techniques scoring on a continuum between 'stable' and 'unstable': maxillary downward movement with semi-rigid or bioresorbable internal fixation, maxillary setback with titanium or bioresorbable RIF, and maxillary upward movement with bioresorbable RIF.

Mandibular surgical movements were, for the most part, 'stable' or 'highly stable', with greater stability when achieved through BSSO for mandibular setback and RIF with miniplates and bicortical screws for rotations.

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Patient consent

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References

1. Proffit WR, Turvey TA, Phillips C. Orthognathic surgery: a hierarchy of stability. *Int J Adult Orthodon Orthognath Surg* 1996;**11**:191–204.
2. Proffit WR, Turvey TA, Phillips C. The hierarchy of stability and predictability in orthognathic surgery with rigid fixation: an update and extension. *Head Face Med* 2007;**30**:3–21.
3. Van Sickels JE, Richardson DA. Stability of orthognathic surgery: a review of rigid fixation. *Br J Oral Maxillofac Surg* 1996;**34**:279–85.
4. Haas Junior OL, Guijarro-Martínez R, Gil APS, Meirelles LS, 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.
5. Agnihotry A, Fedorowicz Z, Nasser M, Gill KS. Resorbable versus titanium plates for orthognathic surgery. *Cochrane Database Syst Rev* 2017;**10**:CD006204.
6. Al-Moraissi EA, Wolford LM. Is counterclockwise rotation of the maxillomandibular complex stable compared with clockwise rotation in the correction of dentofacial deformities? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2016;**74**:2066.e1–..
7. Convens JM, Kiekens RM, Kuijpers-Jagtman AM, Fudalej PS. Stability of Le Fort I maxillary inferior repositioning surgery with rigid internal fixation: a systematic review. *Int J Oral Maxillofac Surg* 2015;**44**:609–14.
8. Joss CU, Vassalli IM. Stability after bilateral sagittal split osteotomy advancement surgery with rigid internal fixation: a systematic review. *J Oral Maxillofac Surg* 2009;**67**:301–13.
9. Becker LA, Oxman AD. Chapter 22: Overviews of reviews. In: Higgins JPT, Green S, editors. *Cochrane handbook for systematic reviews of interventions version 5.1.0.*. The Cochrane Collaboration; 2011.
10. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017;**358**:j4008.
11. Joss CU, Vassalli IM. Stability after bilateral sagittal split osteotomy setback surgery with rigid internal fixation: a systematic review. *J Oral Maxillofac Surg* 2008;**66**:1634–43.
12. Greenlee GM, Huang GJ, Chen SSH, Chen J, Koepsell T, Hujoel P. Stability of treatment

