Systematic Review
Mouth and Jaw Surgery

Incidence of condylar resorption after bimaxillary, Lefort I, and mandibular surgery: an overview

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Abstract: The aim of the present overview was to evaluate the outcomes of systematic reviews to determine the incidence of condylar resorption in patients submitted to orthognathic surgery and analyze whether the risk of developing this condition is related to a specific type of surgery. Searches were conducted in the PubMed/MEDLINE, Embase, and Cochrane electronic databases for systematic reviews with quantitative data on condylar resorption due to any type of orthognathic surgery for dentoskeletal deformities published up to May 25, 2019. The AMSTAR 2 and Glenny tools were applied for the quality appraisal. Five systematic reviews were included for analysis. Only one article was considered to have high quality. Among a total of 5128 patients, 12.32% developed condylar resorption. From those patients, 70.1% had double jaw surgery, 23.4% had mandibular surgery alone, and in 6.5% a Lefort I technique was used. Based on these findings, bimaxillary surgery could be considered a risk factor for condylar resorption. However, these results should be interpreted with caution, since other factors, such as pre-operative skeletal deformities, type of movement, and type of fixation, can contribute to the development of this condition. Further studies should consider reporting main cephalometric data, temporomandibular diagnosis, hormonal levels, and tomographic measures before and after the surgery at least every 6 months during the firsts two years to identify accurately risk factors for condylar resorption.

Keywords: Bone Resorption; Mandibular Condyle; Orthognathic Surgery.

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Introduction

Orthognathic surgery is used to treat dentoskeletal deformations and establish both functional and esthetic harmony. After this procedure, the condylar bone undergoes changes to adapt to the new condition.[1,2] Thus, bone remodeling occurs, with areas of resorption and new formation throughout the entire condylar surface.[3,4] The loss that occurs through resorption is considered normal when within a maximum limit of 2 mm. When resorption exceeds this limit, however, it can be considered a pathological condition.[3,5]

Condylar resorption (CR) is defined as a progressive change in the morphology of the mandibular condyles and may be associated with intrinsic factors, such as sex, age, and type of skeletal deformity, as well

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as extrinsic factors associated with the type and characteristics of the surgery.[3,6,7,8,9,10,11] Excessive CR can result in changes in condylar shape, with the loss of condylar height and skeletal relapse, leading to the reestablishment of the pre-surgical condition or even a worse condition.[3,5,12] Studies report that CR is clearly identifiable after 12 months of follow-up, although it can occasionally be observed in a shorter period of time.[3,5,9,13,14,15,16,17] Mandibular retrognathia, anterior open bite, decreased posterior facial height, and clockwise mandibular rotation are some of the clinical manifestations that can be found in CR.[1,2,6,18,19]

Studies and systematic reviews have established that, although CR is not a frequent condition, it is associated with the type of orthognathic surgery.[5,7,8,11,13,18,20,21,22] In mandibular surgery alone, such as bilateral sagittal split osteotomy, an unexpected torque effect can occur on the condylar surface due to the rotation effect of the mandibular ramus. Likewise, changes in the condyle position could generate excessive pressure on the condylar morphology, causing reabsorption and skeletal relapse.[6,12,16,23]

In Le Fort I surgery, auto-rotation of the mandible may occur, such as in the treatment of open bite. This phenomenon has an effect on the relationship between the condyle and glenoid fossa, which may cause a change in the condylar structure that may initially be adaptive, but could gradually cause a superficial imbalance and lead to an exaggerated reabsorptive response.[6,22,23]

Regarding bimaxillary surgery, CR has been observed in a number of studies in patients submitted to this procedure, especially those with a high mandibular plane who require a counterclockwise movement. Some theories have been put forth to explain resorption following this surgery. One is related to the effect of the maxillary movement explained above. Another is the effect of the movements on both the maxilla and mandible, causing differences in the relationship of the articular surfaces.[6,14,23]

Nonetheless, many theories agree that, due to these movements, condylar rotation could affect the proximal segment of its surface, which did not receive much load in its pre-surgical mandibular position, but becomes overexposed to masticatory forces after the movement.[1,2,3,6,7,18,23] However, no analysis has focused on determining whether the risk of CR is greater in bimaxillary surgery, Le Fort I surgery, or mandibular surgery alone.[19] Therefore, the purpose of the present study was to investigate the incidence of CR in patients submitted to orthognathic surgery and determine whether the risk of developing this condition is associated with a specific type of surgery.

