

## Systematic Review Orthognathic Surgery

# Bone grafting in orthognathic surgery: a systematic review

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**Abstract.** Bone grafting has been used in orthognathic surgery to fill the gaps created by jaw repositioning, with the intention of improving healing and stability. Since the majority of orthognathic cases have a satisfactory result, the decision to graft or not is a clinical dilemma. A systematic review of the literature was performed on the use of bone grafts in orthognathic surgery. A search of PubMed, MEDLINE, Embase, and the Cochrane Central Register of Controlled Trials yielded 1927 articles published up until 2018. An additional 10 articles were retrieved through manual searching of the reference lists and citations. After title and abstract screening, 58 articles were potentially eligible; full-text screening excluded 10 of these. Thus 48 articles were included in this review. The present literature highlights the benefits of grafting bony gaps during orthognathic surgery in terms of healing, stability, and aesthetic outcomes. Generally, there was no difference between the various types of bone graft, although calcium phosphate cement and hydroxyapatite were found to increase the rate of infection. The conclusion of this review is that there remains a lack of evidence in the literature regarding the grafting of osteotomy sites in orthognathic surgery. Guidelines are proposed based on the present evidence; however, future research is needed to validate these.

Key words: orthognathic surgery; bone grafting; systematic review.

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Orthognathic surgery has become routine clinical practice worldwide for the treatment of dentomaxillofacial deformities by oral and maxillofacial surgeons. The most common surgical orthognathic procedures are the Le Fort I osteotomy, bilateral sagittal split osteotomy (BSSO), and genioplasty. Since the introduction of these procedures, extensive research has been done towards improving the surgical results. Despite the good and predictable outcomes of orthognathic surgery, ob-

served adverse effects of jaw repositioning are unfortunately not uncommon. Inadequate bone contact after large mandibular movements and inferior repositioning of the maxilla or the chin may result in compromised bony union with potential subsequent skeletal relapse<sup>1</sup>. In addition, a resultant bony defect after sagittal split and chin osteotomies may be clinically noticeable to the patient, with aesthetic implications in the region of the buccal sagittal corticotomy or paramedian chin,

respectively<sup>2</sup>. Hence, bone grafting at the osteotomy site in orthognathic surgery has been performed to overcome these adverse effects.

The purpose of this systematic review was to evaluate current evidence on the grafting of bony osteotomy sites in orthognathic surgery, especially with regard to improvement of the surgical outcomes in terms of bony healing, stability, complications, and the prevention of aesthetic defects.

Table 1. Search terms.

Primary key words	Secondary key words
Orthognathic	Grafting, Bone
Orthognathic surgery	Bone Grafting
Corrective jaw surgery	Bone Graft*
Jaw surgery	Transplantation, Bone
Maxillary osteotomy	Replacement Material, Bone
Lefort/Le Fort	Replacement Materials, Bone
Le Fort osteotomy	Bone Substitute
LeFort osteotomy	Substitute, Bone
Le Fort I osteotomy	Substitutes, Bone
Mandibular osteotomy	
Bilateral sagittal split osteotomy	
Sagittal split osteotomy	
Sagittal split ramus osteotomy	
Sagittal split ramal osteotomy	
Vertical subisigmoid osteotomy	
Ramus osteotomy	
BSSO	
SSO	
SSRO	
BSSRO	
IVRO	
EVRO	
Genioplasty	
Chin osteotomy	
Chin repositioning	
Zygoma osteotomy	
Malar bone osteotomy	
Cheek bone osteotomy	

Table 2. Inclusion and exclusion criteria.

Inclusion	Exclusion
<ul style="list-style-type: none"> <li>• All original reports regarding bone grafting in orthognathic surgery</li> <li>• Published in the English language literature</li> <li>• Published up until January 2018</li> <li>• Follow-up of more than 6 months</li> <li>• Human studies</li> <li>• Non-syndromic subjects</li> </ul>	<ul style="list-style-type: none"> <li>• Letters and review articles</li> <li>• Reports in languages other than English</li> <li>• Follow-up of less than 6 months</li> <li>• Animal or laboratory studies</li> <li>• Cleft or syndromic cases</li> <li>• Pre-prosthetic osteotomies</li> <li>• Augmentation bone grafts</li> <li>• Poorly reported studies where data extraction is not possible</li> </ul>

## Materials and methods

A systematic review of the literature on bone grafting in orthognathic surgery was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) criteria. A pilot search with initial key words related to bone grafting in orthognathic surgery was first done in PubMed (National Library of Medicine, NCBI), and related articles were checked for relevant key words. All terms were analyzed with medical subject headings (MeSH) and the final list was revised to fit the inclusion and exclusion criteria (Table 1). The search strategy was reviewed by a health information specialist and was limited to the English language literature. The inclusion criteria encompassed original human studies on grafting of non-

syndromic, non-cleft orthognathic osteotomy sites, with a follow-up period of more than 6 months, published up until January 2018. All studies on osteotomies for pre-prosthetic reconstruction or bone augmentation were excluded (Table 2).

