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TMJ response to mandibular advancement surgery: an overview of risk factors

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ABSTRACT

Objective: In order to understand the conflicting information on temporomandibular joint (TMJ) pathophysiologic responses after mandibular advancement surgery, an overview of the literature was proposed with a focus on certain risk factors. Methods: A literature search was carried out in the Cochrane, PubMed, Scopus and Web of Science databases in the period from January 1980 through March 2013. Various combinations of keywords related to TMJ changes [disc displacement, arthralgia, condylar resorption (CR)] and aspects of surgical intervention (fixation technique, amount of advancement) were used. A hand search of these papers was also carried out to identify additional articles. Results: A total of 148 articles were considered for this overview and, although methodological troubles were common, this review identified relevant findings which the practitioner can take into consideration during treatment planning: 1- Surgery was unable to influence TMJ with preexisting displaced disc and crepitus; 2- Clicking and arthralgia were not predictable after surgery, although there was greater likelihood of improvement rather than deterioration; 3- The amount of mandibular advancement and counterclockwise rotation, and the rigidity of the fixation technique seemed to influence TMJ position and health; 4- The risk of CR increased, especially in identified high-risk cases. Conclusions: Young adult females with mandibular retrognathism and increased mandibular plane angle are susceptible to painful TMJ, and are subject to less improvement after surgery and prone to CR. Furthermore, thorough evidenced-based studies are required to understand the response of the TMJ after mandibular advancement surgery.

Keywords: Temporomandibular joint. Orthognathic surgery. Mandibular advancement. Bone resorption.

INTRODUCTION

Temporomandibular joint (TMJ) response to mandibular advancement surgery is sporadically associated to arthralgia (pain), functional limitations, condylar resorption and skeletal relapse. When the mandible is advanced and fixed, the adjacent tissues are stretched and tend to displace the distal segment back toward its original position[46,54,96,97]. This response to mandibular advancement is countered bilaterally by the TMJs and may contribute to less stability[76].

The adverse effects of mandibular advancement surgery on the TMJs form a pertinent theme well explored in the literature[5,7,20,29,56,65,81,99,104,105,134,138,139,142]. The TMJ response ranged from adaptive, which included physiological bone remodeling[28,34,45], to irreversible complications[9,10,55]. Undesired TMJ responses to treatments in both short and long-term follow-up periods, such as condyle torque[14,138], joint sounds (clicking, popping, crepitus)[53], deteriorated discomfort and pain[107,141], deviated or limited mouth opening[55,96,138], and condylar resorption (CR)[29,81,96] have all been reported. However, the limitations and heterogeneity of the studies cannot be overlooked, and because the TMJ response is of multifactorial origin and there is a wide range of individual variability as well as different surgical techniques, there is still controversy as to whether mandible advancement surgery is detrimental to the TMJ. Systematic reviews published in this field found an intermediate degree of evidence and proved inconclusive[1,6,76,77]. Moreover, for ethical reasons, randomized clinical trial designs involving surgery are limited.

In order to understand the conflicting information on the TMJ response to mandibular advancement surgery and to allow the practitioner to take this into consideration during treatment planning, this overview centered on five risk factors: disk displacement, arthralgia, CR, mandibular fixation techniques, and the amount of mandibular advancement.

METHODS

Criteria for including studies in this review

High-quality research, such as randomized clinical trials, systematic reviews and meta-analysis, is uncommon in the surgical field, despite current high levels of emphasis on evidence-based Dentistry. Hence, intermediate degrees of evidence were found in systematic reviews published on this theme[1,6,76,77]. Although the issue in this research refers to intervention, the study design pertained to a wider spectrum of studies, which included animal searches, serial cases, updates and observational studies on temporomandibular disorders (TMD), comprising a narrative review (non-systematic review).

Search strategy

Publications were identified through searches of the following databases: Cochrane, PubMed, Scopus and Web of Science in the period from January 1980 through March 2013. Databases were searched for papers published in English. The following search terms were used and combined (AND): "condylar resorption", "mandibular advancement surgery", "rigid internal fixation" (RIF), "sagittal split ramus osteotomy" (SSRO), "temporomandibular disorder" (TMD), and "relapse". In addition, a hand search of the reference lists was carried out to identify additional papers.

Data synthesis

Data was pooled into evidence tables and grouped according to the subjects (1-articular disc displacement, 2- arthralgia, 3- CR, 4- mandibular fixation techniques, and 5- amount of advancement). The study design was identified and a descriptive summary was performed.