for anterior open-bite malocclusion: a meta-analysis. *Am J Orthod Dentofacial Orthop* 2011;**139**:154–69.
13. Yang L, Xu M, Jin X, Xu J, Lu J, Zhang C, Li S, Teng L. Skeletal stability of bioresorbable fixation in orthognathic surgery: a systematic review. *J Craniomaxillofac Surg* 2014;**42**:e176–81.
14. Al-Moraissi EA, Ellis 3rd E. Is there a difference in stability or neurosensory function between bilateral sagittal split ramus osteotomy and intraoral vertical ramus osteotomy for mandibular setback? *J Oral Maxillofac Surg* 2015;**73**:1360–71.
15. Al-Moraissi EA, Ellis 3rd E. Stability of bicortical screw versus plate fixation after mandibular setback with the bilateral sagittal split osteotomy: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2016;**45**:1–7.
16. Starch-Jensen T, Blaehr TL. Transverse expansion and stability after segmental Le Fort I osteotomy versus surgically assisted rapid maxillary expansion: a systematic review. *J Oral Maxillofac Res* 2016;**7**:e1.
17. Al-Moraissi EA, Al-Hendi EA. Are bicortical screw and plate osteosynthesis techniques equal in providing skeletal stability with the bilateral sagittal split osteotomy when used for mandibular advancement surgery? A systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2016;**45**:1195–200.
18. Yang L, Xiao Y, Liang Y, Wang X, Li J, Liao G. Does the surgery-first approach produce better outcomes in orthognathic surgery? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2017;**75**:2422–9.
19. Luo M, Yang X, Wang Q, Li C, Yin Y, Han X. Skeletal stability following bioresorbable versus titanium fixation in orthognathic surgery: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2018;**47**:141–51.
20. Medeiros RB, de Araújo LFC, Mucha JN, Motta AT. Stability of open-bite treatment in adult patients: a systematic review. *J World Fed Orthod* 2012;**1**:e97–101.
21. Al-Thomali Y, Basha S, Mohamed RN. The factors affecting long-term stability in anterior open-bite correction—a systematic review. *Turkish J Orthod* 2017;**30**:21–7.
22. Saltaji H, Major MP, Altalibi M, Youssef M, Flores-Mir C. Long-term skeletal stability after maxillary advancement with distraction osteogenesis in cleft lip and palate patients. A systematic review. *Angle Orthod* 2012;**82**:1115–22.
23. Vilani GNL, Mattos CT, Ruellas ACO, Maia LC. Long-term dental and skeletal changes in patients submitted to surgically assisted rapid maxillary expansion: a meta-analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012;**114**:689–97.
24. Langravère MO, Major PW, Flores-Mir C. Dental and skeletal changes following surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg* 2006;**35**:481–7.
25. Buck LM, Dalci O, Darendeliler MAH, Papapdopoulou AK. Effect of surgically assisted rapid maxillary expansion on upper airway volume: a systematic review. *J Oral Maxillofac Surg* 2016;**74**:1025–43.
26. Rossini G, Vinci B, Rizzo R, Da TM, Pinho C, Deregibus A. Mandibular distraction osteogenesis: a systematic review of stability and the effects on hard and soft tissues. *Int J Oral Maxillofac Surg* 2016;**45**:1438–44.
27. Scolozzi P. Distraction osteogenesis in the management of severe maxillary hypoplasia in cleft lip and palate patients. *J Craniofac Surg* 2008;**19**:1199–214.
28. Viwattanatipa N, Puntien T, Nanthavanich N. Systematic review and meta-analysis: mandibular plane change after orthognathic surgery and distraction osteogenesis in cleft lip and palate patients. *Orthodontic Waves* 2015;**74**:27–36.
29. Viwattanatipa N, Puntien T, Thakkinstian A. Systematic review and meta-analysis of maxillary change among 3 surgical techniques in cleft patients. *Orthodontic Waves* 2013;**72**:63–76.
30. Austin SL, Mattick CR, Waterhouse PJ. Distraction osteogenesis versus orthognathic surgery for the treatment of maxillary hypoplasia in cleft lip and palate patients: a systematic review. *Orthod Craniofac Res* 2015;**18**:96–108.
31. Cheung LK, Chua HDP. A meta-analysis of cleft maxillary osteotomy and distraction osteogenesis. *Int J Oral Maxillofac Surg* 2006;**35**:14–24.
32. Kloukos D, Fundalej P, Sequeira-Byron P, Katsaros C. Maxillary distraction osteogenesis versus orthognathic surgery for cleft lip and palate patients. *Cochrane Database Syst Rev* 2016;**9**:CD010403.