The primary search was done in the PubMed, MEDLINE, and Embase databases and the Cochrane Central Register of Controlled Trials. A secondary search was done of the grey literature (<http://www.opengrey.eu/>) and clinical trials registry (<https://clinicaltrials.gov/>). All articles were screened by title and abstract and all irrelevant reports were excluded. The reference lists of remaining articles were screened for similar studies. Google Scholar was then used to search for citations for each article (snowballing). The full text of all eligible articles was read and a final decision was made. Two inde-

pendent reviewers were involved in the search and screening process, and all studies were included or excluded by consensus.

A modified Cochrane data collection form with items related to the topic of this systematic review was used by the reviewers to extract the relevant data<sup>3</sup>. Included articles were categorized based on the measured outcome (healing, stability, aesthetic defect, and complications), osteotomy site (Le Fort I, BSSO, genioplasty, and zygoma), and type of publication (case series, cohort study, and clinical trial) (Table 3). A flowchart of the search strategy and selection process according to the PRISMA criteria is provided in Fig. 1.

## Results

The primary search identified 1927 papers. Title and abstract screening excluded 1825 records, and the citations and reference lists of the remaining 102 papers led to the addition of 10 new papers. The secondary search failed to identify any relevant additional papers. Abstract screening excluded 54 papers and another 10 papers were excluded after full-text reading. Finally, a total of 48 papers were included in this systematic review (Fig. 1). The 10 excluded articles were found to be poorly reported case reports ( $n = 6$ ), review articles ( $n = 2$ ), and studies with follow-up of less than 6 months ( $n = 2$ ).

Most of the included articles were observational studies. Eleven cohort studies, 30 case series, three case reports, and only four clinical trials were identified. The primary measured outcome was healing or union of the osteotomy site ( $n = 35$  studies), followed by stability ( $n = 22$  studies). Two studies evaluated the effect of the grafting material on nerve healing<sup>4,5</sup>. Another article assessed the effect of bone grafting on condylar position<sup>6</sup>, while the risk of developing an inferior mandibular border defect after BSSO with or without bone grafting was investigated in one study<sup>7</sup>. The maxilla at the Le Fort I level was the most grafted osteotomy site, while chin extrusion with an interpositional graft and ramus osteotomy came next, followed by a few reported cases of zygomatic osteotomy sites. Porous hydroxyapatite (HA) was the most commonly used grafting material, followed by autogenous and allogeneic bone. Only a few reports used bovine bone, calcium phosphate cement, and bioactive glass. The reported complications regarding bone grafting osteotomy sites were infection, exposure or rejection, sinusitis, and chronic inflammation. Porous HA was the

Table 3. Characteristics and main outcomes of the included studies regarding healing, stability and complications.

