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Review

Management of condylar resorption before or after orthognathic surgery: A systematic review

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ABSTRACT

Background: Orthognathic surgery is a surgical procedure for the correction of maxillofacial deformities. The existence of condylar resorption before orthognathic surgery affects the selection of surgery time and plan. Besides, condylar resorption after orthognathic surgery often leads to the recurrence of deformities and affects the long-term effect of surgery. The purpose of this study was to perform a systematic review of the management of condylar resorption before or after orthognathic surgery.

Methods: A systematic review of the scientific literature listed on PubMed, Embase, and Cochrane Controlled Trials Register was performed, up to October 2018. The outcome of the search was reviewed with a chart.

Results: Ten articles with 180 patients were included in this study based on inclusion and exclusion criteria. We compared these studies to examine the effectiveness of the management of condylar resorption.

Conclusion: The occurrence of condylar resorption can be influenced by complex factors. The management of condylar resorption before or after orthognathic surgery should base on the severity of condylar resorption. As the eligible studies with small sample sizes, heterogeneity in management method and outcome, high-quality clinical study concerning condylar resorption treatment is needed.

1. Introduction

Orthognathic surgery (OS) is an established and well-documented surgical procedure for the correction of severe dentofacial deformities. It can restore the aesthetics and function of patients by altering the spatial position of facial bone segments. Combined with orthodontic treatment, the aesthetics and function of the dentofacial region could achieve a stable result. OS, especially the bimaxillary surgery, usually changes the load distributed on condyle or the position of the condyle, which may trigger condylar remodeling, even condylar resorption (CR). Condylar remodeling is a physiological balance between bone resorption and bone formation, which is adapted to new functional requirements of the temporomandibular joint (TMJ). When these changes exceed the natural capacity of the condyle, it might lead to CR. CR is regarded as a well-documented but poorly understood pathological entity, which shows an irreversible progressive alteration of condylar morphology, as well as reduction of condylar volume and mass (Lee et al., 2016; da Silva et al., 2017). CR could be classified into primary condylar resorption and secondary condylar resorption according to whether there is a clear etiology. Primary condylar resorption, also known as idiopathic condylar resorption, refers to a progressive process with condylar volume reducing and morphological changing without a known cause. It often occurs in both sides of the condyle and more frequently occurs in women aged 15–35 years (Huang et al., 1997; Hwang et al., 2004). Secondary condylar resorption has definite local or systemic pathogenic factors. Local etiology includes infection, trauma, tumor, arthritis, ischemic necrosis, and others. Systemic etiology includes rheumatic immune disease, connective tissue disease, estrogen imbalance, use of steroids, and so forth (de Bont and Stegenga, 1993). In addition, CR could also be divided into deep bites resorption and anterior open bites resorption in accordance with

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the occlusal relationship of anterior teeth. The former usually occurred in the superior site of the condyle, while the latter occurred in the superior and anterior of the condyle (Hoppenreijs et al., 1999). Progressive condylar resorption often leads to changes in facial appearance, which can be accompanied by TMJ symptoms, such as TMJ pain, but nearly 25% of the patients are asymptomatic (Wolford and Goncalves, 2015). In the early stage of CR, a slight mandible retraction of the patient can be noted. As the disease progresses, a noticeable retraction of the chin with an apparent anterior open bite, class II malocclusion, and evident decreased vertical posterior facial height could be observed (de Bont and Stegenga, 1993). The changes of maxillofacial morphology usually include progressive open bite, mandibular retrusion, reduction of overbite and increase of overjet, formation of class II malocclusion, increase of mandibular plane angle, decrease of mandibular ramus' height and even narrowing of the oropharyngeal airway in some patients (Fig. 1A-F) (Kobayashi et al., 2012; Wolford, 2007). Unilateral CR can lead to chin deviating to the affected side, ipsilateral class II malocclusion, early contact and crossbite of posterior teeth of the affected side, and anterior and contralateral open bite (Fig. 2A-F) (Wolford, 2001; Valladares-neto et al., 2014). So the resorption of condyle often results in progressive worsening occlusion and aesthetic appearance, and that is when patients consult their doctors (Wolford and Cardenas, 1999).

