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Surgery first in orthognathic surgery: A systematic review of the literature

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Introduction: Compared to the conventional approach to orthognathic surgery, "surgery first" protocols could be advantageous in terms of shortened treatment times and immediate esthetic improvement. However, consensus regarding patient selection, technical protocol, and stability is still lacking. **Methods:** A systematic review of the scientific literature on surgery-first treatment (January 2000 to January 2015) was performed. The PubMED and Cochrane Library databases were accessed. Patient selection criteria, specific surgical-orthodontic protocol, treatment duration, patient and orthodontist satisfaction, and stability of results were compared with a similar population treated conventionally. **Results:** The search yielded 179 publications. The application of strict selection criteria gave the final group of 11 articles. In total, 295 patients were managed with a surgery-first approach. A Class III malocclusion was the most prevalent underlying malocclusion (84.7%). Total treatment duration was shorter in surgery-first patients than in those treated conventionally. There was substantial heterogeneity among articles and high reporting bias regarding the inclusion and exclusion criteria, the orthodontic and surgical protocols, and the stability of results. A meta-analysis of combined data was not possible. **Conclusions:** The surgery-first approach is a new treatment paradigm for the management of dentomaxillofacial deformity. Studies have reported satisfactory outcomes and high acceptance. However, the results should be interpreted with caution because of the wide varieties of study designs and outcome variables, reporting biases, and lack of prospective long-term follow-ups. (Am J Orthod Dentofacial Orthop 2016;149:448-62)

Until recently, the conventional approach to orthognathic surgery involving preoperative orthodontics, followed by surgery and postoperative orthodontics, was the sole recognized approach to orthognathic surgery. The first orthognathic surgeons realized that the amount of mandibular setback was limited by the magnitude of overjet between the maxillary and mandibular incisors.[1] Consequently, the "orthodontics-first" concept became a widely acknowledged dogma.[2] It emphasized that optimal surgical repositioning of the jaw was possible only after the removal of all dental compensations before surgery. Over the years, acceptable levels of stability and satisfaction with posttreatment outcomes have validated this approach.[3]

In 1959, Skaggs[4] raised the issue of surgical timing in relation to orthodontic treatment and suggested that surgery should precede orthodontic treatment if a satisfactory interarch relationship can be reached surgically. This is, to our knowledge, the first documented reference to what is currently known as "surgery first." Behrman and Behrman[5] hypothesized that when the jaw position is corrected, the normalized surrounding soft tissues—lips, cheeks, and tongue—facilitate postoperative tooth movement and reduce the length of orthodontic treatment. They illustrated this concept metaphorically with their suggestion to "build the house and then move the furniture." Brachvogel et al[6] defined further potential advantages of this surgery-first approach, suggesting that dental arch alignment after surgery is similar to orthodontic treatment in any Class I case, and that possible postsurgical relapse can be easily addressed with postoperative orthodontics. Whereas the case report by Nagasaka et al[7] in 2009 is often cited as the

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first clinical application of this approach, an article by Dingman[8] in 1944 reported an "improved" method for correcting mandibular prognathism based on performing surgery before orthodontics.

Subsequent research has demonstrated that compared with the traditional scheme, surgery-first protocols seem to reduce total treatment time and obtain immediate improvement of the facial profile or upper airway constriction. These factors may lead to high patient satisfaction rates from the early stages of treatment and improved cooperation during postoperative orthodontics.[9-11] The observed reduction in total treatment time is related to more efficient postoperative orthodontics.[10-15] It has been suggested that surgery-first patients typically require shorter orthodontic treatment times.[10-14] This observation may be related to partial resolution of dentoalveolar compensation after surgery, leading to less complex orthodontic treatment.[13,16] After the correction of the skeletal base discrepancy, the direction of postsurgical treatment coincides with the natural direction of spontaneous dental compensation and muscular force, thereby decreasing the time to full compensation.[11,15] Moreover, orthodontic tooth movement may be facilitated by the surgically induced regional acceleratory phenomenon.[9-11,16] This metabolic process is a complex physiologic phenomenon involving accelerated bone turnover and decreased regional mineral density.[16]

The proposed benefits of surgery first have led to a growing acceptance in surgical and orthodontic communities toward these protocols. Nevertheless, there is currently no consensus regarding surgical protocols, specific complications or limitations of this treatment sequence, and stability of the results. Consequently, the aims of this systematic review were to analyze current protocols and results of patients treated with surgery first and to compare the outcomes with those obtained from a conventional approach.

MATERIAL AND METHODS

The PICOS (participants, intervention, comparisons, outcomes, and study design) criteria focused on nongrowing, nonsyndromic patients with a skeletal maxillofacial deformity treated with a surgery-first approach and a similar population treated with the conventional orthognathic approach. Outcomes assessed included treatment duration, patient satisfaction, orthodontist satisfaction, and stability. Regarding the study design, a level of evidence of at least IV was required. In the level III group, case series with a sample size less than 10 were excluded.

An electronic search of PubMed and Cochrane Library databases was performed from January 2000 to January 2015. The search strategy was designed to include 2 aspects: terms related to the surgical procedure of interest (orthognathic surgery) and terms related to the specific approach of interest (surgery first). The following term sequence was used in PubMed: ("surgery first") AND ("orthognathic surgery") OR ("surgery first") AND ("orthodontics" [MeSH]). No preliminary exclusion of articles based on language of publication was applied. The electronic search was augmented with manual searches of the reference lists of the selected publications.

This search strategy was undertaken independently by 2 investigators (M.A.P-G., R.G-M.). All titles obtained by the electronic searches were screened. When the title did not contain enough information for exclusion, the article was selected for abstract evaluation. Subsequently, the abstracts of all potentially relevant articles were reviewed based on the inclusion criteria. Those that apparently fulfilled these criteria and articles whose title and abstract did not contain enough relevant information were obtained in full. The Cohen kappa coefficient was used to measure interrater agreement for title and abstract selection.[17] Full-text articles were analyzed for final inclusion with reasons for rejection noted. In case of a discrepancy between investigators, a consensus decision was made.