RESULTS

This overview comprised a total of 148 articles. Retrospective and prospective clinical studies involving TMJ and mandibular advancement surgery were classified and distributed according to the above-mentioned subjects, and shown in Table 1.

Articular disc displacement

Disc displacement (or internal derangement) is subdivided into disc displacement with and without reduction and the latter is further subdivided into with or without limited mouth opening[40]. Disc displacement with reduction and no further signs or symptoms is considered not clinically relevant[127]. Anterior and medial or lateral disc displacement is the most common TMJ disorder in people in general and seems to be more prevalent in patients with dentofacial deformity[30,63,88,130,146,147].

Arthralgia is not always followed by disc

Table 1- Classification and distribution of retrospective and prospective clinical studies

Category	Number of papers (n)	References	Percentage (%)
1. Articular disc displacement/ Clicking	6	6,56,62,103,106,144	7.3
2. Arthralgia (TMJ pain)	23	1,6,12,20,29,32,33,37,49,62,78,88,101,104, 107,108,109,115,120,124,141,142,146	28
3. Condylar remodeling and resorption	12	11,29,68,69,70,72,73,74,79,82,91,134	14.6
4. Mandibular fixation techniques	14	16,18,19,20,22,23,31,49,51,55,62,119,12, 138	17.1
5. Amount of mandibular advancement	9	11,18,19,23,29,42,119,135,138	11
6. Others (releapse and condylar position)	18	4,7,14,15,21,28,38,40,64,65,66,78,94,95,9, 126,131,140	22

TMJ=temporomandibular joint

displacement, but noise (clicking) or restricted mouth opening are the most frequently found clinical signs. Clicking and arthralgia have been proven to fluctuate over time[89], and, because of this complex interaction, a wide range (26 to 97%) of disc displacement has been found in asymptomatic patients seeking orthognathic surgery[2,30,54,88,147]. No association was seen between disc displacement, pain and the type of dentofacial deformity[30].

The relationship between disc displacement and degenerative bony changes has still not been fully clarified. There is a consensus that the natural progression of disc displacement with reduction precedes disc displacement without reduction, but the natural progression of the joint disc displacement in CR has not been well defined[83]. The clinical signs and symptoms of anterior disc displacement without reduction tended to alleviate during the natural course of the condition[83,118], except for a quarter of patients who showed no improvement after 2.5 years of follow-up, but there was no deterioration either or change in CR during this period of time[83]. Disc displacement and CR probably often occur simultaneously, but are considered independent disorders, with CR being trigged by other factors, including age[82,83].

Systematic reviews on temporomandibular disorder (TMD) both before and after orthognathic surgery have also reported a heterogeneous study design and controversial results[1,6]. Hackney, et al.[61] (1989) did not find any significant difference in the incidence of TM pain or clicking following bilateral sagittal split osteotomy and rigid fixation. But the major evidence with regard to clicking after orthognathic surgery points to the fact that there is greater likelihood of improvement rather than deterioration[6,55,67,107,120,146], even if such improvement is temporary[89]. For these reasons, there is no individual guarantee for the evolution of clicking, in contrast to disc displacement and crepitus which do not seem to be affected by SSRO for mandibular advancement or setback[6,80,133], unless a specific surgical intervention is undertaken to recapture the disc in TMJ[57].

Arthralgia (TMJ pain)

Temporomandibular arthralgia can be defined as pain and tenderness in the joint capsule and/or the synovial lining of the TMJ due to an inflammatory process[40]. This localized condition is didactically separated into capsulitis and synovitis. The diagnosis is based on pain during palpation in one or both joint sites (lateral pole and/or posterior attachment), plus one or more self-reports of pain in the region of the joint, during maximum opening and/or during lateral excursion[34,88]. Arthralgia can lead to a reduction in chewing efficiency and limitation of mouth opening, and can be detected before[2,31,79] and/or after[54] orthognathic surgery. There are doubts about the efficiency of mandibular surgical advancement in mitigating temporomandibular symptoms.

In general, in terms of arthralgia, there is greater likelihood of improvement rather than deterioration after orthognathic surgery, but there is no individual guarantee of its evolution[6,31,32,36,67,107,108,115,133,141,142]. In the short term, an increase in muscle and TMJ symptoms was normally found after mandibular advancement surgery, and this tended to decline over time, without being considered a risk factor for TMD[54]. On the other hand, it cannot be overlooked that there is also a risk of asymptomatic patients developing TMD after surgery[20,79,115,120,124,142], and the condition of patients with TMJ symptoms worsening after surgery[12,103,108,142].