Methodology

Protocol registration

This study was registered in the PROSPERO database under protocol code CDR42019119712. This overview was performed considering the Cochrane Collaboration Handbook recommendations for overviews of systematic reviews.[24]

Focused question

The guiding question was "Does a specific type of orthognathic surgery increase the risk of post-surgical condylar resorption?"

Search strategy

Searches for relevant systematic reviews were performed in the Pubmed/MEDLINE, Embase, and Cochrane electronic databases up to May 25, 2019. The following Medical subject heading (MeSH) terms and key words were considered: condylar resorption OR condylar atrophy OR dysfunctional condylar remodeling OR progressive condylar resorption AND Orthognathic surgery OR bilateral sagittal split ramus osteotomy OR mandibular bilateral sagittal split osteotomy OR bimaxillary surgery.

The inclusion criteria were systematic reviews published in English with quantitative data on condylar resorption as a consequence of any type of orthognathic surgery for dentoskeletal deformities. Systematic reviews involving idiopathic condylar resorption and condylar resorption due to a fracture were excluded. No restriction was imposed regarding the year of publication.

Screening process

Two blinded independent researchers (T.N-S and R.A) performed the screening process by analyzing titles and abstracts. In cases of a divergence of opinion regarding the inclusion or exclusion of an article, the two reviewers discussed the article in question until reaching a consensus. When necessary, authors were contacted for additional information and a third researcher (B.V) was consulted to make the final decision. The level of agreement between the researchers after the selection of the titles and abstracts was determined using the Kappa statistic.[25]

Data extraction

Two tables were created to display the most relevant data for this overview. Demographic characteristics, incidence of condylar resorption in each type of surgery, follow up period, and additional surgical characteristics were extracted from the selected articles.

Quality appraisal of systematic reviews

The quality of the systematic reviews was appraised by two reviewers (T.N-S and R.A). The 16-item AMSTAR 2 tool was applied.[26] The terms 'yes', 'no', 'cannot answer', and 'not applicable' are attributed to each item. The score is generated considering only items for which 'yes' was attributed. Therefore, the total score ranges from 0 to 16 points. In addition, the Glenny et al. Scale was applied.[27] In this 15-item scale, scoring was performed as follows: one point is assigned for a "yes" answer, and the total score obtained can range from 0 to 15 points. A score of 10 to 15 indicates high quality, 5 to 9 points indicates average quality, and 0 to 4 points indicates low quality.

Results

The initial search led to the retrieval of 1801 titles in Pubmed/MEDLINE, 1800 in Embase, and one in Cochrane. After the removal of duplicates, 1036 articles were submitted to reading of titles and abstracts and 11 articles were selected for full-text analysis.[6,7,10,11,19,21,22,28,29,30,31]

The Kappa coefficients for agreement regarding the pre-selection of articles based on the analysis of the titles and abstracts was 1.0 for all three databases, which according to Landis and Koch, demonstrates a high level of agreement.[25] After the full-text analysis, six articles were excluded for not having data available to compare condylar resorption in bimaxillary surgery vs. mandibular surgery alone.[7,10,11,21,29,32] Hence, five systematic reviews were selected for qualitative analysis.[6,19,22,30,31] Figure displays the article selection process.

The entire sample of consecutive patients was 10,097. Data on demographic characteristics, type of surgery, incidence of condylar resorption, diagnosis, etc. were analyzed in 5128 patients aged 12 to 54 years. A total of 2098 patients were submitted to bimaxillary surgery, 2376 were submitted to mandibular surgery alone, and 654 were submitted to Le Fort I osteotomy alone (Table 1).

Incidence of condylar resorption per type of surgery

Patients submitted to a bimaxillary surgery, mandibular surgery, and maxillary surgery, respectively, who developed CR was 26.9, 5.76, and 6.67% in Gill et al,[22] 21.5, 3.83, and 6.67% in Moraes et al.,[30] 17.3, 10.27, and 7.11% in Catherine et al,[19] 22.6, 5.03, and 0% in Mousoulea et al.,[6] and finally,

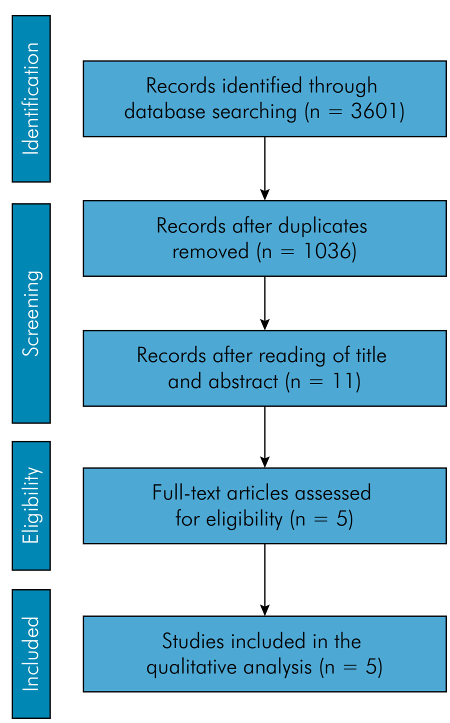

Figure. Article selection process.