The methodologic quality of studies was assessed for a risk of bias independently by the same 2 investigators. Depending on the type of study—randomized or nonrandomized—the use of the Cochrane Collaboration Tool[18] or the Newcastle-Ottawa scale[19] for quality and risk of bias assessment was planned. In case of a discrepancy between the investigators, a consensus decision was made.

RESULTS

The electronic search produced 164 publications in PubMed and 15 in the Cochrane Library (total, 179). After removal of duplicates, 177 potentially relevant titles were assessed. Of these, 29 were selected for further abstract analysis (interrater agreement, $\kappa = 0.89$). Subsequently, 23 articles were retrieved for full-text evaluations. Manual search led to the inclusion of 10 additional articles (Tables I and II).

Application of the inclusion criteria caused the exclusion of 21 articles. One publication was not retrievable.[24] Eleven articles fulfilled the inclusion criteria and were selected for systematic analysis. The PRISMA flow diagram (Fig 1) gives an overview of the selection process. Table 1 summarizes the sample's demographic

Table I. Overview of the studies in this systematic review: sample demographic characteristics, study aims, malocclusions, types of intervention, total treatment times, and stability outcomes

Authors and year of publication	*Origin*	*Study type*	*Sample size and distribution*	*Mean age at time of surgery (y)*	*Aim of study*	*Type of malocclusion*	*Type of intervention*	*Total treatment time (mo)*	*Stability or relapse*
Baek et al,[11] 2010	South Korea	Prospective, case series	n = 11 (5 male, 6 female)	22.95	To evaluate surgical movement and postoperative orthodontic treatment of the SFA for the correction of skeletal Class III malocclusion.	Skeletal Class III	Bimaxillary surgery: LeFort I osteotomy (with posterior impaction of the maxilla) and BSSO for mandibular setback	12.18 ± 3.57	NR
Wang et al,[20] 2010	Taiwan	Retrospective, case control	n = 36 (18 CA, 18 SFA)	CA 22.3 ± 3.8 SFA 23.3 ± 4.2	To investigate transverse dimensional changes of the dental arches in skeletal Class III malocclusion treated with the SFA vs CA.	Skeletal Class III	Bimaxillary surgery: LeFort I osteotomy and/or BSSO	NR	NR
Liao et al,[15] 2010	Taiwan	Retrospective, case control	n = 33 (13 CA, 20 SFA)	CA 21 ± 4 SFA 23 ± 4	To compare the SFA vs CA in terms of treatment outcome (facial esthetics, occlusion, stability, and efficiency).	Skeletal Class III and open bite	Bimaxillary surgery: LeFort I osteotomy (with posterior impaction, with or without segmentation) and BSSO	CA 17.1 ± 3.4 SFA 11.4 ± 4.2	At debonding, maxillary stability was good in both the horizontal and vertical directions. In the horizontal direction, mild rmandibular relapse was found in both groups. Although the vertical mandibular stability was worse in the SFA group than in the CA group, the direction of instability was favorable for open-bite correction.
Ko et al,[21] 2011	Taiwan	Retrospective, case control	n = 53 (27 male, 26 female) 35 CA: 19 male, 16 female; 18 SFA: 8 male, 10 female	CA 22 ± 4.1 (range, 18-34) SFA 24.6 ± 4.9 (range, 18-33)	To compare the SFA vs CA in terms of (1) progressive dental and skeletal changes, (2) postsurgical stability, (3) treatment efficacy of skeletal Class III correction.	Skeletal Class III (ANB <0°)	Bimaxillary surgery: BSSO and 1 of these 3 options: (1) presurgical nonextraction therapy + maxillary segmentation + tooth extraction during surgery; (2) presurgical nonextraction therapy + LeFort I osteotomy with clockwise rotation; or (3) presurgical extraction therapy + LeFort I osteotomy	SFA 17.8 ± 5 CA 15.76 ± 2.7	NR

Table I. Continued

Authors and year of publication	*Origin*	*Study type*	*Sample size and distribution*	*Mean age at time of surgery (y)*	*Aim of study*	*Type of malocclusion*	*Type of intervention*	*Total treatment time (mo)*	*Stability or relapse*
Liou et al,[16] 2011	Taiwan	Prospective, cohort	n = 22	NR	To study postoperative changes in bone physiology and metabolism and the corresponding responses in the dentoalveolus.	NR	Bimaxillary surgery: LeFort 1 osteotomy and BSSO	NR	NR
Ko et al,[22] 2013	Taiwan	Retrospective, cohort	n = 45 (19 male, 26 female)	23.2	To identify parameters related to skeletal stability after OGS in skeletal Class III with SFA; to compare dental and skeletal variables between patients with better and worse surgical stability; and to evaluate correlations between variables and mandibular stability.	Skeletal Class III (ANB $<0°$)	Bimaxillary surgery: LeFort I osteotomy, BSSO, and genioplasty (the latter only in 22 subjects)	13.9	At debonding, 12.46% relapse. Mean B-point relapse, 1.44 mm.
Choi et al,[12] 2015	South Korea	Prospective, case control	n = 56 (16 male, 40 female) 24 CA, 32 SFA	22.4	To clarify the hypothesis: "OGS without presurgical orthodontics (SFA) may be as effective as the CA in correcting dentofacial deformities."	Skeletal Class III	Bimaxillary surgery: LeFort I osteotomy with posterior impaction of the maxilla and BSSO or mandibular setback	SFA 19.4 CA 22.3	At 12 to 36 months follow-up, relapse rate was not statistically significant different between groups except for the lower anterior facial height ratio.
Hernandez-Alfaro et al,[10] 2014	Spain	Prospective, case series	n = 45 (18 male, 27 female)	23.5 (range, 17-36)	To describe a specific orthodontic and surgical protocol for SFA, discuss its benefits and limitations, and update its indications.	Skeletal Class II (n = 19), skeletal Class III (n = 22), asymmetry (n = 4)	Bimaxillary surgery (n = 30): 1. LeFort I osteotomy + BSSO (n = 29) 2. LeFort I osteotomy + mandibular front-block (n = 1) Maxillary surgery (n = 11): LeFort I osteotomy Mandibular surgery (n = 4): BSSO	10.2	NR