The existence of CR before OS affects the selection of surgery time and plan. Besides, CR after OS often leads to the recurrence of deformities and affects the long-term effect of surgery (Hwang et al., 2000). Many studies have been conducted on the subject of CR and OS, but there is a lack of consensus on the treatment of CR. In this article, we make a systematic review using a chart that concerns the treatment of CR in those orthognathic patients to a deeper understanding of how to manage CR before or after OS.

2. Methods

This research was performed on the basis of PRISMA guidelines (Moher et al., 2009). The aim of this systematic review was to include all publicly available literature on the treatment of CR before or after OS. This study was not registered.

2.1. Searching strategy

A thorough search was performed in electronic databases: PubMed, Embase, and Cochrane library (the last date was up to October 2018). The following searching terms were used: ("orthognathic surgery" OR "maxillofacial surgery") AND ("condylar resorption" OR "condylar atrophy" OR "condylysis"). Additionally, a hand research was performed to find additional relevant studies in the reference lists of the included articles.

2.2. Selection of Articles

The selection of articles was carried out by two independent authors (H.-Z.J. and W. D.). After removing the duplicates, they screened the titles, abstracts or full text to decide whether the article was eligible. Whenever there was disagreement, a discussion between the two authors or a consult to a third reviewer (E.L.) followed.

In the research, the selection was carried out as follows.

Inclusion criteria: (1) Study design: Any study design was considered eligible, including randomized, non-randomized, prospective, retrospective studies; (2) Types of participants: Patients of any age diagnosed as CR; (3) Type of intervention: The intervention was any type of therapeutic methods to manage CR; (4) Follow-up: At least 6 months; (5) Language: There was no restriction in language.

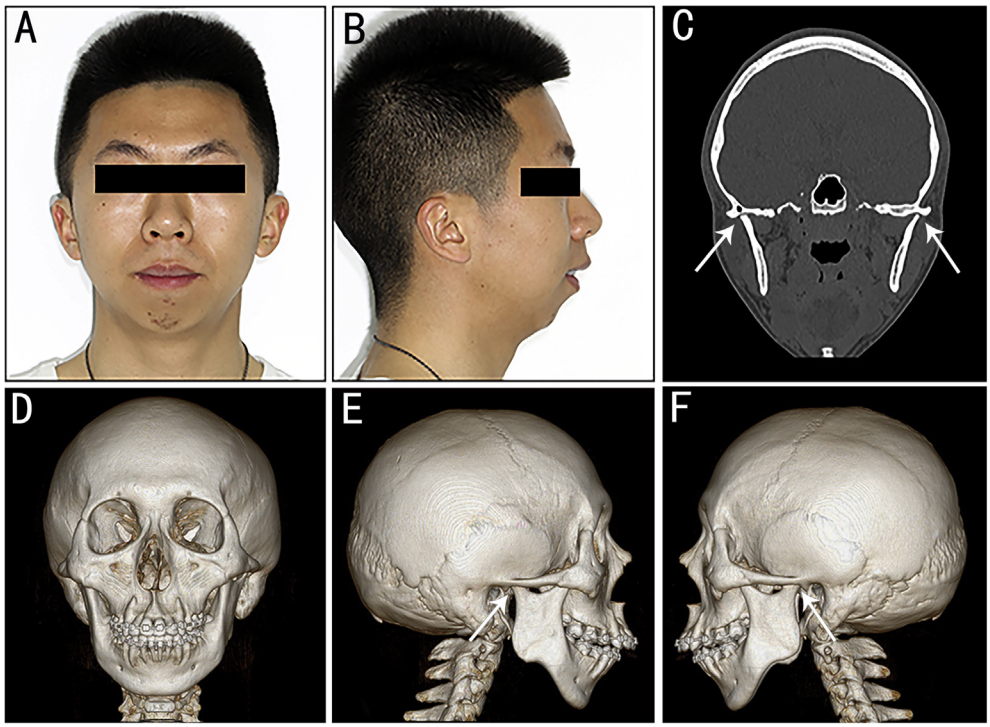

Fig. 1. (A–F) Characteristics of patients with bilateral condylar resorption (both sides). (A) frontal photograph. (B) lateral photograph. (C) sections of coronal CT scan demonstrating significant loss of vertical condylar height and transverse width on both sides (arrows). (D) frontal view of 3D reconstruction of spiral CT. (E–F) lateral views of 3D reconstruction of spiral CT shows: condylar resorption on the both sides (arrows), mandibular retrusion, class II malocclusion, high mandibular plane angle and short mandibular ramus.