Table 1. Demographic characteristics and incidence of condylar resorption (CR).

Author, year	Sample	Total included patients	Age	CR F:M ratio	Bimaxillary surgery	# Patients with CR	Mandibular Surgery	# Patients with CR	Maxillary surgery	# Patients with CR	Follow-up (months)
Gill et al, 2008[22]	3059	1132	13–53	≈ 21.2: 1	416	112	521	30	195	13	12–69
De Moraes et al, 2012[30]	2567	1223	14–46	≈ 41.6: 1	479	103	549	21	195	13	12–69
Catherine et al, 2015[19]	3200	1643	14.8–50	≈ 4.5: 1	877	152	555	57	211	15	12–120
Mousoulea et al, 2017[6]	1069	928	12–54	≈ 8.3: 1	239	54	636	32	53	0	12–101

≈Approximate value of studies with reported data.

25.3, 6.96, and 0% in Nunes et al.[31]. The follow up of these patients ranged from 12 to 120 months (Table 1).

Pre-operative skeletal deformities

Table 2 displays the surgical characteristics of the patients. Class II dentoskeletal diagnosis was predominant in three articles.[6,22,31] Class II patients were also included in the study by Catherine et al., but the quantity was not specified.[19] Patients were diagnosed with Class III in two articles,[6,31] and only one review had Class I patients.[6] In the mandibular diagnoses, the main characteristics were retrognathia and mandibular deficiency/hypoplasia.[6,22,30] Catherine et al. and Nunes et al. did not report the mandibular diagnoses.[19,31] None of the reviews mentioned maxillary diagnoses.[6,19,22,30,31] A total of four articles reported patients with high mandibular plane angle (MPA)[6,19,2230], however in Catherine et al., the number of those patients was not specified.[19] Preoperative open bite was mentioned in four articles,[6,19,22,30] but there was missing data in two of them.[19,22] Preoperative TMJ disorders were reported in 149 patients,[6] but were not specified in three reviews.[19,22,30]

Surgical movement and type of fixation

As Class II was the main diagnosis, the most common form of treatment was mandibular advancement, but it was not specified in two reviews.[19,30] Advancement combined with counterclockwise rotation was reported in 36 patients,[6] but was not specified in one review.[19] Mandibular setback was performed in 7 patients in Mousoulea et al.,[6] and 95 in Nunes et al..[31] Mandibular repositioning for occlusal control was performed in the 12 Class I patients.[6] Maxillary surgery was not reported in most reviews.[19,22,30,31] The exception was the study by Mousoulea et al.,[6] who reported 29 patients submitted to maxillary replacement.[6]

Regarding fixation, in Gill et al.,[22] 3.6, 4.3, 15.4, 10, 5.8, and 3.1% of the patients developed CR when using only plates, plates with screws combined with intermaxillary fixation, plates with screws and suspension wires, screws and suspension wires, skeletal fixation, and screws combined with intermaxillary fixation, respectively. In De Moraes et al.,[30] 13% of the patients developed CR when rigid fixation was applied.

A total of 9.9% of the patients submitted to a wire fixation had CR in both De Moraes and Catherine.[19,30] Meanwhile, in Catherine et al., 6.3% of the patients developed CR when using rigid fixation.[19] Mousoulea et al.[6] reported the development of CR in 10.3, 7.8, and 3.6% when using intermaxillary fixation alone, with miniplates, or miniplates without intermaxillary fixation. Finally, Lima et al.[31] reported a CR incidence of 1.6% with plates with monocortical screws, and when bicortical screws alone were used, 32.8% of the patients developed CR.

Quality appraisal

Both in Glenny and AMSTAR scales, most articles failed in some stages of the conception and planning of the systematic review. The main guide for the proper development of the review is the guiding question and that was absent in all reviews.[6,19,22,30,31] The description of the design 'a priori' was not detailed in three articles[19,22,30] and only one article had

Table 2. Surgical characteristics.