Table I. Continued

Authors and year of publication	*Origin*	*Study type*	*Sample size and distribution*	*Mean age at time of surgery (y)*	*Aim of study*	*Type of malocclusion*	*Type of intervention*	*Total treatment time (mo)*	*Stability or relapse*
Kim et al,[14] 2014	South Korea	Retrospective, cohort	n = 61 (28 male, 33 female) 38 CA, 23 SFA	CA 21.6 ± 3.5 SFA 23 ± 6.3	To compare the SFA vs CA in terms of stability after mandibular setback in skeletal Class III subjects.	Skeletal Class III	Mandibular surgery: BSSO	SFA 15.4 CA 22.5	At debonding, mandible moved anteroinferiorly. Average amounts of anterior relapse, 1.6 mm in the CA group and 2.4 mm in the SFA group. Vertical relapse pattern was similar. Relapse >3 mm comprised 39.1% of the SFA group vs 15.8% of the CA group. Relapse <1.5 mm more dominant in CA. Significant association between degree of relapse and group difference.
Park et al,[13] 2014	South Korea	Retrospective, case control	n = 60 (24 male, 36 female) 36 CA, 24 SFA	CA 22.4 ± 4.4 SFA 22.4 ± 4.6	To compare the SFA vs CA in terms of differences in the amount and pattern of maxillary incisor inclination change in skeletal Class III treated with extraction of the maxillary 1pm and bimaxillary surgery.	Skeletal Class III	Bimaxillary surgery: LeFort I osteotomy + BSSO. Maxillary 1pms were extracted during surgery in the SFA group	NR	NR
Kim et al,[23] 2014	South Korea	Retrospective, case series	n = 37 (20 male, 17 female)	23 ± 4	To evaluate postoperative stability of the treatment of mandibular prognathism treated with the SFA (with IVRO instead of BSSO for the mandible).	Skeletal Class III	Bimaxillary surgery: LeFort I osteotomy + IVRO	14 ± 6	At debonding, postoperative changes in skeletal variables were measured for 1 year postoperatively and showed no remarkable changes of the maxillary position in either plane. The mandible had no significant relapse horizontally, but vertical relapse was significant at all time intervals, particularly during the first 6 months postoperatively. Both anterior and posterior facial heights were decreased 1 year postoperatively, and most changes occurred during the first 6 months postoperatively.

BSSO, Bilateral sagittal split osteotomy; *IVRO*, intraoral vertical ramus osteotomy; *CA*, conventional approach; *SFA*, surgery first approach; *OGS*, orthognathic surgery; *1pm*, first premolar; *NR*, not reported.

Table II. Overview of the studies in this systematic review: orthodontic protocols and occlusal stabilization techniques

Authors and year of publication	*Preoperative orthodontic preparation*	*Preoperative orthodontic appliance used for SFA*	*Postoperative orthodontic protocol*	*Mean postoperative orthodontic treatment time*	*Postoperative splint use/ intermaxillary fixation*
Baek et al,[11] 2010	NR	Passive surgical wires bonded directly to tooth surface or ligated to brackets.	NR	8.91 ± 3.14 months	4 weeks
Wang et al,[20] 2010	1-2 weeks	0.022 × 0.028-in preadjusted appliance and sliding mechanics bonded without forces.	NR	NR	NR
Liao et al,[15] 2010	1 month	0.022 × 0.028-in brackets are bonded, and 1-3 days before surgery, a 0.016 × 0.022 NiTi wire was placed.	Orthodontic treatment was initiated immediately after surgery because the active archwire was left in place. For segmental surgery patients, sectional archwires were replaced with continuous archwires. If there was a shift to an undesirable bite, occlusal adjustment or light elastics were used to stabilize jaw position. Incomplete arch coordination can be assisted by light transpalatal elastics, an active palatal arch, or an active lingual arch. Once alignment, leveling, and coordination were achieved, 0.016 × 0.022 SS was used. Incomplete incisor decompensation can be assisted by Class II elastics.	NR	NR
Ko et al,[21] 2011	SFA 21 ± 4.5 days CA 154 ± 59.3 days	Full bonding and passive 0.016-in SS archwire.	NR	NR	NR
Liou et al,[16] 2011	NR	NR	NR	NR	NR
Ko et al,[22] 2013	NR	NR	NR	12.2 months	NR
Choi et al,[12] 2015	NR	Application of 1 bracket for intermaxillary fixation	NR	NR	NR
Hernandez-Alfaro et al,[10] 2014	1 week	Full bonding 1 week preoperatively and placement of a soft arch the day before surgery	Initiation of orthodontic treatment 2 weeks postsurgery; archwire change every 2-3 weeks.	9.5 months (range, 6-13)	Fixation of end splint to maxilla (2 weeks) only in the case of maxillary segmental surgery.
Kim et al,[14] 2014	CA 12.9 months SFA 1 month	Full bonding without archwire	Both groups received the same postoperative management. Use of intermaxillary elastics.	SFA 14.3 months CA 9.6 months (but 12.9 months of preoperative orthodontics)	Use of intermaxillary elastics and an interocclusal splint for 4-6 weeks.
Park et al,[13] 2014	NR	NR	NR	NR	NR

Table II. Continued

Authors and year of publication	*Preoperative orthodontic preparation*	*Preoperative orthodontic appliance used for SFA*	*Postoperative orthodontic protocol*	*Mean postoperative orthodontic treatment time*	*Postoperative splint use/intermaxillary fixation*
Kim et al,[23] 2014	2-3 weeks	Full bonding (archwires placed preoperatively for surgical anchorage)	Postoperative active physiotherapy with Class II elastics (2 weeks) followed by orthodontic treatment.	12 ± 6 months	Intermaxillary fixation for 2 weeks followed by active physiotherapy using Class II elastics until the patient could open the mouth at least 30 mm, with confirmation of a stable occlusion with a surgical wafer.