It has been suggested that Class II malocclusions with severe mandibular retrognathism and a hyperdivergent skeletal pattern are risk factors for painful TMD[75,93,100], and are subject to lesser improvement after surgery[31,36,141].

Studies have concluded that SSRO of the mandible has a favorable effect on TMJ symptoms[20,31,55,120,141,142], with better evolution for mandibular prognathism than mandibular retrognathism[141,142]. More specifically, De Clercq, et al.[31] (1995) found significantly fewer post-operative TMJ symptoms in normal/low angle mandibular deficiency deformity, while there was no significant difference in the high angle group.

Condylar remodeling and resorption

In both animal and human studies, condylar and fossa remodeling are common response to treatment involving mandibular advancement surgery. Ellis and Hinton[45] (1991) have shown remodeling changes occurring in the TMJ of the adult *Macaca mulatta* monkey. In human tomographic radiographs, superficial change with no major clinical relevance has been detected in the contour of healthy TMJ after surgery[28]. Changes in joint loading, muscle activity and the new condylar position may contribute to this adaptive occurrence[28,46].

On average, a more severe irreversible change in condylar shape can take place in approximately 5% of patients who undergo surgery to advance the mandible, but, in the literature[23,33,67,73,81,96,147], a larger range of 1 to 31% was found. Besides the TMJ compression generated by orthognathic surgery, other factors such as autoimmune and connective tissue diseases (rheumatoid arthritis, lupus erythematosis, scleroderma), trauma, infection, hormone imbalance (hyperparathyroidism, extremely irregular menstrual cycles, low 17β-estradiol), nutritional status, drugs (steroid use), repetitive oral habits, age and genetic background, have all been cited as triggering or aggravating this condition[9,10,38,49,58-60,84,144].

The shape and degree of severity of degenerative bony changes has been detected by CT scans. Such

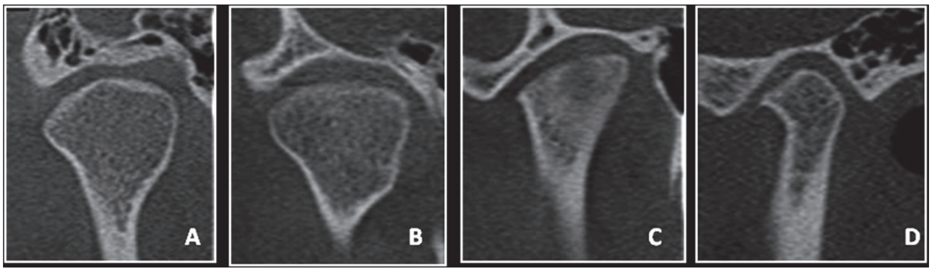

Figure 1- Cone-beam computed tomography images of temporomandibular joint showing morphological variation of the mandibular condyle. A- Normal (coronal view); B- Flattening (coronal view); C- Erosion (coronal view); and, D- Osteophyte (sagittal view)

Figure 2- Cone-beam computed tomography images of temporomandibular joint (coronal view) showing advanced destruction of mandibular condyle

shape changes have been classified as follows[147] according to an earlier report: *flattening* (a flat bony contour deviating from the convex form), *erosion* (a localized area of decreased density in the cortical condylar surface and adjacent subchondral bone), and *osteophyte* (a marginal bony overgrowth on the anterior part of the condyle) (Figure 1). Degrees of resorption of the articular surface have varied from superficial changes to complete destruction at advanced stages[9,10,26,38] (Figure 2).

The spectrum of clinical and pathological changes in CR may include disc displacement, perforation and destruction; crepitus; hyperplastic synovial tissue; synovitis; and loss of articular fibrocartilage. In addition, there have been changes in shape and a reduction in the size of condyles[69,78,144]. Some of the patients affected are asymptomatic, except for joint sounds[78,122], while a quarter may develop pain, crepitus, or irregular or limited mouth opening[9,33,78,81,128,144]. So, symptoms may, or may not, be detected and may vary pre- and post-surgically, and may worsen after surgery. Pain intensity was not correlated with the severity of the CR, except in one study using 3D surface models[26].