First author, year	Study design	Type of bone used	Surgical site	Sample (n)	Outcome measured	Follow-up	Complications
<b>Healing</b>							
Allard 1987 <sup>18</sup>	Cohort study	Autogenous (iliac) vs. allograft	Maxilla, mandible, and chin	19	Healing	1–6 years	1 infection in the autogenous group
Epker 1976 <sup>33</sup>	Case series	Freeze-dried allograft	Maxilla	18	Healing	18 months	9 infections (50%)
Hiatt 1987 <sup>36</sup>	Case series	HA	Midpalatal maxilla	19	Healing	NR <sup>a</sup>	1 exposure of the graft treated conservatively
Holmes 1988 <sup>38</sup>	Case series	HA	Maxilla, mandible, and chin	18	Healing	Average of 9.3 months	8 local infections with exposures
Honda 2005 <sup>22</sup>	Case series	Autogenous (medial mandibular angle)	Maxilla paranasal and orbital rim	20	Healing	Average of 6.4 months	None
Haas Junior 2016 <sup>32</sup>	Case report	Bio-Oss (bovine bone)	Maxilla	1	Healing	6 months	NR
Kim 2014 <sup>29</sup>	Case series	Demineralized bone matrix and fibrin glue	Chin	32	Healing	6 months	None
Lee 2013 <sup>28</sup>	Case series	Autogenous (mandibular angle)	Chin	32	Healing	3–12 months	None
Lee 2014 <sup>15</sup>	Cohort study	Demineralized freeze-dried bone allograft	BSSO	48	Healing	T2: 2 months; T3: 6 months	None
Lye 2008 <sup>16</sup>	Cohort study	Demineralized bone matrix with variable others	Maxilla and chin	113	Healing	6 months	4 sinusitis, 2 local infections, and 2 malocclusions
Matsushita 2010 <sup>25</sup>	Case report	Autogenous (same chin site)	Chin	2	Healing	9 months	None
Moening 1989 <sup>39</sup>	Case series	HA (porous block)	Maxilla, mandible, and chin	49	Healing	27 months	9 local infections with rejection
Mommaerts 1995 <sup>10</sup>	Case series	HA and fibrin glue	Zygoma	20	Healing	At least 1 year	1 sinusitis
Mommaerts 1999 <sup>11</sup>	Case series	HA and fibrin glue	Zygoma	37	Healing	6 years	3 sinusitis
Posnick 2015 <sup>30</sup>	Case series	Allograft	Chin	19	Healing	1 year	1 sinusitis
Ragaey 2017 <sup>17</sup>	Cohort study	β-TCP	Maxilla (incl. segmental)	Study sample 141 Control group 297	Healing	More than 6 months	1 non-union in control group
Rohner 2013 <sup>14</sup>	Clinical trial	Bio-Oss (bovine bone)	Maxilla	9	Healing	6 months for the biopsy and 1 year CBCT	None
Stoor 2017 <sup>41</sup>	Case series	Bioactive glass S53P4	BSSO	25	Healing	33 months	3 wound dehiscence, 2 severe pain, 1 hardware failure, 2 notching of inferior border, 3 occlusal relapse, 1 allodynia requiring continuous meds
Trevisiol 2012 <sup>26</sup>	Case series	Bio-Oss (bovine bone)	BSSO	20	Healing	>1 year	None
Wessberg 1980 <sup>19</sup>	Case report	Autogenous (NR)	Chin	1	Healing	6 months	None
Zeller 1986 <sup>63</sup>	Case series	HA (porous block)	Chin	7	Healing	12 months	None
Ueki 2012 <sup>4</sup>	Clinical trial	α-TCP cement	BSSO	40	Healing + nerve effect	1 year	None
Ueki 2013 <sup>5</sup>	Clinical trial	α-TCP cement	Maxilla	47	Healing + nerve effect	1 year	None
<b>Healing and stability</b>							
Bertossi 2013 <sup>27</sup>	Case series	Fresh frozen allograft	Chin	10	Healing + stability	14 months	None
Braun 1984 <sup>21</sup>	Case series	Autogenous (from same site)	Maxilla, mandible, and chin	3	Healing + stability	2 years	None
Cottrell 1998 <sup>40</sup>	Case series	HA	Maxilla (398), BSSO (18), chin (20), and zygoma (9)	111	Healing + stability	5 years	5% (n = 23) local infection with rejection