CA, Conventional approach; *SFA*, surgery first approach; *NiTi*, nickel titanium; *SS*, stainless steel; *NR*, Not reported.

characteristics, aims, clinical characteristics, types of intervention, total treatment times, and stability for each study. Table II summarizes the orthodontic protocols and splint use.

This systematic review included 5 case-control studies,[12,13,15,20,21] 3 cohort studies,[16,22,23] and 3 case series.[10,11,14] Seven studies were retrospective, and 4 were prospective. The majority of the studies were undertaken in Asia (91%).

Since no clinical trials were retrieved, methodologic quality could not be assessed with the Cochrane Collaboration tool. For case-control and cohort studies, the Newcastle-Ottawa scale was applied (Table III).

Information concerning total treatment duration was absent in 3 articles.[13,16,20] Patient and orthodontist satisfaction was assessed in only 1 publication.[10] Only 3 articles provided complete and detailed information about orthodontic measures.[10,15,23] Only 1 study reported stability outcomes at follow-ups of 1 and 3 years[12]; the rest evaluated the results at appliance removal only.

The included studies focused on (1) assessment of postoperative consequences in terms of skeletal changes,[11,12,15,20,21] dental changes,[13,15,21] esthetic changes,[15] or physiologic changes[16]; (2) assessment of stability[14,15,21-23]; (3) assessment of satisfaction[10]; and (4) report of a specific protocol.[10]

Overall, in the 11 selected articles, a total of 295 patients with a mean age of 23.13 years at the time of surgery were treated with a surgery-first approach. The sample sizes ranged from 11[11] to 45 subjects,[10] with ages from 16[15] to 36 years,[10] although 1 study failed to report information concerning age.[16]

Regarding the type of malocclusion, Class III was the most prevalent (84.7%; Table I). Only 1 article reported on different types of malocclusion: 19 skeletal Class II patients (6.4% of the total sample), 4 with skeletal asymmetry (1.4%), and the remaining 22 patients were skeletal Class III.[10] Liou et al[16] did not specify the types of malocclusions included in their research.

A total of 239 patients (84.7%) underwent bimaxillary surgery (Tables I and II). A LeFort I osteotomy (segmented or not) and a bilateral sagittal split osteotomy were performed in 201 patients (68.1%).[10-12,15,16,20-22] One study group reported intraoral vertical ramus osteotomy[14] without segment fixation in 37 patients (12.5%).[10,23] One patient (0.3%) was managed with a LeFort I osteotomy plus a mandibular front-block osteotomy.[10] Eleven patients (3.7%) received an isolated LeFort I osteotomy,[10] and 45 (15.2%) underwent isolated bilateral sagittal split osteotomy.

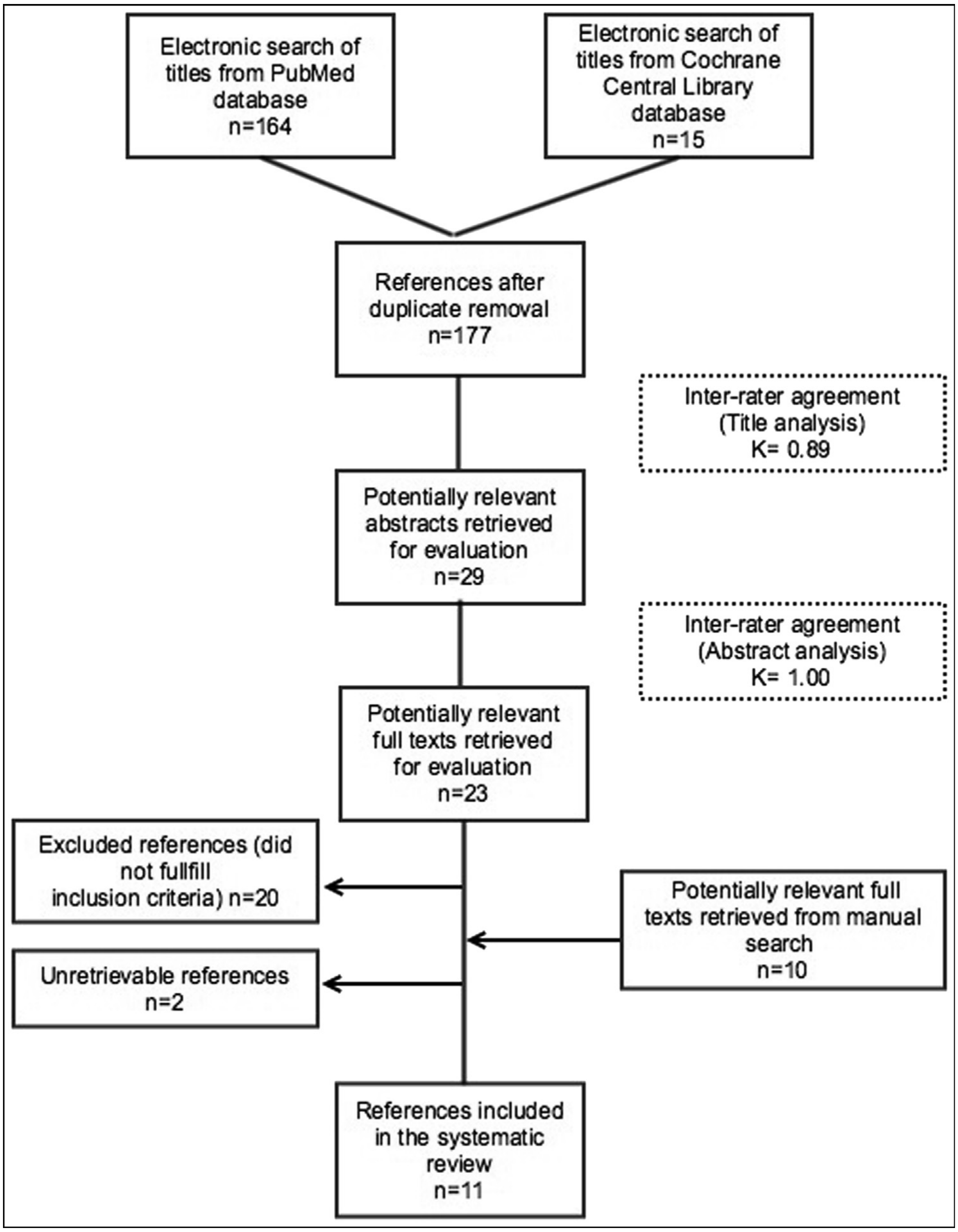

Fig 1. PRISMA flow diagram of the selection process.