Localized (non-systemic) inflammatory disease has been called *idiopathic CR* when individual susceptibility is present and no identified etiologic factor is detected[113]. This bone loss has also been named *condylisis* (or *condylolysis*)[38], *condylar atrophy*[33,78,122], *progressive condylar resorption*[68,81], or *progressive mandibular retrusion*[9,10]. First described by Sesanna and Raffaini[122] (1985) and confirmed by others[69,81], a progressive, slow irreversible relapse of the mandible develops after mandibular advancement surgery, with a subsequent reduction in the height of the ramus, downward and backward rotation of the mandible, resulting in skeletal Class II malocclusion with an anterior open bite, a steep mandibular plane angle, increased lower facial height, and decreased chin projection. A decrease in the pharyngeal air way space has also been mentioned. Both joints can be symmetrically affected, or just one with minor occurrence, while bilateral involvement with an asymmetric outline is also common[56,144]. Several studies[23,33,68,72,74,78,81,92,94,96] have shown that the first signs of postsurgical development were detected 6 months or more after surgery and developed up to 2 years after surgery and was related to a long-term skeletal relapse. On the other hand, idiopathic CR has not been found only after orthognathic surgery, and may be observed during or after active dental restorative, orthodontic or before orthognathic surgery[113].

Idiopathic CR is a multifactorial disease, with surgical and non-surgical risk factors[23,69,73,74,81]. Retrospective[23,29,33,67,68,72-74,81,96,121] and prospective[22,120] studies have named some morphological features and outlined some risk factors. From these studies, it was concluded that idiopathic CR primarily affects 16 to 26-year-old females with a mean male/female ratio of 1/8, with skeletal Class II malocclusion due to mandibular retrognathism, and high mandibular plane angles combined with a low posterior facial height. Short condyles with posterior inclination, and/or bone loss before treatment were prone to CR after surgery, and there was a positive correlation with the amount of mandibular advancement and the degree of maxillomandibular counter-clockwise rotation.

Contributing surgical factors have been associated with mechanical overloading and a reduction in vascular supply to the condyle, which may exacerbate the disease in susceptible patients who have undergone mandibular advancement surgery[67,96].

Mandibular fixation techniques

Methods of stabilizing the proximal to distal segments at the moment of surgery have progressed from wire fixation to rigid internal fixation (RIF). Wire osteosynthesis was performed in conjunction with a 6 to 8-week period of maxillomandibular fixation (MMF) and was linked, with some exceptions[39,135], to postsurgical relapse[16,23,37,95,119], due to the weak bone union of the segments which permits proximal segment rotation at the osteotomy sites[16]. However, in terms of temporomandibular joint pain[48,50,101,129] and the mandibular range of motion[65], no differences were detected between MMF and RIF.

Spiessl[125] (1974) introduced RIF in 1974. His method involved using three lag-screws at the osteotomy site (two above the neurovascular bundle, and one below). The advantages of RIF included an early return to normal function, better nutrition support and improved stabilization of the bony segments, which allows for faster bony repair without MMF. Studies on mechanical proprieties and stability at the osteotomy site have attested that RIF is better than wire fixation[27,37,95,98,106,110,137]. However, the major concern when the mandible is being surgically advanced and rigidly fixed is the risk of damaging the neurovascular bundle and imprecise condylar positioning due to the torque of the rami. In this respect, animal studies[45,99] have detected a more pronounced effect of the condyle when the rigidity of the fixation method was greater. The intense rigidity brought about by bicortical lag-screws may close the gap between the bone segments and torque the condyle, move it out of the mandibular fossa and cause transverse displacements of the proximal segments[14,15,42,140]. Consequently, several modifications of RIF patterns have been proposed, varying according to type, number, site, size and placement of screws and miniplates[8,24,47,51,52,62,66,76,90,112,117,136].

One way of maintaining the gap while at the same time applying stable fixation is to use positional bicortical screws (non-compressive or non-lag), miniplate systems, or both (*hybrid* technique)[42,103,111]. Large gaps between the proximal and distal segments can be minimized by the removal of bone interferences or by using secondary osteotomy before fixation of the mandible[42].

Positional bicortical screws have been commonly applied in three linear or L designs[66] (pattern, backward, inverted, and inverted backward); and inserted at 90° (perpendicular) or 60° angles[117,132]. One of the advantages of using screws at a 60° angle is the possibility of intrabuccal insertion. Miniplate systems have been used with the technical variant of a horizontal or oblique direction, and fixed with monocortical screws. They also obviate the need for transcutaneous puncture, and its subsequent scarring, reduce time spent in surgery, and pose less risk of nerve damage and condylar torque[15]. Because the system is less rigid[106,117], it is also called *semi-rigid* fixation[99,109]. Several *hybrid* techniques have been cited, such as the miniplate with monocortical screw fixation and positional screws placed bicortically, by means of the plate, or placed separately above or below the plate[98,103,107,111].