33. Saltaji H, Major MP, Alfakir H, Al-Saleb MAQ, Flores-Mir C. Maxillary advancement with conventional orthognathic surgery in patients with cleft lip and palate: is it a stable technique? *J Oral Maxillofac Surg* 2012;**70**:2859–66.
34. Yamaguchi K, Lonic D, Lo LJ. Complications following orthognathic surgery for patients with cleft lip/palate: a systematic review. *J Formos Med Assoc* 2016;**115**:269–77.
35. Huang CS, Hsu SSP, Chen YR. Systematic review of the surgery first approach in orthognathic surgery. *Biomed J* 2014;**37**:184–90.
36. Raposo R, Peleteiro B, Paço M, Pinho T. Orthodontic camouflage versus orthodontic-orthognathic surgical treatment in class II malocclusion: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2018;**47**:445–55.
37. Al-Moraissi EA, Ellis III E. Bilateral sagittal split ramus osteotomy versus distraction osteogenesis for advancement of the retrognathic mandible. *J Oral Maxillofac Surg* 2015;**73**:1564–74.
38. Al-Moraissi EA, Ellis 3rd E. Biodegradable and titanium osteosynthesis provide similar stability for orthognathic surgery. *J Oral Maxillofac Surg* 2015;**73**:1795–808.
39. Buijs GJ, Stegenga B, Bos RRM. Efficacy and safety of biodegradable osteofixation devices in oral and maxillofacial surgery: a systematic review. *J Dent Res* 2006;**85**:980–9.
40. Al-Moraissi EA, Wolford LM. Does temporomandibular joint pathology with or without surgical management affect the stability of counterclockwise rotation of the maxillo-mandibular complex in orthognathic surgery? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2017;**75**:805–21.
41. Catherine Z, Breton P, Bouletreau P. Condylar resorption after orthognathic surgery: a systematic review. *Rev Stomatol Chir Maxillofac Chir Orale* 2015;**117**:3–10.
42. Solano-Hernández B, Antonarakis GS, Scolozzi P, Kiliaridis S. Combined orthodontic and orthognathic surgical treatment for the correction of skeletal anterior open-bite malocclusion: a systematic review on vertical stability. *J Oral Maxillofac Surg* 2013;**71**:98–109.
43. Catherine Z, Breton P, Bouletreau P. Management of dentoskeletal deformity due to condylar resorption: literature review. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016;**121**:126–32.
44. He J, Liu C, Wang C, Wang S, Guo X. Skeletal stability of bioabsorbable fixations versus titanium system for orthognathic surgery: a meta-analysis. *Hainan Med J* 2015;**26**:3233–8.
45. Xueyan L, Mengxuan D, Xiaoping Y. Stability of anterior teeth and hard tissue of skeletal class III malocclusion after orthodontic surgery: systematic review. *West China J Stomatol* 2015;**33**:267–71.
46. Sonego CL, Bobrowski AN, Chagas Jr OL, Torriani MA. Aesthetic and functional implications following rotation of the maxillo-mandibular complex in orthognathic surgery: a systematic review. *Int J Oral Maxillofac Surg* 2014;**43**:40–5.
47. Peiró-Guijarro M, Guijarro-Martínez R, Hernández-Alfaro F. Surgery first in orthognathic surgery: a systematic review of the literature. *Am J Orthod Dentofacial Orthop* 2016;**149**:448–62.
48. Mucedero M, Coviello A, Baccetti T, Franchi L, Cozza P. Stability factors after double-jaw surgery in class III malocclusion. *Angle Orthod* 2008;**78**:1141–52.
49. Wei H, Liu Z, Zang J, Wang X. Surgery-first/early-orthognathic approach may yield poorer postoperative stability than conventional orthodontics-first approach: a systematic review and meta-analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2018;**126**:107–16.
50. Minami-Sugaya H, Oliveira-Lentini DA, Carvalho FR, Machado MAC, Marzola C,

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Saconato H, Prado GF. Treatment for adults with prominent lower front teeth. *Cochrane Database Syst Rev* 2012;**5**:CD006963.
51. Fedorowicz Z, Nasser M, Newton T, Oliver R. Resorbable versus titanium plates for orthognathic surgery. *Cochrane Database Syst Rev* 2007;**2**:CD006204.
52. Pieper D, Buechter R, Jerinic P, Eikermann M. Overviews of reviews often have limited rigor: a systematic review. *J Clin Epidemiol* 2012;**65**:1267–73.
53. Bougioukas KI, Liakos A, Tsapas A, Ntzani E, Haidich A. Preferred reporting items for overviews of systematic reviews including harms checklist: a pilot tool to be used for balanced reporting of benefits and harms. *J Clin Epidemiol* 2017;**93**:9–24.
54. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;**33**:159–74.

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