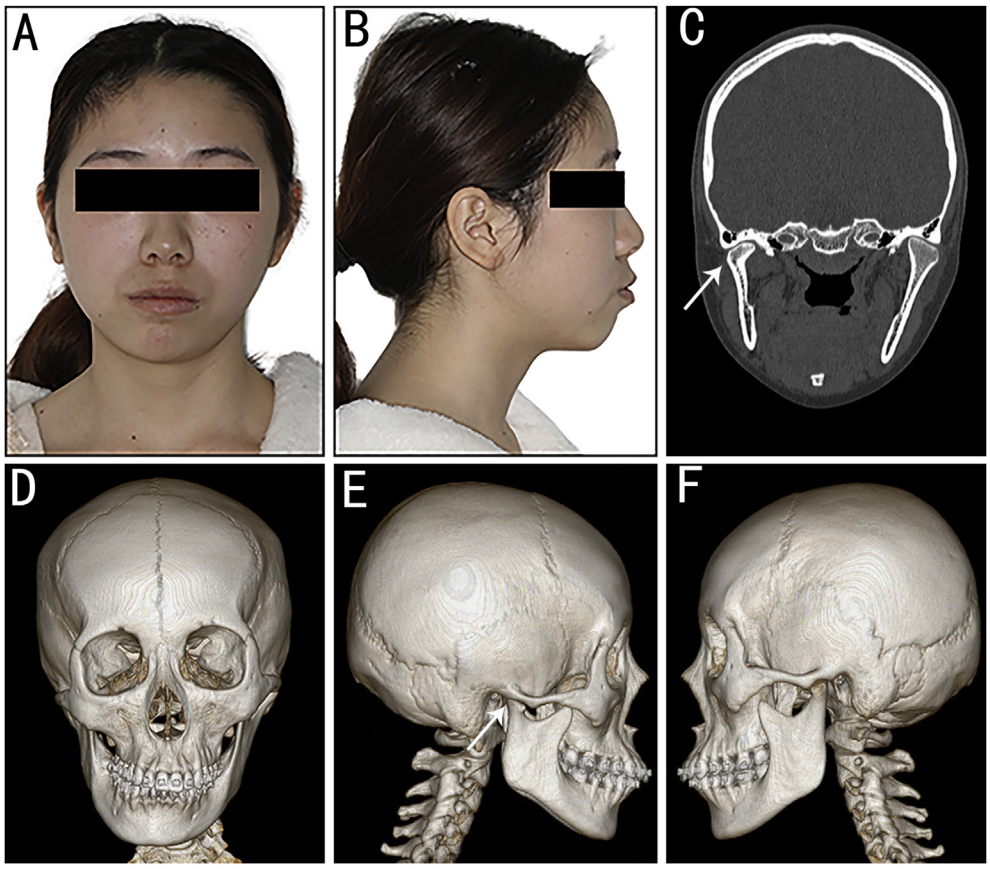

Fig. 2. (A–F) Characteristics of patients with unilateral condylar resorption (right side). (A) frontal photograph. (B) lateral photograph of the affected side. (C) sections of coronal CT scan demonstrating the presence of condylar resorption on the right side (arrow). (D) frontal view of 3D reconstruction of spiral CT shows: mental deviated to the affected side. (E) lateral view of 3D reconstruction of spiral CT of the affected side shows: condylar resorption (arrow), class II malocclusion, short mandibular ramus. (F) lateral view of 3D reconstruction of spiral CT of the unaffected side.

Exclusion criteria: (1) Animal or in vitro studies; (2) Literature reviews; (3) Case reports or case series were excluded.

2.3. Data extraction process

The data extraction of the selected articles was carried out by two authors (H.-Z.J. and C.-W.X.) and there was no blinding to the authors during the process. Any disagreements were resolved by a discussion or a consult to a third author (Z.H). The following data were collected in all selected articles: first author, year of publication, country of the author, gender, mean age, number of patients, diagnosis, management methods, follow-up, outcome measured and relapse rate.