Retrospective clinical studies[18,67] have shown that postsurgical stability and condylar changes were not significantly different after using either the miniplate system or positional screws in sagittal split ramus osteotomy. However, *in vitro*[8,24,62,106,112,117,123,136] and finite element[27,47,90] studies have shown that miniplate systems provided less mechanical stability in bone segments when compared with different arrangements of bicortical positional screws, and this has been supported by clinical reports that malocclusions developed from a loss of miniplate fixation after mandibular advancement surgery[44].

In summary, earlier biomechanical studies compared different designs of mandibular fixation and showed that[24,98,106,117,132]: 1) three positional screws were equivalent to the *hybrid* technique with one miniplate fixed with monocortical screws and one positional screw; 2) 2.7 mm screws offered no advantage over 2.0 mm bicortical screws; 3) the angle of insertion of the screw at 90° (percutaneous placement) or 60° (transoral placement) made no significant difference in the resistance of sheep osteotomized mandibles. However, perpendicular insertion (90°) of the screws in inverted-L and linear configurations offered greater laboratory resistance in polyurethane models; and, 4) obliquely placed miniplates offered greater biomechanical stability than those placed horizontally.

Amount of mandibular advancement

The amount of mandibular advancement is another surgical aspect which would appear to contribute towards increasing mechanical loading on TMJ[43,45]. Elis and Sinn[46] (1994) demonstrated that the extent of the stretched tissue correlated with the amount of mandibular advancement, suggesting that a larger surgical movement showed a greater tendency towards distal displacement of the surrounding soft tissue in the postsurgical period.

In consonance with this statement, several studies corroborated a considerable correlation between the amount of mandibular advancement and an increase in condylar displacement[4,43,45,139], muscle and TMJ symptoms[54], relapse rate[11,18,19,21,39,75,137,139] and the occurrence of CR[29,117,118]. However, others failed to demonstrate a tendency towards relapse[41,95,114], probably because there were not many patients in the samples with greater mandibular advancement.

A systematic review conducted by Joss and Vassalli[76] (2009), with regard to surgical stability, pointed out that a ≥7 mm mandibular advancement predisposed towards horizontal relapse. In the literature, surgical technique modifications are used to alleviate stretched tissues and prevent skeletal relapse. Suprahyoid miotomy involved detaching the geniohyoid and anterior digastric muscle in order to reduce stretched tissue at the time of mandibular advancement[43]. However, clinical studies have not been able to confirm this effect[121].