Postoperatively, the final splint was left in place as a means of occlusal stabilization for 4 to 6 weeks in 2 studies.[11,23] Hernandez-Alfaro et al[10] restricted final splint fixation to maxillary segmental cases. Kim et al[14] maintained maxillomandibular fixation without a splint for 2 weeks, followed by active use of intermaxillary elastics.

In the surgery-first approach, fixed orthodontic appliances were typically placed 1 to 6 weeks preoperatively (Table II). One study group bonded a single bracket for surgical fixation,[12] and another bonded the arch directly to the teeth in some patients.[11]

Most articles reported the use of a manufactured passive wire.[11,14,21] The arch was installed 2 to 3 weeks preoperatively in 1 study[23] and at an average of 21 ± 4.5 days before surgery in another study.[21] Two study groups did not place an arch preoperatively.[14,20] Placement of a soft arch 1 day before surgery,[10] or between 1 and 3 days before surgery, was mentioned.[15] In 3 publications, details about orthodontic preparation were lacking.[13,16,22]

Only 3 articles provided information about postoperative orthodontic treatment.[10,14,15] According to the protocol followed by Hernandez-Alfaro et al,[10] orthodontic movements started 2 weeks after surgery, and archwire changes took place every 2 to 3 weeks. Kim et al[14] maintained maxillomandibular fixation plus active physiotherapy with Class II elastics until mouth opening reached 30 mm with confirmation of a stable occlusion using a surgical wafer, followed by postoperative orthodontic treatment. Liao et al[15] began postsurgical orthodontics immediately after surgery because the active archwire was left in place. For patients receiving segmental surgery, sectional archwires were replaced with continuous archwires at the first postsurgical orthodontic appointment or at the time of surgery. The authors specified that if there was a shift to a convenience bite, occlusal adjustment or light elastics were used to guide and stabilize the jaw position. Incomplete arch coordination was managed with light transpalatal elastics, an active palatal arch, or an active lingual arch. Once alignment, leveling, and coordination were achieved, a 0.016×0.022-in stainless steel wire was placed. Incomplete incisor decompensation was addressed with Class II elastics.

Three articles reported the use of miniscrews to facilitate postoperative orthodontic treatment.[10-12] Four to 8 miniscrews were placed, depending on whether the maxillary osteotomy was undertaken segmentally.[10]

The mean total duration of treatment after the surgery-first approach was 14.2 months (range, 10.2-19.4 months). Based on comparative studies in which surgery first was compared with the conventional approach, total treatment time was longer in the conventional group (mean, 20.16 months; range, 15.7-22.5 months).[12,21,23]

The reported advantages and disadvantages of the surgery-first approach are given in Table IV.

Four articles discussed the potential drawbacks of a surgery-first scheme.[10-12,23] The most commonly reported drawbacks and caveats included the following.

1. Premium on patient selection.[10,23] Since the baseline occlusion cannot guide treatment goals, clinical expertise,[10] accurate prediction of postoperative tooth movement, and precise assessment of the skeletal discrepancy[11,12] are mandatory.
2. The bending procedure for the passive surgical wire is time-consuming and complex.[11]
3. Bonding and removal of the surgical wire are troublesome, and there is a relatively high bonding failure rate before and during surgery.[11]
4. The extent of surgical movements may be greater because surgical correction needs to account for dental compensation.[11,23]
5. Impacted mandibular third molars could add difficulty to the surgical procedure.[11]
6. Postsurgical instability during bone healing may cause skeletal instability,[11,23] and its influence in relapse has not yet been fully investigated.[23]
7. Orthodontic appointments must be scheduled more often than for a conventional approach.[10]
8. Constant communication between the surgeon and the orthodontist is indispensable.[10]

Six articles discussed the potential advantages of a surgery-first scheme.[10-14,23] The most commonly reported benefits were the decrease in total treatment time, which may be potentiated by the regional acceleratory phenomenon,[14] and the early improvement of the facial profile.[10-15,23] Additional reported advantages included high levels of patient and orthodontist satisfaction,[10,11] which may translate into improved cooperation.[11] Furthermore, orthodontic decompensation is efficient and effective,[11,12,15] since a correct maxillomandibular relationship is established before orthodontic treatment starts.[13] Rapid recovery after surgery[12] and early correction of sleep-disordered breathing when this prompted the surgical decision were also mentioned as potential advantages.[10]

The stability of the surgery-first patients was reported in 5 publications,[12,14,15,22,23] with a maximum follow-up of 3 years (Table I).[12] In general, good stability in both the horizontal and vertical planes was found.[14,15] The highest relapse rate was found in relation to the position of the mandible.[15,22,23] Horizontally, Ko et al[22] reported a mean B-point relapse of 1.44 mm (12.46%) at the 1-year follow-up. When comparing surgery first with conventional treatment, Kim et al[23] found average amounts of anterior relapse of 1.6 mm in the conventional group and 2.4 mm in the surgery-first group, whereas Liao et al[15] reported mild horizontal relapse in both groups. In the vertical plane, mandibular stability was reported to be worse in the surgery-first group than in the conventional group.[12,15] Changes in the vertical dimension were the only statistically significant differences in 1 study.[12] Whereas vertical mandibular relapse occurred in a clockwise direction in 1 study,[23] counterclockwise rotation was reported in another.[14] A statistically significant association between the degree of relapse and the treatment approach was found in 1 study, with most changes occurring during the first 6 months postoperatively.[23] In particular, patients with a relapse rate above 3 mm comprised 39.1% of the surgery-first group vs only 15.8% of the conventional group. However, relapse below a threshold of 1.5 mm was more common in the conventional group than in the surgery-first group.