2.4. Risk of Bias assessment

The risk of bias of all studies included was assessed by two authors (W.D. and H.-Z.J.) individually and in duplicate. Any inter-examiner disagreements were resolved by discussion or consult to a third author (Z.H). Cochrane risk of bias tool was used to evaluate randomized controlled trials, while non-randomized studies were evaluated by the methodological index for non-randomized studies (MINORS). This index evaluates comparative studies in 12 domains and the ideal score is 24, and non-comparative studies in 8 domains and the ideal score is 16. Higher score manifests higher quality and lower risk bias.

3. Results

3.1. Study selection

Through an electronic search of the three databases, 271 articles were found. After the removal of duplicates, 181 articles were obtained. 21 articles were found by screening the citations and reference lists of the selected studies. According to the inclusion and exclusion criteria, 146 articles were excluded after evaluating the titles and abstracts of these articles. Further evaluations of the full texts were performed in these 56 remaining articles. Finally, a total of 10 articles were obtained for data extraction and analysis (Fig. 3).

3.2. Study characteristics

Table 1 presents an overview of the characteristics of all included studies. The included studies were all retrospective studies or prospective studies, and there were no randomized controlled trials related to the management of CR, thus MINORS was used to assess the bias of these studies. Only one comparative study was identified, and had a score of 15 out of 24, which indicated a moderate risk of bias. The other nine studies yielded an average score of 10.4 out of 16, which also indicated a moderate risk of bias. The most common methodological flaws seen in these studies were short of sample size calculation, absence of an unbiased assessment of the outcome variables, and the lack of a long-