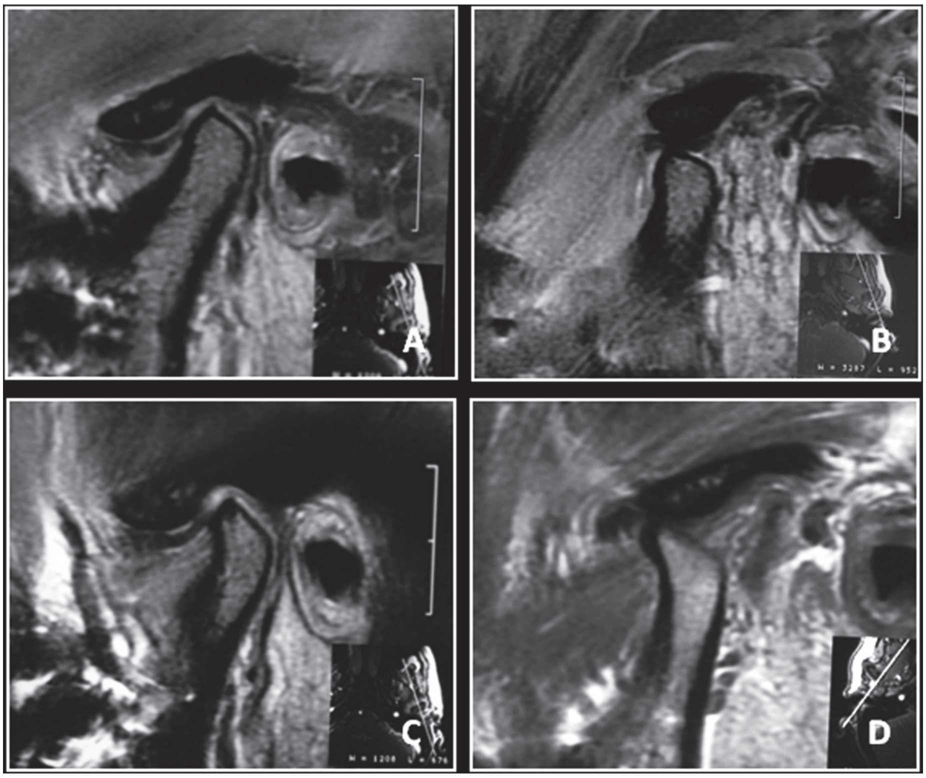

Figure 3- Presurgical magnetic resonance of temporomandibular joint showing disc displacement with reduction (A and B), and 10 years after mandibular surgical advancement (C and D) showing the maintenance of the disc status and the onset of condylar degeneration

Figure 4- A 23-year-old woman who had maxillary posterior impaction, mandibular autorotation and genioplasty for advancement. Relapse of Class II maloclusion was evident at long-term postsurgery due to condylar resorption. Facial photos before orthognathic surgery (A); 6 months (B) and 3 years (C) after orthognathic surgery are shown. Patient signed informed consent authorizing the publication of these pictures

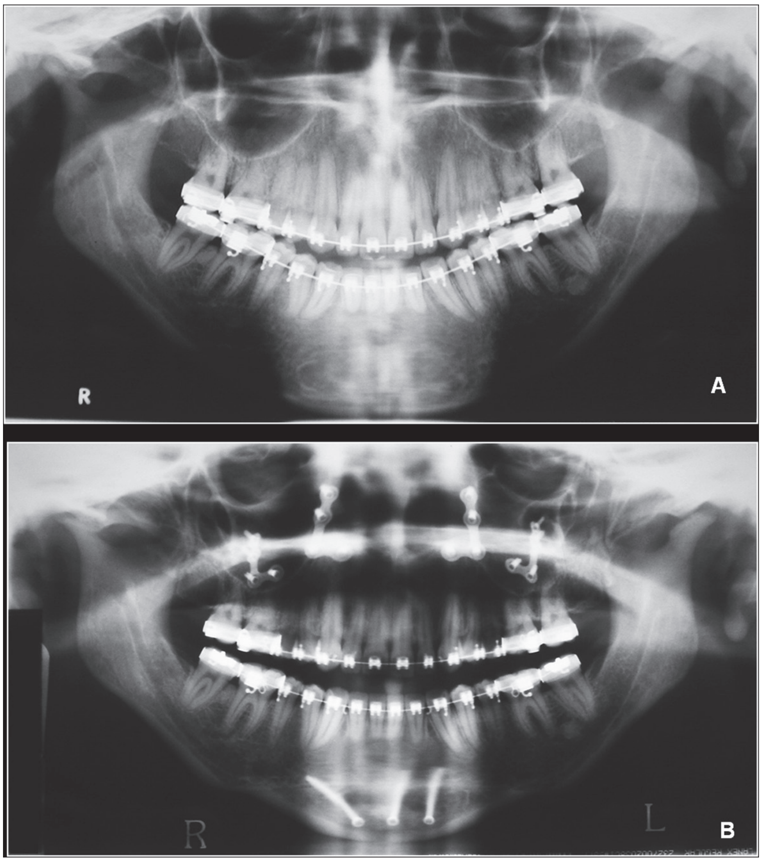

Figure 5- Sequence of figure 6 presenting panoramic images before (A) and after (B) surgery showing the pre-existing juvenile idiopathic arthritis and the deterioration after surgery

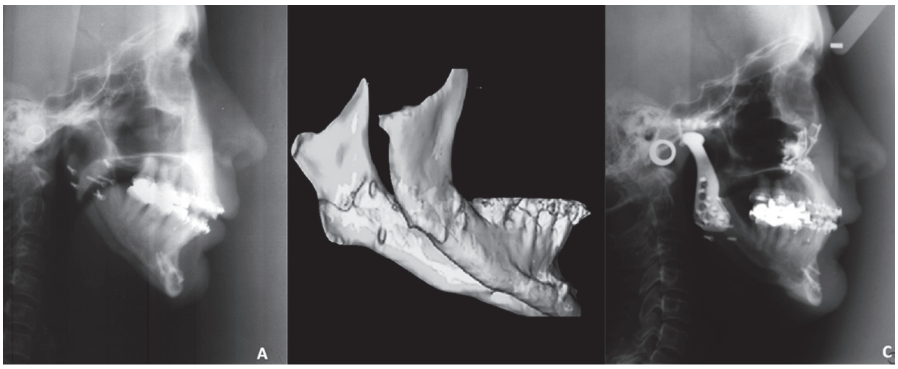

Figure 6- Complete destruction of condyle in a patient who had undergone orthognathic surgery, and was re-treated with the aid of temporomandibular joint prostheses. Before surgery (A), 3D image of the mandible showing bilateral absence of condyles (B), and after surgery (C)