Author, year	Diagnosis	Mandibular diagnosis	Mandibular plane angle	Occlusal diagnosis	TMJ dysfunctions	Movement	Fixation	Level of evidence AMSTAR	Level of evidence Glenny Scale	Main outcomes/conclusions
Gill et al., 2008[22]	Class II: 684	Retrognathia: 2135	High: 2135	Open bite: NS	Presurgical: NS	Advancement: 203	Plates: 222; CR 8 Plates, screws, intermaxillary: 1247; CR: 53 Wire, plates, screws, suspension wires: 259; CR: 40 Screws, suspension wires: 100; CR: 10 Skeletal Fixation: 206; CR: 12 Screws, intermaxillary: 1025; CR: 32	Low	Average	Methodological heterogeneity. More evidence is needed. The potential risk factors for CR are: -Female patients -Mandibular retrognathia -Increased mandibular plane angle -Pretreatment condylar atrophy -Undergoing posterior condylar displacement -Upward and forward rotation of the mandible at the time of surgery.
De Moraes et al., 2012[30]	NR	Mandibular prognathism: 148 Mandibular deficiency (Low-relative): 890; CR: 18 Absolute mandibular deficiency: 541; CR: 118	Low-Normal: 828; CR (18) High: 541; CR: 118	Open bite: 96	Presurgical: NS	Advancement: NS	Wire: 676; CR:67 Rigid: 430; CR: 56	Low	Average	Methodological heterogeneity More evidence is needed Potential risk factors for CR: -Female patients -Mandibular deficiencies with high mandibular plane - Advancement surgery -Bimaxillary surgery -Counterclockwise movement
Catherine et al., 2015[19]	Class II: NS	NR	High: NS	Open Bite: NS	Presurgical: NS	Advancement: NS	Wire: 676; CR:67	Low	Low	Methodological heterogeneity More evidence is needed No treatment protocol officially accepted Potential risk factors for CR:

Continue

Continuation

										-Female patients -14 to 40 years -Class II malocclusion with anterior open bite -High mandibular plane (>40º) -Sagittal posterior condylar neck inclination -Bimaxillary surgery -Mandibular advancement (>10 mm) -Wire fixation
						Counterclockwise rotation: NS	Rigid: 1692; CR: 107			-Counterclockwise rotation
Mousoulea et al., 2017[6]	Class I: 12	Mandibular deficiency/ hypoplasia: 602	High: 507	Open bite: 237	Presurgical: 149	Mandibular repositioning for occlusal control: 12		High	High	Methodological Heterogeneity
						Mandibular advancement: 1014	Intermaxillary fixation: 329; CR: 34			More evidence is needed
										Potential risk factors for CR: -Bilateral sagittal split osteotomy -Young, female patients
						Mandibular advancement+ Counterclockwise rotation:36	Intermaxillary fixation, miniplates: 103; CR: 8			-Mandibular deficiency
	Class II: 319					Maxillary replacement: 29				-High mandibular plane
	Class III: 7	Mandibular retrognathia: 235	Low-Normal: 102	-	-	Mandibular setback: 7	Miniplates 222; CR: 8			-Surgical counterclockwise rotation
Nunes et al., 2018[31]	Class III: 95	NR	NR	NR	NR	Setback: 95	Plates with monocortical screws:129; CR: 2	Average	Average	CR is a uncommon condition Associated with relapse, but in a small percentage of the patients.
							Bicortical screws: 67; CR: 22			Seems to occur in Class II patients
	Class II: 107					Advancement: 107	Plates with monocortical screws or bicortical screws: 6; CR: 6			More evidence is needed

CR: condylar resorption; NS: Not specified; NR: Not reported.

an appropriate register of the protocol,[31] indicating an oversight in the methodology of some reviews.

The search for articles was made in English,[30,31] English and French,[19] or it was not specified;[22] only one article had no language restriction.[6] Also, the absence of a search in the grey literature should be highlighted,[6,19,22,30,31] as well as the lack of an appropriate hand search to find other important sources of information in three articles.[19,30,31] On the other hand, the inclusion and exclusion criteria in many articles were not very clear and there was no list that explained those criteria in detail, specially the exclusion criteria.[6,19,22,30,31] The independent and blind search of two researchers did not occur in two reviews.[19,22]

In both scales, the evaluation of the quality of the primary articles was an essential part to which only two articles complyed.[6,31] These shortcomings were

Table 3. Assessment of systematic reviews by AMSTAR scale.