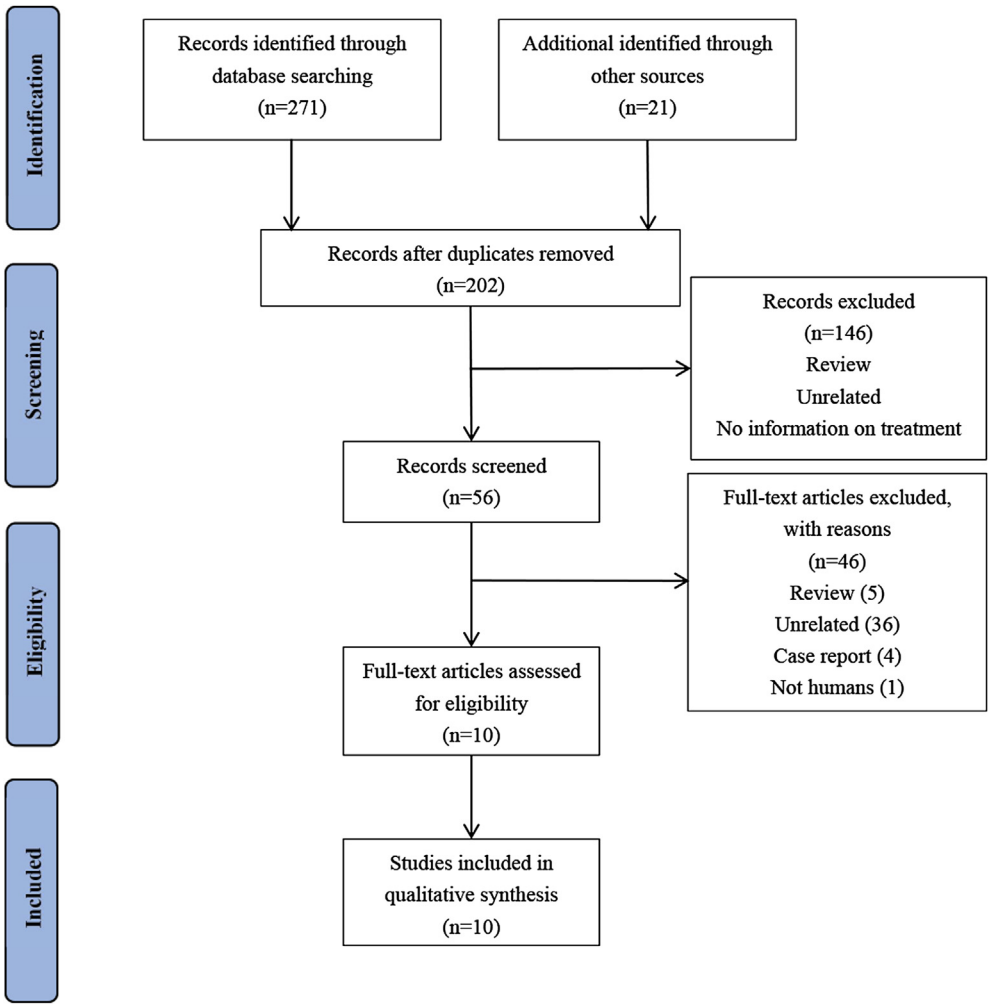

Fig. 3. Flow chart of the study selection process.

term follow-up. According to the risk of bias assessment, excluding specific studies was not needed. In these 180 patients, 142 were diagnosed with CR, the rest were CR after OS. Through chart analysis, the disease affects females (94%) more frequently than males (6%). The age of the patients ranged from 13 to 44 years, and the mean age was 22 years, of whom the young females accounted for the majority.

3.3. Treatment performed

Various methods have been used to treat CR, which results in different relapse rates. The most common therapy was OS combined with conservative treatment and it might have an acceptable result. OS usually includes bilateral sagittal split osteotomy (BSSO), Le Fort I osteotomy, and it might add genioplasty if indicated. The main purpose of OS was counter-clockwise advancement rotation of the maxillo–mandibular complex to correct dentofacial deformities. Conservative management usually includes occlusal splints, medicine, orthodontic and restorative treatment. Several studies chose conservative treatment alone to control CR in progression and it might come to a stable result. Nevertheless, conservative treatment might halt the resorption, but it could not correct the dentofacial deformities due to CR. Additionally, OS alone, also used in some studies, leads to a relatively higher relapse rate. Some surgeons might prefer more aggressive methods to manage CR, such as disc reposition and stabilization, condylectomy and costochondral grafts or total alloplastic TMJ reconstruction. These more aggressive methods have more skeletally stable and TMJ functional result for the most part. What should be noted is that the selection of treatment was based on the severity of CR, the experience of the surgeon and the inclination of the patients.

By analyzing these methods and comparing their results, we have drawn a flow chart to instruct the treatment selection of CR before OS (Fig. 4).

4. Discussion

Various measures have been discussed to quantify CR in different studies, but its diagnosis still remains controversial. A diagnosis of CR can be made based on the combination of radiological signs and clinical evaluation (Wolford, 2001). In some cases, a difference of more than 6% in vertical dimension between left and right sides of condyle could be considered as CR (Moore et al., 1991). However, condylar asymmetries within a margin of 6% on panoramic X-ray may be caused by technical failures and it is not easy to distinguish (Habets et al., 1988). Recently, a loss of 17% original condylar volume concerned as a diagnostic method for CR by application of a validated 3D condylar segmentation technique (Xi et al., 2015).

Table 1
Characteristics of included studies.

Authors (year)	Country	Study design	Assessment of bias	Gender (female: male)	Age	Number	Diagnosis	Management	Follow-up (months)	Outcome measured	Relapse rate
Merkx and Van Damme (1994)	Netherlands	RS	10/16	8:0	23 ± 7	4	OSCR	OS: ma ± mb	12–36 m	a, b, c, d	100%
						4	OSCR	CT: occlusal split ± orthodontics, prosthetic therapy			0
Wolford and Cardenas (1995)	USA	RS	9/16	-	21 ± 15	12	CR	DRF + OS (bi)	18–68 m	a, b, c, d, e, f	0
Huang et al. (1997)	USA	RS	10/16	26:2	24 ± 12	18	16CR 2OSCR	OS: (mb ± ma) ± ge	>24 m	a, b, c, d, f	25% 0
						4	2CR 2OSCR	CCG			0
						6	CR	CT			–
Hoppenreijs et al. (1999)	Netherlands	RS	15/24	23:3	22 ± 15	13	OSCR	CT: splints, orthodontics ± restorative dentistry	24–132 m	a, b, c, d	0
						13	OSCR	OS (mb ± ma)+ CT (splints, medicine)			46%
Hwang et al. (2006)	South Korea	RS	10/16	15:0	<25	15	CR	OS: bi	12 m	a, d	0
Teitelbaum et al. (2007)	France	RS	10/16	10:0	26 ± 14	10	CR	OS:(ma, mb, or bi ± ge)	12 m	a, b, c, d	0
Troulis et al. (2008)	USA	RS	12/16	13:2	24 ± 20	15	CR	CCG ± ge	12–84 m	a, b, c, d, f	0
Arnett and Gunson (2011)	USA	PS	9/16	-	-	21	CR	OS (bi) + CT (medicine)	>12 m	b, c, d, f	0
Mehra et al. (2016)	USA	RS	12/16	21:0	25 ± 7	21	CR	TJR + OS (mb ± ma)	60–144 m	a, b, c, d, e, f, g, h, i	0
Galiano et al. (2017)	USA	RS	12/16	20:4	16 ± 4	24	CR	DRF + OS (bi)	12–72 m	a, b, c, d, e, f, g, h, i	0