DISCUSSION

Several studies point to mandibular advancement surgery as a potential factor in bringing about TMJ changes, especially in condylar position and shape[4,46,63,64,97,126,138,139]. A successful functional outcome depends on the final TMJ position and the patient's health, including the remission of preexisting TMD. This study reviewed the response of the TMJ to mandibular advancement surgery by analyzing certain risk factors, which included three TMJ changes (disk displacement, arthralgia, and CR) and two treatment variables (fixation techniques and the amount of advancement). Overall, surgery did not manage to change the presurgical disc position or correct the anterior disc displacement; although it tended to improve preexisting arthralgia without individual guarantees or in a predictable way; and increased the risk of CR, especially in identified high-risk cases. The amount of mandibular advancement[81,119], counterclockwise rotation[74], and the rigidity of the fixation technique[45] seemed to influence TMJ position and health. However, the literature frequently presented methodological problems, which limited the final evidence.

Little information was found in the literature to reduce bias and strengthen the evidence[6,13,56,82]. Certain methodological problems were identified, including: sample size; a lack of defined inclusion criteria; the presence of heterogeneous groups made up of patients who had undergone different types of surgery; the presence of confounding factors; longitudinal studies with short follow-up periods; error analysis method; blinding in measurements; inadequate statistics; extrapolation from animal studies to humans; generalization of *in vitro* biomechanical results without considering individual variation; little research on the correlation between clinical findings and TMJ images; poor imaging techniques; lack of longitudinal observational and interventional studies; TMD type not always identified; unrecognized TMJ problems before surgery; lack of functional data; different characteristics of the sample with regard to the skeletal relationship, race and age; and lack of internal controls. Although magnetic resonance imaging is the diagnostic "gold standard" for disc displacement, few studies used this methodology before or after orthognathic surgery in a long follow-up period. Nevertheless, relevant data from this overview is useful for clinical comprehension and practice.

It has been assumed that joints with preexisting displaced discs and crepitus are more likely not to change or improve after mandibular surgery[6,55,57,104], unless a specific surgical intervention is undertaken to recapture the disc[57,143,144] in TMJ. This could be explained by the persistent compression of the condyle against the posterior ligament after surgery. The significance of this persistent disc displacement after surgery is unknown especially in relation to the onset of degenerative disease, as the natural course of the disease could be superimposed on the effects of the treatment and act as a confounding factor (Figure 3).

Most patients present limited or deviated mouth opening shortly after surgery[55]. This condition can be of muscular or joint origin. When it is of muscular origin, it is attributed to myositis, associated with surgical trauma and can lead to severe functional impairment and disability. But the condition improves post surgically, and most patients regain their full range of movement in the long-term[6,65]. It is also hypothesized that improvement in self-image after surgery reduces patients' negative feelings, irrespective of the functional outcome[108]. On the other hand, it cannot be ruled out that persistent orofacial pain after surgery can be modulated by the central nervous system. When of joint origin it is presumed to be temporary[54]. It would also be associated with disc displacement without reduction, which does not seem to be directly influenced by the surgery[6].

It has been considered that minimal condylar and fossa remodeling are unavoidable after mandibular advancement surgery, thus falling within the physiological range of adaptation. An exception is greater condylar destruction, which extrapolates the level of adaptive tolerance and precipitates the development of occlusal and skeletal changes[81]. According to Proffit[114] (2000), a loss of more than 2 mm occurred in 10% of patients undergoing mandibular advancement surgery and occlusal instability was found in half (5%) of these patients. The amount of bone loss in TMJ detected in images extrapolating the level of adaptive tolerance in unknown, but the precise limit can be established in accordance with the development of occlusal and skeletal changes[56].

Because idiopathic CR is more common among females, it has been proposed that it may be related to the sex hormone[9,58,59]. In animal studies[102,148], estrogen has been implicated as a mediator of degenerative remodeling of the TMJ, and the increased number of receptors may predispose to an exaggerated response to the loading of the condyle after mandibular advancement surgery. A factor also to be considered in this context is the higher prevalence of TMJ dysfunction among females[89].