Eser 2015 <sup>55</sup>	Cohort study	Xenogeneic spongiotic bone material (Osteoplast-Flex)	Maxilla	80	Healing + stability	1 year	None
Posnick 2015 <sup>31</sup>	Case series	Allograft	Maxilla	50	Healing + stability	1 year	None
Rosen 1989 <sup>8</sup>	Case series	HA (porous block)	Maxilla and chin	46	Healing + stability	6–20 months	2 rejection
Rosen 1991 <sup>9</sup>	Case series	HA (porous block)	Maxilla	76	Healing + stability	16.3 (6–46) months	3 rejection
Christian 1982 <sup>20</sup>	Case series	Frozen heads of femur	Mandibular ramus (2), segmented maxilla (3), and maxilla (7)	12	Healing + stability	12–36 months	1 local infection
Kent 1986 <sup>35</sup>	Case series	HA	Maxilla, mandible, and chin	55	Healing + stability	variable 4–40 months	1 infection and 4 rejection
Kuvat 2009 <sup>24</sup>	Case series	Human demineralized bone matrix (1 ml) and 20 mg bovine bone collagen–protein extracts	Maxilla	10	Healing + stability	14.5 months	None
Layoun 2003 <sup>56</sup>	Case series	6 HA and 12 autogenous	Zygoma	18	Healing + stability	1 year	2 infection and 1 rejection
Wolford 1987 <sup>37</sup>	Case series	HA (porous block)	Maxilla and mandible	92	Healing + stability	12 months	10 rejections + 4 chronic infection
<b>Stability</b>							
Araujo 1978 <sup>52</sup>	Cohort study	NR	Maxilla	21 (8 cleft)	Stability	6 months–4 years	3 infection
Kerawala 2001 <sup>46</sup>	Case series	Autogenous (anterior iliac)	Maxilla	112	Stability	12 months	Donor morbidity (>scarring)
Kim 2005 <sup>23</sup>	Case series	Autogenous (anterior iliac)	Chin	23	Stability	1 year	None
Mayrink 2014 <sup>58</sup>	Case series	Calcium phosphate cement	Maxilla	8	Stability	6 months	None
Mehra 2001 <sup>12</sup>	Cohort study	HA (porous block)	Maxilla	74	Stability	>1 year (12–136 months)	None
Mehra 2002 <sup>13</sup>	Case series	HA (porous block)	Maxilla	78	Stability	15 months	NR
Ueki 2013 <sup>34</sup>	Cohort study	α-TCP cement	Maxilla	45	Stability	12 months	None
Waite 1996 <sup>53</sup>	Cohort study	Autogenous (chin)	Maxilla	22	Stability	6 months	NR
Wardrop 1989 <sup>64</sup>	Case series	HA (porous block)	Maxilla	24	Stability	16 months	3 rejection
Lee 2015 <sup>59</sup>	Case series	Autogenous (maxilla propeller graft)	Maxilla	15	Stability	6 months	None
<b>Others</b>							
Coppey 2017 <sup>34</sup>	Cohort study	Calcium phosphate cement	BSSO	196	Infection rate	8 months	18.6% infections in study group; 5.3% infections in control group
Cifuentes 2018 <sup>7</sup>	Cohort study	Allograft + PRP + collagen membrane	BSSO	501	Inferior mandibular border defect	>1 years	Infection around 5% in all groups
Kang 2010 <sup>6</sup>	Clinical trial	Autogenous (proximal segment of mandible)	BSSO	Study sample 30 Control group 30	Condylar position	1–2 months	None

α-TCP, alpha-tricalcium phosphate; β-TCP, beta-tricalcium phosphate; BSSO, bilateral sagittal split osteotomy; CBCT, cone beam computed tomography; HA, hydroxyapatite; NR, not reported; PRP, platelet-rich plasma.

<sup>a</sup>Not reported, but cases were treated up until 1986 and publication was 1987.