Table III. Newcastle-Ottawa quality assessment scale

Authors and year of publication	*Study type*	*Sample size and distribution*	*Newcastle-Ottawa scale outcome (range, 0-9)*
Baek et al,[11] 2010	Prospective, case series	11	NA
Wang et al,[20] 2010	Retrospective, case control	36 (18 CA, 18 SFA)	6
Liao et al,[15] 2010	Retrospective, case control	33 (13 CA, 20 SFA)	6
Ko et al,[21] 2011	Retrospective, case control	53 (35 CA, 19 SFA)	5
Liou et al,[16] 2011	Prospective, cohort	22	7
Ko et al,[22] 2013	Retrospective, cohort	45	7
Choi et al,[12] 2015	Prospective, case control	56 (24 CA, 32 SFA)	6
Hernández-Alfaro et al,[10] 2014	Prospective, case series	45	NA
Kim et al,[14] 2014	Retrospective, cohort	61 (38 CA, 23 SFA)	7
Park et al,[13] 2014	Retrospective, case control	60 (36 CA, 24 SFA)	4
Kim et al,[23] 2014	Retrospective, case series	37	NA

CA, Conventional approach; *SFA*, surgery first approach; *NA*, not applicable.

Table IV. Reported advantages and disadvantages of the surgery-first approach

Advantages	*Disadvantages*
1. Total treatment time is shorter.[7-12,20]	1. Patient selection is critical because the baseline occlusion cannot guide treatment goals.[7,20] Consequently, high clinical expertise,[7] accurate prediction of postoperative tooth movement, and precise assessment of skeletal discrepancy[8,9] are mandatory.
2. The facial profile is improved from the onset of treatment as a result of skeletal base correction.[7-12,20]	2. The bending procedure for a passive surgical wire is time-consuming and complex.[8]
3. Patient and orthodontist satisfaction rates are high.[7,8] High patient satisfaction is associated with improved cooperation during postoperative orthodontics.[6-8]	3. Bonding and removal of the surgical wire are troublesome; there is a relatively high bonding failure rate before and during surgery.[8]
4. Orthodontic decompensation is efficient and effective[8,9,12] in response to the establishment of a proper maxillomandibular relationship[10] and the regional acceleratory phenomenon.[11]	4. The extent of surgical movements is necessarily greater, because surgical correction needs to make up for dental compensation.[8,20]
5. Patient recovery takes place quickly.[9]	5. Impacted mandibular third molars could add difficulty to surgery.[8]
6. When sleep-disordered breathing is the main indication for treatment, early maxillomandibular advancement increases the dimensions of the upper airway immediately.[7]	6. Postsurgical instability during bone healing could cause skeletal instability,[8,20] and its influence in relapse has not yet been fully investigated.[20]
	7. Orthodontic appointments should be scheduled more often than in a conventional approach. This could be stressful for the orthodontist.[7]
	8. Constant communication between the surgeon and the orthodontist is indispensable.[7]

DISCUSSION

The surgery-first approach has gained popularity as a new treatment concept for the management of dentomaxillofacial deformity. This popularity and progressive acceptance is reflected in the increasing number of publications in both orthodontic and surgical fields (Figs 2 and 3; Table V). [F2-4/C] [F3-4/C] After the first clinical description,[7] most subsequent publications were case reports documenting the potential value of the approach. However, as with any immature technique, consensus regarding indications, technical protocol, and stability is still lacking. This systematic review, the first on this topic according to the PRISMA guidelines,[25] has exposed the lack of randomized studies concerning this approach. The heterogeneity and low evidence level of the retrieved publications, combined with the wide variety of outcome variables, precluded a meta-analysis.

The 11 articles included in this systematic analysis were chosen on the basis of strict selection criteria and represent only a small proportion of the available literature on surgery first (Table V). Several case reports and opinion articles, despite their exclusion from this systematic review, provided relevant preliminary results and technical guidelines that have informed subsequent

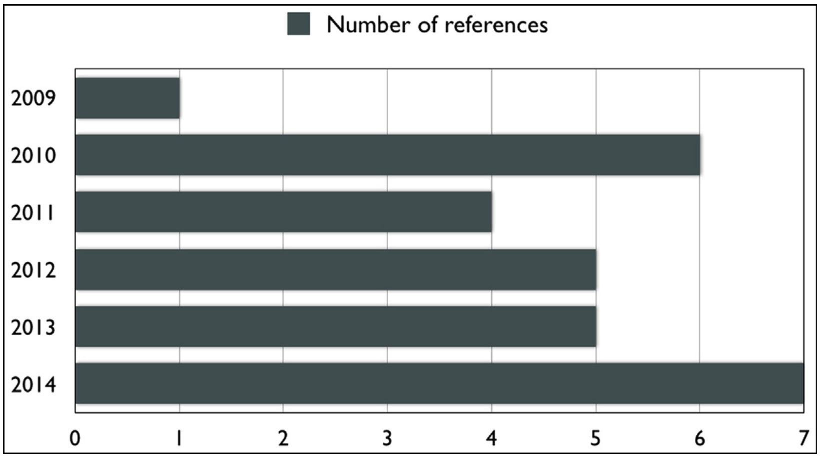

Fig 2. Chronologic distribution of all surgery-first publications in the literature.