RS, retrospective study; CR, condylar resorption; OSCR, condylar resorption after orthognathic surgery; OS, orthognathic surgery; ma, maxillary surgery; md, mandibular surgery; CT, conservative treatment; DRF, disk reposition and fixation; bi, Bimaxillary surgery; ge, genioplasty; CCG, costochondral grafts; PS, prospective study; TJR, total alloplastic TMJ reconstruction. a, skeletal stability; b, occlusal stability; c, TMJ condition; d, radiographic feature; e, pain; f, maximal interincisal opening; g, functional disability; h, dietary restriction; i, headache.

At present, several studies have been conducted on the relationship between OS and CR, although there is still a lack of unified standards to manage CR. Optimal anesthetic and functional outcome, as well as long-time skeletal and occlusal stability, could be defined as successful treatment (Mitsimponas et al., 2017). Generally, CR is not a contraindication to OS, but active CR preoperatively is more likely to cause the recurrence of maxillofacial deformities, which affects the long-term effect of OS. Therefore,

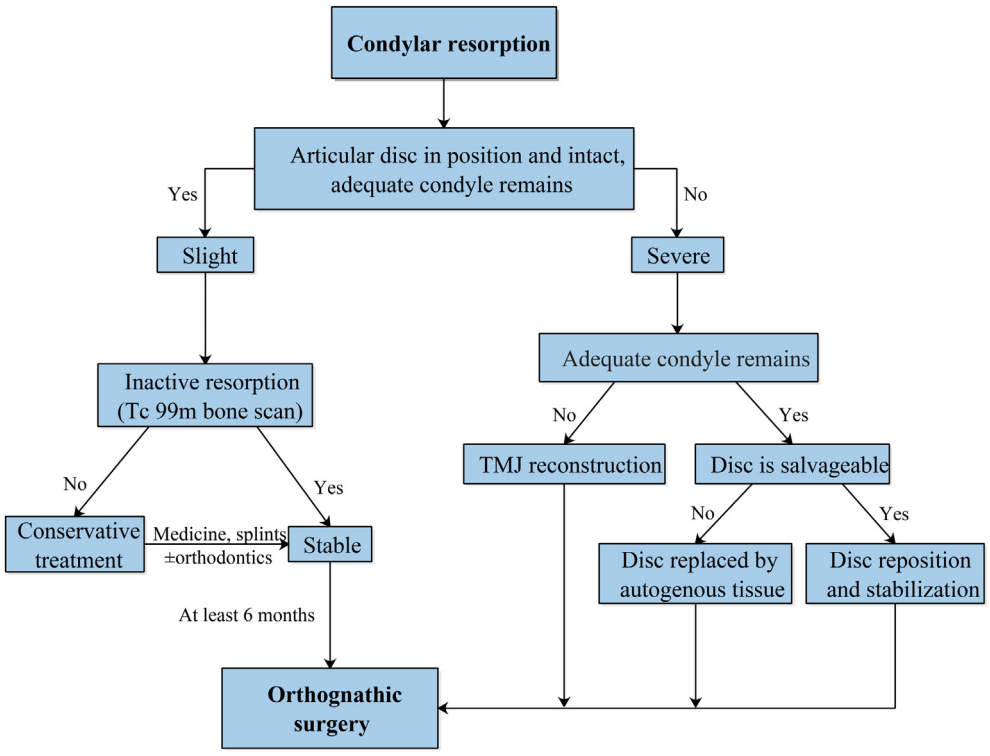

Fig. 4. The treatment strategy of condylar resorption before orthognathic surgery.