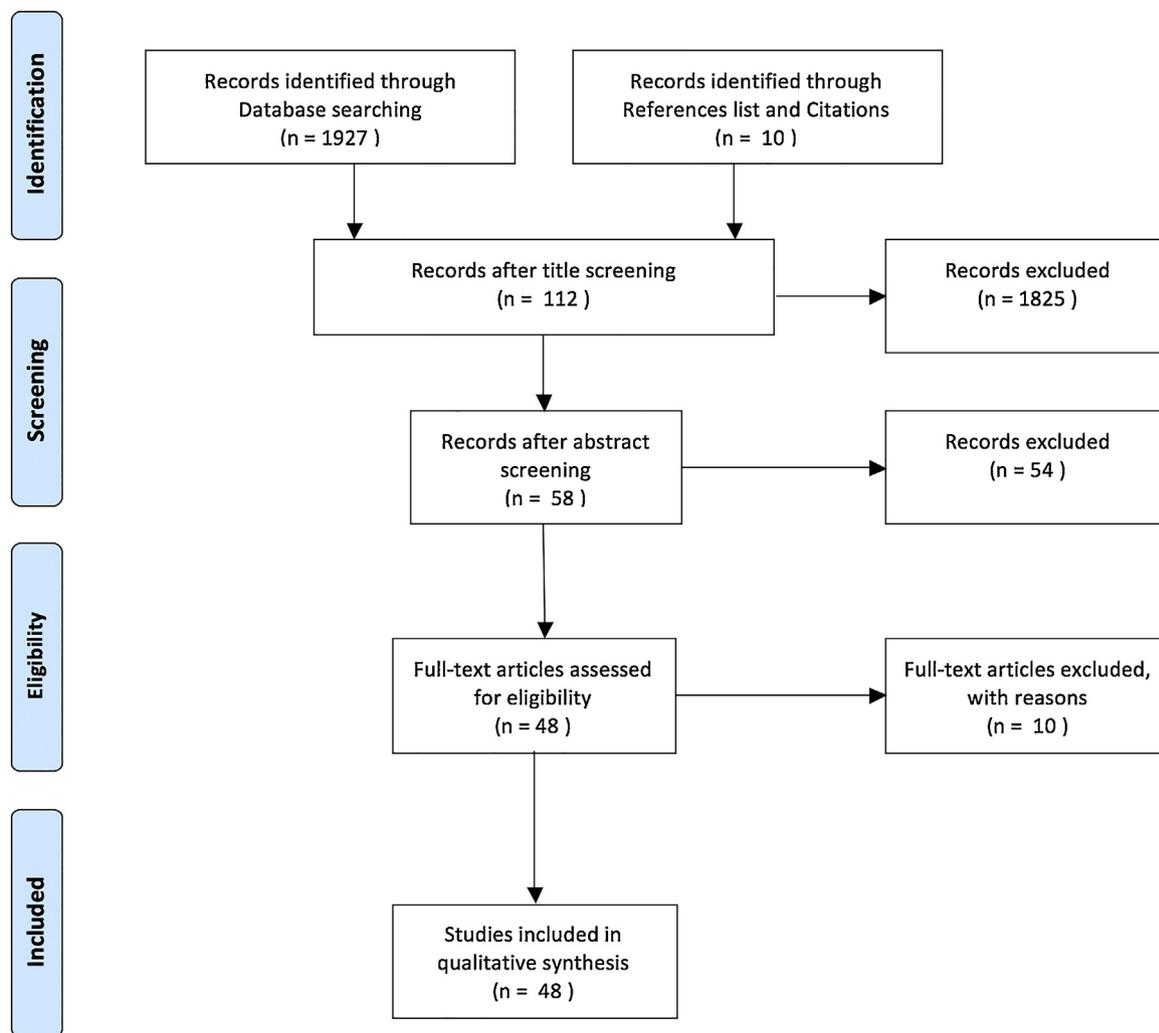


Fig. 1. Flowchart of the methodology of the search and selection process using PubMed, Embase, and the Cochrane Library.

most common graft material related to these complications.

## Discussion

This systematic review shows that the present literature on bone grafting in orthognathic surgery mostly consists of case series and cohort studies, with only a few clinical trials. The level of evidence regarding important clinically relevant questions is listed in Table 4. Overall, the studies showed that the use of bone grafts in orthognathic surgery was advantageous, but more clinical trials are needed to provide solid evidence. The studies included varied in purpose, site, and material used. Moreover, similar studies were reported by similar groups of authors, leading to the risk of overlapping or repeated data<sup>8-13</sup>. Unfortunately, two important clinical variables, 'operating time' and 'costs', which were included

on the data extraction form, were not reported in any of the articles included.

## Healing

In orthognathic surgery, healing of the osteotomy has the same biological basis as fracture healing. The osteotomy can be considered as a controlled displaced fracture. This displacement creates less bone contact, which may compromise the union at the osteotomy site. In the case of inferior repositioning of the maxilla or chin, there may even be a state of gap healing.

Rohner et al.<sup>14</sup> conducted a split-mouth trial on nine patients who had a Le Fort I osteotomy with advancements of 5 mm or less. One side was grafted with Bio-Oss Collagen and the other side was left without a graft and served as a control. After 6 months, all of the grafted sites had healed without a defect, whereas three of the control sites had fibrous gap healing.

Two clinical trials were conducted by Ueki et al. comparing the healing of Le Fort I osteotomy and BSSO in patients who received alpha-tricalcium phosphate ( $\alpha$ -TCP) versus a control group<sup>4,5</sup>. After 1 year of follow-up, multi-slice computed tomography (MSCT) examination showed that most of the control sites (18/23) had bony defects at the level of maxillary osteotomy, while all study sides had complete bony continuity.

In a cohort study done by Lee et al.<sup>15</sup>, healing of the BSSO gap grafted with demineralized bone matrix (DBM) was compared with no grafting in 48 patients. In serial postoperative cone beam computed tomography examinations at 1 week, 3 months, and 6 months, the study group showed a continuous increased bone volume in comparison to the control group. In 2008, Lye et al.<sup>16</sup> examined different types of bone graft with or without DBM at Le Fort I and chin osteotomy sites in a very

Table 4. Level of evidence.