AMSTAR questions	Gill et al., 2008[22]	De Moraes et al., 2012[30]	Catherine et al., 2015[19]	Mousoulea et al., 2017[6]	Lima et al., 2018[31]
(1) Was an 'a priori' design provided?	No	No	No	Yes	Yes
(2) Was there duplicate study selection and data extraction?	No	Yes	No	Yes	Yes
(3) Was a comprehensive literature search performed?	Yes	Yes	No	Yes	Yes
(4) Was the status of publication (*i.e.*, gray literature) used as an inclusion criterion?	No	No	No	Yes	No
(5) Was a list of studies (included and excluded) provided?	No	No	No	No	No
(6) Were the characteristics of the included studies provided?	Yes	Yes	Yes	Yes	Yes
(7) Was the scientific quality of the included studies assessed and documented?	No	No	No	Yes	Yes
(8) Was the scientific quality of the included studies used appropriately in formulating conclusions?	No	No	No	Yes	Yes
(9) Were the methods used to combine the findings of studies appropriate?	No	No	No	Yes	No
(10) Was the likelihood of publication bias assessed?	No	No	No	No	No
(11) Was the conflict of interest stated?	No	No	Yes	Yes	Yes
(12) Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	No	No	No	Yes	No
(13) Did the review authors account for risk of bias in individual studies when interpreting/discussing the results of the review?	No	No	No	Yes	No
(14) If meta-analysis was performed, did the review authors assess the potential impact of risk of bias in individual studies on the results of the meta-analysis or other evidence synthesis?	NA	NA	NA	NA	NA
(15) If meta-analysis was justified, did the review authors use appropriate methods for statistical combination of results?	NA	NA	NA	NA	NA
(16) Did the review authors use a satisfactory technique for assessing the risk of bias in individual studies that were included in the review?	No	No	No	Yes	Yes
Total (Yes)	2	3	2	12	8

increased by not analyzing in detail the risk of bias of the individual studies.[6,19,22,30,31] Regarding the results, these were presented in a clear and organized way in all the reviews.[6,19,22,30,31] The heterogeneity of the data was visible in all reviews, but only two articles mentioned this fact,[6,30] however, only in one article the explanation was satisfactory.[6]

Considering the aforementioned information, three of the reviews had low quality based on the AMSTAR 2 criteria.[19,22,30] Nunes et al. obtained half of the possible points[31] and Mousoulea et al. obtained the highest number of points compared to the other systematic reviews.[6] Only item 6 was scored as positive in all articles. Items 14 and 15 were not applicable because none of the systematic reviews employed meta-analysis[26] (Table 3). On the other hand, according to the Glenny et al. Scale, one article was rated as low,[19] three were considered average,[22,30,31] and one was estimated as high quality[6] (Table 4).

Discussion

Summary of evidence: demographic characteristics

In the present overview, a total of 10,097 registers of patients undergoing orthognathic surgery were recruited, but detailed information was missing on 49.2%. The loss of information during follow up is one of the reasons why the incidence of CR cannot be reported accurately. Although CR is described in several studies, many of its characteristics and concepts remain unclear.

The lack of information even among the patients included was reflected in the demographic characteristics. Most of the reports failed to mention the mean age at the time of the occurrence of CR.[6,19,22,30] However, we were able to determine that the earliest age of onset was 12 years and the most advance age was 54 years, constituting a very broad age group. Another

Table 4. Assessment of systematic reviews using Glenny scale.

Glenny questions	Gill et al., 2008[22]	De Moraes et al., 2012[30]	Catherine et al., 2015[19]	Mousoulea et al., 2017[6]	Lima et al., 2018[31]
(1) Did review address a focused question?	0	0	0	0	0
(2) Did authors look for appropriate papers?	1	1	1	1	1
(3) Do you think authors attempted to identify all relevant studies?	1	1	1	1	1
(4) Search for published and unpublished literature	0	0	0	1	0
(5) Were all languages considered?	0	0	0	1	0
(6) Was any hand-searching carried out?	1	0	0	1	0
(7) Was it stated that the inclusion criteria were carried out by at least two reviewers?	0	1	0	1	1
(8) Did reviewers attempt to assess the quality of the included studies?	0	0	0	1	1
(9) If so, did they include this in the analysis?	0	0	0	1	1
(10) Was it stated that the quality assessment was carried out by at least two reviewers?	0	0	0	1	1
(11) Are the results given in a narrative or pooled statistical analysis?	0	0	0	0	0
(12) If the results have been combined was it reasonable to do so?	0	0	0	0	0
(13) Are the results clearly displayed?	1	1	1	1	1
(14) Was an assessment of heterogeneity made and reasons for variation discussed?	0	1	0	1	0
(15) Were results of review interpreted appropriately?	1	1	1	1	1
Total	5	6	4	12	7

point to be highlighted was that when combining data of all reviews, 12.32% of the patients submitted to orthognathic surgery developed CR. However, this incidence varies considerably in the literature. For example, De Clercq et al.[33] reported an incidence almost three times higher than that obtained in the present overview, whereas only six patients out of 730 patients in the study by Politis et al.[34] developed slight CR that only required conservative treatment.