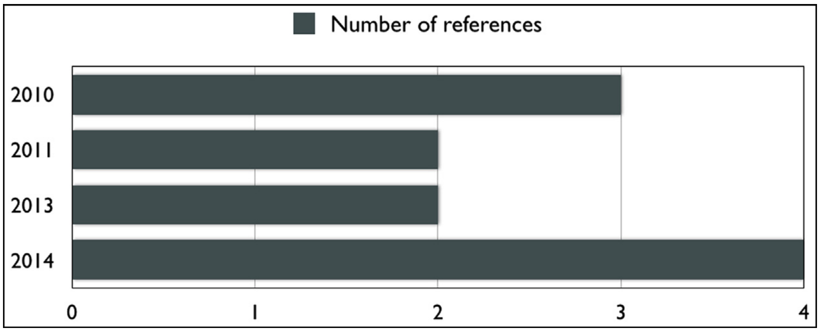

Fig 3. Chronologic distribution of the publications included in this systematic review.

studies. Examples are the first clinical reports of the application of a surgery-first sequence to monomaxillary[7,26,27,36] and bimaxillary[9,28] orthognathic surgery, the first compilation of orthodontic principles and guidelines for model surgery,[29] and an analysis of accelerated tooth movement in a rodent model.[35]

In spite of the heterogeneity of publications, a shorter treatment time seems to be a consistent finding in the surgery-first reports in general and in this systematic review in particular.[10-14,23] Overall, the mean treatment time was 14.2 months (range, 10.2-19.4 months) in the surgery-first groups. When surgery first was compared with the conventional approach, the total treatment time was substantially longer in the latter (mean, 20.16 months; range, 15.7-22.5 months).[12,15,21,23] In a surgery-first context, improved orthodontic efficiency has been related to transient demineralization of the operated bones because of the regional acceleratory phenomenon and to a more favorable soft tissue tone after skeletal correction.[9,15,27,37-40] This may lead to a synergistic effect between the orthodontic force and the newly established adaptive force from the lip and the tongue in the direction of tooth movement during postoperative orthodontics, decreasing the time to full compensation.[11,12,15] The temporary decrease in muscle activity, bite force, and occlusal pressure for a few weeks after surgery could be an additional facilitating factor.[36]

Outside this systematic review, orthodontic treatment for the conventional approach has been reported to last from 15 to 24 months preoperatively[41] and from 7 to 12 months postoperatively.[41] It has been suggested that the orthodontist is the key arbiter of this duration.[41] Of the 4 articles that provided data concerning the conventional approach in this systematic review,[12,15,21,23] only 2 specified the length of preoperative orthodontics.[21,23] They reported comparatively shorter total treatment times compared with other reports of conventional orthodontic treatment in the literature. In addition, the calculated time range was relatively narrow. Since orthodontic treatment is considered technically demanding in a surgery-first context and the orthodontists in these studies were also managing the surgery-first patients,

Table V. Scientific literature on surgery first

Authors	*Year*	*Origin*	*Study type*
Nagasaka et al[7]	2009	Japan	Case report
Baek et al[11]	2010	South Korea	Case series
Sugawara et al[26]	2010	Japan	Case report
Villegas et al[27]	2010	Colombia	Case report
Wang et al[20]	2010	Taiwan	Case control
Yu et al[28]	2010	Taiwan	Case report
Liao et al[15]	2010	Taiwan	Case control
Ko et al[21]	2011	Taiwan	Case control
Liou et al[16]	2011	Taiwan	Cohort
Liou et al[29]	2011	Taiwan	Expert opinion
Hernández-Alfaro et al[9]	2011	Spain	Case report
Oh et al[30]	2012	South Korea	Case report
Villegas et al[31]	2012	Colombia	Case report
Leelasinjaroen et al[32]	2012	Thailand	Literature review
Miguel et al[24]	2012	Brazil	Case report
Aymach et al[33]	2013	Japan	Case report
Choi et al[12]	2015	South Korea	Case control
Park et al[13]	2013	South Korea	Case report
Uribe et al[3]	2013	United States	Case report
Uribe et al[34]	2013	United States	Case report
Ko et al[22]	2013	Taiwan	Cohort
Hernández-Alfaro et al[10]	2014	Spain	Case series
Huang et al[1]	2014	Taiwan	Review
Kim et al[14]	2014	South Korea	Case series
Kim et al[23]	2014	South Korea	Cohort
Park et al[13]	2014	South Korea	Case control
Yuan et al[35]	2014	China	Experimental animal-based study
Raberin and Mauhourat[34]	2014	France	Expert opinion

a high level of expertise can be assumed.[10,29] This orthodontic proficiency may justify the improved time results for the conventionally treated patients.

Together with the decrease in total treatment time, early improvement of the facial profile was the most commonly reported advantage of a surgery-first approach.[10-15,23] The majority of identified studies came from Asia[1,7,11-16,20-23,26,28-30,32,33,35,36] and the United States[3,27,31,42] (Table V). Only 3 articles were European,[9,10,34] and 2 came from the same study group.[9,10] Two studies were from South America.[27,31] Early correction of facial deformity, irrespective of ethnicity, leads to an improvement in facial esthetics from the onset of treatment, and this may have a positive impact on quality of life[10-15,23] and satisfaction with treatment.[10]

Careful patient selection has been emphasized as a critical factor for clinical success.[9,10] According to the characteristics of the underlying malocclusion, patients were selected for a surgery-first scheme based on a skeletal malocclusion requiring combined orthodontic-surgical treatment.[10,12-14,16,20-23] In addition, at least 3 stable occlusal stops were required by 2 study groups.[12,23] For some study groups, the indication for a surgery-first vs conventional approach depended mainly on the managing surgeon-orthodontist team; no specific occlusal criteria were provided.[10,15,20,21]