Question	Answer	Level of evidence	Reference
Does bone grafting promote osteotomy healing?			
Le Fort I osteotomy	Yes	I	Rohner 2013 <sup>14</sup>
BSSO	Yes	I	Ueki 2012
Chin osteotomy	Yes	IV	Kim 2014 <sup>29</sup> , Lee 2013 <sup>28</sup> , Posnick 2015 <sup>30</sup>
Zygoma osteotomy	Yes	IV	Mommaerts 1999 <sup>11</sup> , Layoun 2003 <sup>56</sup>
Does bone grafting affect condylar position?	No	I	Kang 2010 <sup>6</sup>
Does bone grafting decrease skeletal relapse?			
Le Fort I osteotomy	Yes	III	Waite 1996 <sup>53</sup> , Araujo 1978 <sup>52</sup>
BSSO	–	–	No reports
Chin osteotomy	Yes	IV	Kim 2005 <sup>23</sup> , Bertossi 2013 <sup>27</sup>
Zygoma osteotomy	Yes	IV	Layoun 2003 <sup>56</sup>
Does bone grafting decrease the risk of an inferior border defect in BSSO?	Yes	III	Cifuentes 2018 <sup>7</sup>
Does bone grafting increase the infection rate?			
Autogenous, allogeneic, xenogeneic	No	III	Waite 1996 <sup>53</sup> , Lee 2014 <sup>15</sup> , Eser 2015 <sup>55</sup>
Calcium phosphate paste	Yes	III	Coppey 2017 <sup>34</sup>
Porous HA	Yes	IV	Wolford 1987 <sup>37</sup> , Moenning 1989 <sup>39</sup>
$\alpha$ -Tricalcium phosphate	No	I	Ueki 2012, Ueki 2013
$\beta$ -Tricalcium phosphate	No	III	Ragaey 2017 <sup>17</sup>
Does bone grafting increase costs and time?	–	–	No reports

heterogeneous sample. In Le Fort I patients, the DBM group had slightly increased complications, such as sinusitis and infection. Another cohort study evaluated the use of beta-tricalcium phosphate ( $\beta$ -TCP) at Le Fort I osteotomy sites in 141 patients and compared these patients to 297 controls<sup>17</sup>. After 6 months, all study group osteotomy sites had healed very well, while one case of non-union was seen in the control group. The latter case was a large advancement (8 mm) in a smoker patient.

Allard et al.<sup>18</sup> compared the healing of maxillary and mandibular osteotomies using autogenous bone graft versus frozen femoral allogeneic bone in a small sample ( $n = 19$ ) of patients. In general, there was no difference in healing between the two groups.

Thus most of the reports appeared to show improved signs of bony healing when an osteotomy site was grafted compared to no grafting. Furthermore, different types of bone graft were used with comparable results.

### Complications

Concern for possible complications may limit the use of bone grafts in routine orthognathic surgery. In this systematic review, the reported complications were evaluated based on the type of bone and a comparison was made with the reported rate of complications in general during orthognathic procedures. Although the reports were very limited, autogenous, allogeneic, and xenogeneic grafts were not found to increase the rate of infection in orthognathic surgery<sup>14,15,18–32</sup>.

One case series reported a high incidence of infection (50%) with allogeneic grafts in patients where wire fixation was used at the maxillary osteotomy sites<sup>33</sup>. In a retrospective study, Coppey et al.<sup>34</sup> compared two groups of 196 patients who underwent BSSO with or without calcium phosphate paste. They observed an increased rate of infection in the calcium phosphate paste group of more than three times the rate in the control group. On the other hand, the two clinical trials conducted by Ueki et al.<sup>4,5</sup> mentioned above, evaluated the use of self-setting  $\alpha$ -TCP in Le Fort I and BSSO defects and did not report any case of infection in either group.

In several case series, porous HA showed an increased rate of infection, exposure, sinusitis, and chronic inflammation<sup>8,9,35–40</sup>. Most of the case series of HA were reported by similar research groups of surgeons. Bioactive glass was used in one case series to graft the BSSO defects<sup>41</sup>. The results were not encouraging as dehiscence and unexplained severe pain were observed in a few cases.

In general, no grafting material showed an increased rate of complications except calcium phosphate cement and HA, which increased the rate of infection. Despite the small sample ( $n = 25$ ), bioactive glass showed different unexplained complications.

### Stability

The stability of orthognathic surgery depends on many factors. Despite the use of rigid fixation, a variable amount

of relapse is observed, especially with inferior repositioning of the maxilla<sup>1,42–45</sup>. Improving the quality of bone union by filling the osteotomy gaps with bone graft probably provides better long-term stability<sup>46</sup>. Many studies comparing the stability of maxillary osteotomies with or without bone grafts have been conducted in cleft patients<sup>47–51</sup>. In this systematic review, in which cleft patients were not included, several cohort studies evaluated different types of bone regarding stability. In a cohort study, Araujo et al.<sup>52</sup> compared the rate of relapse between 10 patients who had the maxillary osteotomy plus bone graft and 11 controls. The vertical and horizontal relapse in the grafted group was significantly less than that in the control group. In another cohort study, Waite et al.<sup>53</sup> compared two groups of patients with obstructive sleep apnoea who underwent maxillomandibular advancement of around 10 mm with or without chin bone grafts. Using conventional lateral cephalometric analysis, the average relapse was 0.7 mm in the grafted patients and 1.8 mm in the control group.