Most articles, including those mentioned above, are in agreement with the results presented in this overview regarding the fact that CR secondary to orthognathic surgery is more prevalent in women than men.[6,19,22,30,31] An explanation for both findings that is widely mentioned in the literature is the role of hormones in this condition.[3,9,19,20,28,35] While no clinical study offers strong scientific evidence to support this premise, such investigations are required because hormonal aspects could constitute a risk factor that needs to be controlled.[20,28,35]

Risk of CR in double jaw surgery

According to the data found in this study, the incidence of condylar resorption in double jaw surgery is almost three times higher than in mandibular surgery alone. This may give the idea that bimaxillary surgery could be a risk factor for CR, as has been hypothesized in previous reports.[6,14,23,31,36,37] These results may be associated with maxillary movement. According to different reports, maxillary intrusion could be related to condylar resorption in bimaxillary surgeries.[9,12,13]

However, in this overview, these premises cannot be confirmed because the isolated maxillary movement does not represent a significant risk by itself, since there was ten times greater risk of having CR due to bimaxillary surgery than the Le fort I movement. Hence, another explanation for these findings could be the mandibular movement that accompanies the maxilla. More specifically, maxillary intrusion usually occurs along with mandibular counterclockwise rotation, which is a combination that could increase the risk of CR, although this premise should be explored further.[8,13,38]

As mentioned above, this overview lacks the necessary information to explain statistically the high incidence of CR after bimaxillary surgery, especially regarding the maxillary bone, since there is no report or in-depth analysis on the characteristics of its movement. It should also be pointed out that 6.2% of the population submitted to Le Fort I osteotomy developed CR. There was incomplete information regarding the role this bone plays in CR and it was not clear whether it exerted a direct or a complementary influence on condylar deformation.

Pre-operative skeletal deformities and type of movement

De Moraes et al.,[30] Mousoulea et al.,[6] and Gill et al.[22] reported patients with high mandibular plane angle, but only in the study by De Moraes et al.[30] a significant correlation was found. In this review,[30] 21.81% of the patients diagnosed with high mandibular plane angle developed CR after orthognathic surgery, while 2.17% of the patients with a low-to-normal mandibular plane angle had CR.

Most of the patients included in the systematic reviews were women with Class II dentoskeletal deformities with mandibular hypoplasia and/or mandibular retrognathia. According to the evidence presented in this overview, the consideration of these characteristics as risk factors is not warranted yet because the vast majority of the sample was composed of this specific group of patients, as demonstrated in Gill et al.[22] and Catherine et al.[19] Moreover, one out of ten patients had class III dentoskeletal deformities. Thus, there was an important imbalance in the sample, as well as a risk of bias, as seen in Tables 2, 3, and 4. However, as a considerable number of female patients with high-angle retrognathism presented CR, it is worth mentioning the risks of CR after orthognathic surgery in these patients, as suggested by De Clercq.[33]

One hypothesis for the emergence of CR after orthognathic surgery, whether bimaxillary, mandibular alone, or maxillary alone, regards the pre-surgical condition, such as the morphology of each condyle, pre-existing erosion, and/or temporomandibular disorders.[1,2,9,12,14,15,16,18,20,23,33,37,38,39,40] As seen in Table 2, most reviews reported alterations in the temporomandibular joint.[6,19,22,30] The number of patients with such conditions was only specified in the study by Mousoulea et al.,[6] and information on the incidence of CR in these patients was unclear in the study. According to some articles, previous conditions seem to favor an increase in the occurrence of CR.[7,14,16,38] However, other studies found no association between TMD and CR.[9,13,19] Therefore, further evidence is needed on preoperative and postoperative TMJ conditions.