resorption should cease at least 6 months before surgery (Huang et al., 1997). However, some studies also believed that CR needs to be inactive for more than two years before surgery to achieve a stable result (de Bont and Stegenga, 1993). In general, the following methods are helpful to determine whether CR is in a progressive stage: ^{99m}technetium-methylene diphosphonate bone scan, cone beam computed tomography (integrity of the condylar cortical bone), magnetic resonance imaging (integrity of the fibrous cartilage on the surface of the condyle), comparison series imaging data (changes in maxillofacial contour or occlusion) (Valladares-neto et al., 2014).

4.1. CR before OS

OS alone had been used to treat CR in several studies but resulted in a relatively high relapse rate. In the study of Huang et al. (1997), sixteen patients with CR received OS, only eight patients had satisfactory outcomes, while the others had CR recurrence or TMJ symptoms. Hwang et al. (2006) analyzed 15 patients after undergoing OS who showed a relatively stable result. However, it should be noted that the follow-up period used in the study is too short and a longer time is needed. Therefore, it might be essential to manage CR effectively before receiving OS to correct the dentofacial deformities. Occlusal splint combined with orthodontic and restorative treatment can be used to manage slight CR before surgery. Gunson et al. (2012) believed that pharmacologic management had great potential in controlling CR progression, but further studies were needed to prove these effects. In another study, Arnett and Gunson (2011) analyzed 21 patients with pre-existing CR who underwent OS, several techniques were used to minimize CR relapse including pre and post surgical TMJ medical management, non-compressive condylar seating, short BSSO splitting technique, BSSO mini plating without clamping, and post-surgical skeletal and class II elastics. They found that after at an average of 36 months, all patients had stable occlusion and were without TMJ problems. However, for severe CR, OS alone may not eliminate TMJ problems, and it most likely leads to the recurrence of CR. Hence TMJ surgery might be needed (Chigurupati and Mehra, 2018). Wolford (2007) pointed out that if the articular disc could be salvaged and the remaining condyle was adequate, TMJ surgery and OS could be performed at one operation, or TMJ surgery could be performed followed by OS. Patients could achieve satisfactory results by being treated with following steps: Excision of the hyperplastic synovial tissue from the joint, Repositioning and stabilization the articular disc, and Concomitant OS. When the disc could not be salvaged but adequate condyle remains, the damaged disc can be replaced by autogenous tissue (Mitsimponas et al., 2017). If the articular disc is severely damaged and the remaining condyle was not enough, the condylectomy and reconstruction could be performed (Troulis et al., 2008). Because of the growth potential of costochondral graft, the long-term effects of condylectomy and costochondral graft need to be observed (Mercuri, 2007; Troulis et al., 2008). Total alloplastic TMJ reconstruction was also selectable, many studies have shown skeletally stable and good occlusion after surgery (Mehra et al., 2016; Mercuri, 2007).

4.2. CR after OS

CR occurs frequently after bimaxillary surgery or mandibular surgery, but it may also occur after maxillary surgery (Hoppenreijs et al., 1998; de Mol van ottrtloo et al., 1993). OS may result in spatial position of condyle changed or increased loading on the TMJ, thus lead to CR (Dicker et al., 2013), especially for the patients with the characteristics of class II malocclusion combined with anterior open bite. When the proximal segment of mandible was counterclockwise rotated to correct open bite, the anterior of the condyle was rotated superiorly. Therefore, the force loaded on the anterior condyle was increased compared to the past, while the bone density of this site was relatively lower, which could easily lead to CR in this site after surgery (Hwang et al., 2000). Other theories proposed in the literature stated that bone split and surrounding soft tissue dissection during surgery could affect the blood supply of the condyle, which might be the reason for postoperative CR (Borstlap et al., 2005; Schellhas et al., 1989; Chuong et al., 1995).