Ueki et al.<sup>54</sup> evaluated both horizontal and vertical maxillary repositioning with or without a self-setting  $\alpha$ -TCP graft using resorbable plates and found no significant difference in relapse after 1 year. The effect of xenogeneic grafts on maxillary stability was compared with autogenous grafts by Eser et al.<sup>55</sup> in a group of 80 patients. Both types of graft improved stability of the maxilla, with no significant difference between them. Mehra et al.<sup>12</sup> compared two groups of cleft and non-cleft patients who had maxillary osteotomies with HA bone grafts. The relapse

in cleft patients was higher than in non-cleft patients in both the vertical and horizontal planes. Other case series reported the use of different types of bone graft with acceptable stability, except in some HA cases<sup>35,56</sup>.

It seems that the skeletal stability of the osteotomy is dependent on the quality of bone union. Increased bony gaps or compromised healing as a result of infection contributed to the rate of relapse. In HA cases, the rate of relapse was proportional to the rate of complications.

### Aesthetics

The soft tissue response after orthognathic surgery depends mainly on the underlying skeletal support. The presence of a bony defect at the site of a sagittal split or chin osteotomy may create aesthetically displeasing antegonial notching, lower border irregularities, or accentuated jowls. These defects become worse if they are asymmetrical and may require corrective surgery.

Lindquist and Obeid<sup>2</sup> observed inferior border notching and irregularities in conventional radiographs in more than 70% of patients who underwent genioplasty with or without BSSO. Agbaje et al.<sup>57</sup> discussed the risk factors of developing a noticeable notch after BSSO. Age, the amount of advancement, and the osteotomy design were the significant factors in that study. In a retrospective cohort study, Cifuentes et al.<sup>7</sup> compared the incidence of inferior border defects in patients who underwent a BSSO or a modified BSSO with or without bone grafts and found that these occurred significantly less in the grafted group. Trevisiol et al.<sup>26</sup> showed very good bony healing and normal contouring of the inferior mandibular border in 20 BSSO cases with large advancements (>8 mm) grafted with Bio-Oss Collagen.

The inferior border of the mandible ('the jaw line') is considered an important aesthetic component of the face. It can therefore be very unpleasant for patients who undergo orthognathic surgery aimed at improving their function and aesthetics to end up with an aesthetic defect. On the one hand, one could assume that an osteotomy gap will act like a dead space where soft tissue granulation will be faster than osteoid deposition. On the other hand, additional bone resorption can be expected at the level of the osteotomy bony edges and in the area where the periosteum was reflected. Hence, it is unlikely that any intraoperative palpable or noticeable osteotomy gaps will undergo better bony

regeneration and remodelling if left without bone grafting material. Biological factors such as a young active or intact periosteum may succeed in filling the osteotomy gap, and morphological factors such as thick overlying soft tissues may mask inferior border irregularities. This could explain why this aesthetically displeasing complication is relatively under-reported.

From the studies included in this systematic review, it can be clearly seen that grafting the osteotomy bony gap decreases the incidence of this unfavourable outcome.

### Maxilla

Most of the included studies evaluated the bony healing of Le Fort I osteotomy. The anatomy of an osteotomized maxilla with a thin bone interface exposed to open maxillary sinuses may raise the concern of inadequate bony union. It was observed by Rohner et al.<sup>14</sup> that bone union was good along the osteosynthesis plates at the medial piriform and lateral zygomaticomaxillary buttresses. The bony gaps appeared at the anterior thin wall of the maxillary sinus. This could be explained by the fact that this thin bone was resorbed faster than the thick bone at the buttresses and failed to regenerate due to fibrous tissue healing. In addition, it was supposed that the osteosynthesis plates acted as a guided bone regeneration membrane and prevented fibrous formation beneath it. This would explain the good bony union that was found with different types of bone graft, as most of these acted as osteoconductive scaffolds<sup>5,16,58,59</sup>.

In some of the case series, graft exposure was more common in the mid-palate area with thin mucosal coverage and in the pterygomaxillary area where no fixation of the grafts was done<sup>38,39</sup>. Sinusitis and other infections were related to mobility or displacement of the graft material into the sinus<sup>37</sup>. Relapse of inferior repositioning of the maxilla of up to 100% has been reported in the literature<sup>60</sup>. Rigid fixation may provide good initial stability, but in the absence of adequate bony union, long-term stability is questionable. A bony gap of more than 1 mm may fail to heal despite rigid fixation<sup>61</sup>. In the study by Rohner et al.<sup>14</sup> mentioned above, even a maxillary advancement of less than 5 mm could fail to form bone at the level of the anterior wall of the maxillary sinus, although this is not relevant for stability.