Regarding surgical movements, some primary articles reported a direct association between mandibular advancement and CR.[3,15,16,23,38] Also, according to Gill et al.[22] and Catherine et al.[19] studies, the magnitude of the movement could increment the risk of developing CR, because the risk of CR was 20 times higher in mandibular advancements exceeding 10 mm than in mandibular advancements of 5 mm. In addition, counterclockwise movement of the proximal mandibular segment is related to CR, especially in patients with a mandibular plane angle greater than 40°.[6,19,30]

Both movements are reported in some articles to be the base of a series of consequences that induce a mechanical loading. According to De Moraes et al.,[30] mechanical loading could restrict the condylar vascular supply triggering the necessary changes in condylar surface to develop CR. Mousoulea et al.,[6] described an inferior-posteriorly directed force from large advancements that affects the condylar head as a possible cause of CR. Catherine et al.[19] agreed that mandibular advancement generated condylar posterior displacement due to the compressive mechanical stress, and Nunes et al.[31] described that the condylar pressure against the fossa is one important cause to create the resorption.

Notwithstanding those statements, the systematic reviews were consistent about the lack of evidence of these theories.[6,22,30,31] This is especially due to the absence of numerical values of the primary studies to perform any statistical analysis that can confirm the associations between large surgical movements, mechanical loading, and CR.[6,22,30,31] Also, Lima et al.[31] is emphatic that the evidence for mandibular setbacks are scarce.

For these reasons, the quality of the reviews were not high in four articles, which was a critical flaw that does not allow the extrapolation of relevant information. The results of the AMSTAR 2 tool and Glenny et al. Scale[26,27] also revealed a failure in the grouping process of the information related to the presence or absence of rotating movements, which, according to the literature, are considered risk factors.[2,6,20,30]

Role of fixation in condylar resorption

Type of fixation was considered an important factor in all systematic reviews. However, the lack of homogeneity when grouping the data impeded the use of meta-analysis in each article. Gill et al.[22] reported many cases involving wire fixation combined with rigid fixation elements (miniplates and/or screws), making it inappropriate to unite these cases in a single group with the wire fixation group reported in De Moraes et al.[30] and Catherine et al.[19] Therefore, a meta-analysis was not performed in this overview. Nonetheless, an in-depth examination of the data displayed in Table 2 shows that one out of 21 patients with intermaxillary fixation, one out of 13 patients with rigid fixation, one out of 10 patients with wire fixation, and one out of 7 patients using wire fixation combined with rigid elements developed CR. These proportions give an idea of the importance of a detailed analysis of condylar effects after using a specific type of fixation.

Condylar resorption and importance of computed tomography

Radiography has long been the tool used to determine the diagnosis of CR. Although there are other alternatives mentioned in the literature, diagnosis by computed tomography is currently indispensable.[6,31] This is supported by the analysis carried out by Mousolea, emphasizing tomography as a tool that enables the precise location of comparative surfaces and facilitates a more objective, quantifiable analysis.[6] Likewise, the review by Nunes et al. indicates that the use of tomography is a growing trend in the literature, as it allows monitoring condylar changes after orthognathic surgery.[31]

However, quantification methods are limited in many studies, as observed in most of the primary articles of the reviews included in this overview that used tomograms.[1,4,37,41] These investigations showed the remodeling of the condylar surface and its changes. However, no volumetric evaluation expressed in cubic units was performed.[1,4,37,41] Volumetric analysis is important to establish the 3D parameters of the pathological condition, differentiating it from the physiological remodeling process and enabling the determination of correlations with variables, such as fixation, movement, type of surgery, sex, etc., to establish the etiology of the condition.[3,6,31]

Volumetric analysis was performed by Xi et al.,[3] which was the only primary study included in the reviews of both Mousoulea et al.[6] and Lima et al.[31] This analysis determined a positive correlation between relapse and the decrease in condylar volume, which was 6.1%, on average, of the original condylar volume, represented by a mean volume reduction of approximately 105 mm^3.[3] If this methodology were widely studied, it could be the first step towards finding a formula or a numerical parameter to define condylar resorption, establishing a measure such as the 2 mm standard used in radiographs.

Risk of bias of the systematic reviews

Two scales were used to assess the quality of each of the systematic reviews, the Glenny et al. Scale and the AMSTAR tool. Both scales indicate the design and risk of bias control for those reviews. The scales begin with a series of evaluation criteria related to the planning part of the review, which include: the guiding question, the PICO system, the design of the review, among others, in which all the articles presented at least one failure, especially Gill et al,[22] De Moraes et al.,[30] and Catherine et al.[19]

The registration of the protocol is something that should be mandatory when a systematic review is performed. One advantage of this process is the visualization of previous systematic reviews to achieve an understanding of the necessities to improve the methodologies. Also, it allows to evaluate the conception and planning of the review avoiding risk of bias. Besides, it controls the redundant data, avoiding unnecessary duplicates of information. For this reason, 4 of the 5 articles had a lot of information in common and the additional contribution that is given by each review is limited.[6,19,22,30] On the other hand, the article by Nunes et al.,[31] the only one with a registration, presents a novel vision of CR.