The incidence of CR after OS was about 2%–5%, and the incidence in patients with class II malocclusion combined with high mandibular plane angle was approximately 19%–31% (Handelman and Greene, 2013). CR can occur from 6 months to 2 years after surgery (Kobayashi et al., 2012; Valladares-neto et al., 2014). In addition, it is difficult to define whether the resorption is caused by OS or it was still in progression before surgery (Hoppenreijs et al., 2013; Al-Moraissi et al., 2017).

Treating CR after OS must be careful and well planned as the risk of relapse of the disease is very high. To manage slight CR after OS, occlusal splints and medication, sometimes combined with orthodontic treatment, were commonly used as conservative therapy. Two scholars utilized occlusal splints combined with orthodontic treatment to control CR in their respective studies, and it came to a stable and acceptable result during the follow-up observation period of 24–27 months in a total of 17 patients (Hoppenreijs et al., 1999; Merkx and Van Damme (1994)). For patients with severe CR, OS alone takes a high risk of recurrence. In the study of Merkx and Van Damme (1994), four out of eight patients who presented with CR showed poor results after reoperation. In the study of Hoppenreijs et al. (1999), thirteen cases received secondary surgery after CR became inactive through conservative management. During a follow-up period of at least two years, 7 cases showed stable results, while 4 cases showed signs of recurrence in a different degree but with stable occlusion, and 2 cases received reoperation. A similar finding was seen in the study of Crawford et al. (1994), seven patients received reoperation after conservative treatment, two of them had stable skeletal results and good occlusion after a long follow-up, while the other five patients resulted in a different degree of relapse that varied from 25 to 75% relapse at B point. These findings suggest that conservative treatment might be effective to manage slight CR, but TMJ surgery might be needed in these patients with severe CR after OS. Condylectomy and reconstruction would come to a more stable and predictable result (Mercuri, 2007; Huang et al., 1997). The treatment method of CR after OS is mostly selected based on the comprehensive consideration of the severity of CR and the intention of the patient.

4.3. How to prevent CR

Currently, there is no consensus on how to prevent CR after OS, and most of the relevant studies took corresponding measures in

Table 2
Risk factors of condylar resorption.

Patients factors	Surgery factors
Preexisting temporomandibular joint diseases	Bimaxillary surgery
Systematic disorders (such as autoimmune and connective tissue disease)	Mandibular huge advancement > 10 mm
Skeletal classII malocclusion due to mandibular retrognathism	Counterclockwise rotation of the mandibular proximal segments
High mandibular plane angle (>40°)	Overloading on condyle
Posteriorly inclined condylar neck	Condylar displacement
Female between 15–35 years old	Prolonged intermaxillary fixation

terms of the risk factors of CR. Compared with mandibular or bimaxillary surgery, maxillary surgery alone can correct occlusion with more stable results and lower risk of CR, but the efficacy of correction for maxillofacial deformity is limited (Mitsimponas et al., 2017). If there is slight CR before surgery, it is necessary to actively control CR in progression. And a stable condyle for at least 6 months is required before considering OS. For patients with severe CR, stable results can be achieved by disc reposition and stabilization or condylectomy and TMJ reconstruction. For patients with mild or no preoperative CR, measures can be taken to prevent CR according to its related risk factors as summarized in Table 2 (Hwang et al., 2000, 2004; Nogami et al., 2017; Friscia et al., 2017).

5. Conclusion

On the basis of these manifestations, the occurrence of condylar resorption can be influenced by complex factors. The management of condylar resorption before or after orthognathic surgery should be based on the severity of condylar resorption. Since only a few studies with small samples have been conducted and few randomized controlled trials on this subject, it is evident that more high-quality research concerning CR treatment is needed. In the future, the clarification of etiology and pathogenesis of CR will play an important role in the treatment of CR.

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Conflicts of interest

None.

Author Contributions

He Ze, MD Data collection, analysis of data and writing of manuscript.

Ji Huanzhong, PhD Data collection and analysis of data.

Du Wen, PhD Data collection and analysis of data.

Xu Chunwei, PhD Data collection and analysis of data.

Luo En, PhD Analysis of data and writing of manuscript. (senior surgeon).

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