Any occlusal condition with the potential to compromise the surgical procedure or the clinical outcome (severe dental crowding[12,13] needing extractions,[10] significant facial asymmetry[13] with 3-dimensional (3D) dental compensations[10] or chin deviation,[23] severe transverse discrepancy[23] requiring previous surgically assisted rapid palatal expansion,[10] arch discrepancy,[12] missing teeth,[13,23] and Class II Division 2 malocclusion with overbite[10]) was considered a contraindication for surgery first. In this context, the importance of elaborating an accurate visual treatment-objectives analysis representing the expected outcome was highlighted in 1 study.[13] Similarly, a history of facial trauma[21,23] or orthognathic surgery,[14] syndromic or cleft-related dentofacial deformity,[12,13,15,21,23] local infection,[23] acute periodontal problems,[10] temporomandibular joint disease,[10] and any other medical condition capable of impairing the healing potential were considered exclusion criteria as well.[14] This extensive list of exclusion criteria might diminish in the future as experience with the surgery-first scheme increases and current limitations become reasonably controlled.[10] In the absence of any complicating factors, Class III patients appear to be good candidates for surgery first. It has been stated that when these patients are treated with the conventional approach, routine preoperative dental alignment, arch coordination, and incisor decompensation tend to prolong treatment time with little or no significant benefit.[7,20] In addition, preoperative axial correction of the incisors exacerbates a compensated anterior crossbite, thereby accentuating the prognathic profile and intensifying the patient's perception of facial disharmony.[9,10,13,15] Conversely, if bone surgery is performed before orthodontics, total treatment time is reduced noticeably, and the esthetic concern is corrected from the beginning.[9,10,15,31]

The value of minimal orthodontic preparation (1-2 months) in some patients with severe occlusal prematurity (because of crowding and extruded teeth) or a severe discrepancy in the intercanine or intermolar width has been emphasized.[11] In an analysis of the different treatment modalities for orthognathic surgery depending on surgical timing, Hernández-Alfaro and Guijarro-Martínez[43] differentiated this treatment concept from surgery first and referred to it as "surgery early." For them, "surgery early" is indicated when the selection criteria for surgery first are not met completely because of severe crowding requiring extractions or complex 3D dental compensations caused by facial asymmetry, including dental midline deviations. In this context, partial orthodontic preparation is performed. Once severe crowding is managed with extractions and much of the necessary space closure has been achieved, or transverse compensations are resolved in the case of severe 3D compensations or dental midline deviations, surgery is performed.[43] Moreover, they described a "surgery-last" treatment modality comprising patients who had previous compensatory orthodontic treatment but are unsatisfied with the clinical outcomes and have eventually decided to have surgery. In these patients, a compensated, stable occlusion is present, so that no additional orthodontic preparation takes place before surgery. However, the fact that they have undergone orthodontics in the past differentiates them from the surgery-first group. In the surgery-first literature, 1 patient from a case series in 2011[9] and 1 clinical case presented in 2012[31] would currently correspond to this "surgery-last" concept.

A comprehensive surgical protocol including the diagnostic workup and treatment-planning scheme was proposed recently.[10] The authors reported the use of an augmented skull model, a virtual orthodontic setup, and the computer-aided design and computer-aided manufacturing fabrication of intraoperative splints. Although another study group[3,42] reported a similar methodology for virtual treatment planning, its publications did not fulfill the inclusion criteria of this systematic review. In both cases, the augmented skull model for precise representation of the bony and dental anatomies was obtained by .stl file fusion (cone-beam computed tomography scan plus optical intraoral scan).[3,10,31] The justification for the 3D virtual orthodontic setup was that the orthodontist could predict the final (at the end of orthodontic treatment) position and the axial inclination of each tooth accurately. This is considered a crucial step before the surgeon's skeletal-base correction simulation, since the patient's current occlusion cannot serve as a guide for skeletal repositioning.[10,12,23] The so-called 2.5 virtual model surgery represents an alternative virtual approach to treatment planning consisting in digitally fusing 2 x-ray films (frontal and lateral) and an optically scanned alginate model.[30] The specific time needed for these virtual workflows was not specified. On the other hand, nonvirtual treatment planning schemes for surgery first have also been proposed.[11,12,15,21,23] These include the fabrication of both the intermediate and final splints through modified model surgery based on a traditional orthodontic setup[11,12,15,23] or direct surgical planning according to the initial cephalometric analysis.[15,21]

Intraoperatively, the relevance of temporary anchorage devices (TADs)[7,10,26] and interdental corticotomies[10] has been emphasized. TADs are considered mandatory by several study groups because they permit a wider range of orthodontic vectors and avoid premature bracket loading with secondary undesirable dental extrusion.[10,26] The first clinical reports of surgery-first patients described the correction of skeletal Class III[7] and Class II[26] malocclusions with mandibular setback for Class II and mandibular advancement for Class III. Subsequently, final correction for Class I was achieved with skeletal anchorage techniques. The relevance of TADs is such that some study groups have considered orthodontic expertise in general and proficiency in TADs in particular as an inclusion criterion for selecting surgery-first patients.[10]

Postoperative stabilization of the occlusion with the final splint was performed in 4 studies.[10,11,14,23] A range of 2 to 6 weeks was reported.[14,23] One study group restricted final splint fixation to cases of maxillary segmentation with unstable postoperative occlusion.[10,29] It has been suggested that the period of postoperative occlusal stabilization should be minimized to take advantage of regional acceleratory phenomenon-facilitated orthodontic movement.[10,35]

Only Choi et al[12] analyzed stability beyond orthodontic debond. Consequently, only assumptions regarding short-term surgical stability are possible at this stage. In this context, surgery first was considered a stable and predictable treatment scheme.[14,15] The fact that the greatest vertical relapse rate was noted at the 6-month follow-up[14,15] could be due to occlusal instability during postsurgical bone healing,[23] when a transiently increased vertical dimension secondary to premature contacts is present.[14,23] Further research with longer follow-ups is required.

CONCLUSIONS

The surgery-first approach is a new treatment paradigm for the correction of dentomaxillofacial deformities. In certain patients with precise treatment planning, surgery first has been acknowledged to reduce total treatment time significantly and to achieve high levels of patient and orthodontist satisfaction. The results of this systematic review should be interpreted with caution because of the heterogeneity and low evidence levels of the retrieved articles, the wide variety of outcome variables, the substantial reporting biases, and the lack of prospective long-term follow-ups.

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