### Mandible

Few articles on the grafting of BSSO gaps could be included in this systematic review. The BSSO osteotomy design and anatomy provide a greater bony surface interface and better bony union compared to Le Fort I. Relapse in BSSO is more related to muscle action and dynamic remodelling of the condyles<sup>62</sup>. However, the resultant bony union may affect the shape of the mandible and cause inferior border notching<sup>2</sup>. To a certain degree, this notch will not be visible except on radiographs or by digital palpation.

As mentioned above, the risk factors of developing a noticeable antegonial notch after BSSO were evaluated by Agbaje et al.<sup>57</sup>. Patient age >30 years, large mandibular advancements, and osteotomy designs including a discontinuity of the inferior border of the mandible were found to increase the incidence of these defects. Therefore, they recommended a modified sagittal split osteotomy where the lingual part of the inferior border remains with the distal segment. In the experience of the senior author (G.S.), modifying the buccal corticotomy by placing the inferior border cut hidden under the masseter muscle will reduce the incidence of a noticeable notch. Cifuentes et al.<sup>7</sup> observed that by grafting the osteotomy gap, the incidence of mandibular border notching reduced from 54.5% to 1.3%.

The potential influence of bone grafting of the BSSO gaps on condylar position was assessed by Kang et al.<sup>6</sup> in a randomized clinical trial. Using three-dimensional MSCT analysis, the bone graft group was found not to have improved condyle position compared to the control group.

Hence, although bony healing and skeletal stability of BSSO is less of an issue compared to the maxilla, its reflection on the bony shape of the mandibular border is of paramount importance for facial symmetry and aesthetics.

### Chin

A chin osteotomy carries the same risk of developing an inferior border defect as BSSO, and in the case of inferior repositioning, it carries the same risk of skeletal relapse as in Le Fort I. Most of the reported cases of graft use in the chin were either to grafting of the osteotomy site or augmentation grafts. Only grafting of the osteotomy sites was considered in this systematic review. The fact that there are no masticatory forces on the chin explains the overall good bony healing. In the included studies, interpositional

grafting to increase the vertical height was the most common indication for grafting of chin osteotomies. Almost all cases reported excellent healing and stability, regardless of the type of bone used<sup>19,23,25,27–30,63</sup>.

### Zygoma

Zygomatic osteotomy is considered an additional procedure that can be added to the orthognathic armamentarium to improve the aesthetic outcome. The zygomatic ‘sandwich’ osteotomy proposed by Mommaerts et al.<sup>10</sup> makes it possible to combine this osteotomy with the Le Fort I osteotomy at the same stage. In their two consecutive studies<sup>10,11</sup>, zygomatic osteotomies with interpositional porous HA blocks were used to increase the lateral prominence of the malar area. Only a few cases of postoperative sinusitis were observed, which is the same complication related to HA as reported in other studies<sup>37,64</sup>. Layoun et al.<sup>56</sup> reported 18 cases of zygomatic osteotomies with autogenous and porous HA grafts. Three of the HA cases had infections.

### Conclusions

In summary, the results of this systematic review show that there is strong evidence that bone grafting promotes healing of Le Fort I osteotomy and BSSO and that there is acceptable evidence for chin and zygomatic osteotomies (Table 4). Moreover, there is good evidence that bone grafting increases the stability of Le Fort I, acceptable evidence for chin and zygoma, and no evidence for BSSO (Table 4). However, there is good evidence that grafting BSSO gaps significantly decreases the incidence of postoperative inferior mandibular border irregularities (Table 4). Finally, there is good evidence that calcium phosphate paste increases the rate of infection in BSSO and weak evidence that HA increases the rate of infection in orthognathic cases (Table 4).

More randomized clinical trials on healing, stability, complications, and the impact on aesthetics of osteotomy sites with and without grafting are necessary. Based on the level of evidence acquired in this systematic review, bone grafting can be recommended for the following indications during orthognathic surgery: (1) maxillary and mandibular advancements of more than 5 mm and 8 mm, respectively; (2) inferior repositioning of the maxilla and chin of  $\geq 5$  mm, and (3) all intraoperative palpable osteotomy gaps at the BSSO and chin osteotomy sites.

Finally, it is recommended that the following clinically relevant variables be included in further studies regarding this research topic: (1) complications rate, (2) additional operating time, and (3) costs towards grafting osteotomy sites in orthognathic surgery.

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