In three reviews of this overview,[19,22,30] methodological issues were found, especially in the search for suitable articles. Ideally, the selection of articles is performed including any relevant source of information,[24] in any language, and a hand search, grey literature search, among others, should be performed. These procedures are highly recommended to decreased the risk of bias and assure that the data obtained can be extrapolated to the general population.

On the other hand, according to Cochrane handbook of systematic reviews, two blinded and independent reviewers should be included in the selection process.[24] Although this step is mandatory, it was not present or justified in two reviews.[19,22] These situations mainly affect the transparency in the design of the study, especially in the relationship between methodology and presentation of results.

One general failure was the absence of risk of bias analysis of the studies,[6,19,22,30,31] and this is especially important because most of the primary studies that compose these reviews do not have a design that controls bias (for example, blinding and/or randomization). Heterogeneity was a common situation due to the different approaches of the primary studies, but most of the reviews avoided an explanation of this point.[19,22,31] This variation among articles should be considered and discussed for the interpretation of the various results obtained and proposals should be planned to standardize methodologies, allowing greater precision of results and ensuring reliable conclusions.

Considering the aforementioned information, only the article by Mousoulea et al.[6] met most of the quality standards of both scales, although it failed in some criteria because of the absence of registration and the lack of inclusion of the grey literature. The study by Nunes et al. had medium scores in both scales, especially due to the lack of reporting of details that control bias, such as using grey literature or analyzing heterogeneity, among others.[31] The remaining articles, especially the older ones, lacked rigorous design and the minimum standards required for carrying out systematic reviews.

Recommendations for further research

Based on the findings of the present overview, studies should be designed in which the clinical and imaging information is standardized to facilitate data organization. Such information should include a thorough examination of the preoperative and postoperative conditions, a 3D morphometric analysis of the condyles and cephalometry. It is important for all surgical movement data (type and average measurements of direction and rotation) to be available to confirm the association between certain types of movements and CR. It is also necessary to reaffirm certain concepts regarding the definition of CR, as the term resorption is often used indiscriminately to describe condylar remodeling,[3,5,9,20,31] which is an error, since the remodeling process is a biological adaptation, whereas resorption is a pathological condition.

Another aspect to consider is that exams should not be limited to two-dimensional analyses in which the main criterion for CR is bone loss > 2 mm, but also include tomographic analyses to enable broader knowledge and the creation of new diagnostic criteria.[1,2,4,20,31,37] Finally, to improve the grouping of information and reduce the risk of bias, future studies should consider the publication of data related to condylar resorption to the greatest extent possible. It is also important to preserve the preoperative data to avoid the loss of information and perform postoperative follow up for at least one year on all patients submitted to orthognathic surgery to obtain data on the onset of condylar resorption that is more reliable.

For a standardized measure of the incidence of condylar reabsorption after orthognathic surgery, a database must be created in which the diagnosis and cephalometric data, such as skeletal classes, angle of the mandibular plane, and general measurements of maxilla and mandible position should be registered. Dental diagnoses and malocclusions could also be included.

In order to understand the underlying causes and to clarify certain possible hypotheses, a thorough examination of the TMJ must be carried out and the data entered in the database. Since blood tests are mandatory before major surgeries, the opportunity could be taken to look at patients' overall hormone levels. Tomographic images and their description are mandatory to compare post-surgery results with pre-surgery conditions. Data related to type of surgery, type of movement performed in degrees and millimeters, type of fixation, and complications should be entered in that database. Subsequently, the same evaluation criteria before the surgery must be assessed after the surgery at least every 6 months during the firsts two years. This data could help identify relapses, incidence of temporomandibular disorders, in addition to incidence of condylar resorption.

Conclusion

Bimaxillary surgery could be considered a risk factor for condylar resorption. However, other factors, such as pre-operative skeletal deformities, type of movement, and type of fixation, can contribute to the development of this condition. High-quality studies with low risk of bias that investigate these factors in depth with a well defined methodology and three-dimensional imaging are needed to determine the etiology of condylar resorption after orthognathic surgery.

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