The wide range (1 to 31%) of occurrence of CR after orthognathic surgery expressed in the literature may be due to the lack of well-defined diagnostic criteria and the variety of image techniques used. Recent guidelines have recommended computed tomography (CT) as the modality of choice for evaluating TMJ osseous change, as CT images are considered more accurate than panoramic images or cephalograms[3]. Adequate parameters of FOV and voxel size should be adopted, because they strongly influence the diagnostic efficacy to detect erosions in the TMJ[86]. Moreover, a refinement in image analysis for accurate visualization through the reconstruction of 2D images in a 3D surface-mapping technique using cone-beam CT (CBCT) images might provide the location and quantification of previously unidentified CR[25,26].

It is also equally important to consider the idiopathic and rheumatoid CR activity (active or inactive) and the stage of condylar destruction and jaw discrepancy (mild, moderate or severe). This condition has a natural course of evolution and may express a different prognosis. Active resorption has an unpredictable course of duration, but it is known that the idiopathic condition primarily affects young adult females of the age of those most frequently undergoing orthognathic surgeries. It has been presumed that active CR arises out of a loss of cortical bone coverage, typically found at the erosion stage in CT or in magnetic resonance imaging evidencing the lack of cartilaginous integrity of the condylar surface. It is also detected on bone scintigraphy[69,113,130]. Because false positive and false negative may occur with scintigraphy exam, longitudinal CT images should be recommended to identify presurgical condylar variants and map the stages of disease progression after treatment.

Most studies involving CR have focused on postsurgical occurrence and associated long-term relapse[33,68,69,94,96]. The treatment adopted in cases of relapse has varied from non-surgical (splint therapy, orthodontic camouflage and restorative dentistry) to surgical (re-intervention) approaches[17,68,69]. However, CR may be present prior to surgery[81,84], with onset during adolescence and may be of traumatic, rheumatoid, or idiopathic origin; and related to a secondary and late development of skeletal Class II with open bite malocclusion[17,147]. It has been well documented that TMJ degeneration does not improve with surgery[55], and can lead to unfavorable surgical outcomes because of postsurgical mechanical overloading combined with active resorption (Figures 4 and 5). For this reason, in cases of preexisting active CR, doubts arise about the best therapeutic option in terms of preventive management.

Cases of minor jaw discrepancies have been treated by conservative procedures (splint therapy; restorative dentistry; orthodontic treatment with or without skeletal anchorage)[85,92,128]. However, when major jaw discrepancies are present they are mainly treated by surgical protocols for functional and esthetic recovery[17,35,49,144,145]. Mandibular advancement surgery in cases of preexisting active CR has been associated with long-term relapse[69]. Therefore, different protocols have been suggested to help control the advance of condyle resorption or prevent surgical relapse. These include postponing the start of orthodontic-surgical treatment[113]. More recently, pharmacological control has been recommended both before and during orthodontic surgical treatment in order to stabilize active CR[59,84,116]. The different options of treatment include condylectomy and reconstruction with costochondral grafting[49,69,131]; disc repositioning[143-145]; alloplastic joint reconstruction[35,38,91], recommended in cases of advanced condyle destruction (Figure 6).

Careful attention has been recommended for surgical procedures in high-risk CR patients, including the avoidance of excessive mechanical loading on the TMJ. Transverse rotation of the condyles always accompanies ramus surgery to advance the mandible and is thought to be related to how much TMJ dysfunction has occurred[14,142]. Biomechanical studies of RIF methods after mandible advancement surgery have tested the parameter of biomechanical stability. Although SSRO is relatively standardized, in the literature there is no agreement about the procedure for RIF, which was selected according to the surgeon's choice. The exception was the lag-screw, which was considered detrimental[105]. In recent years, the *hybrid* technique, defined as varying combinations of the use of positional screw(s) and miniplates[24,117], is among the most frequently chosen ostheosynthesis methods. The question that arises is if this same hierarchy of rigidity for fixing the mandibule in the *in vitro* model is the same as that transmitted to TMJ, in terms of stress generation: Does the rigidity of fixation imply that the more rigid it is, the more stability there is for early functioning, but, on the other hand, the less stress distribution there is, the more susceptible it is to condylar malpositioning (torque), resorption and relapse?

In vivo animal studies investigated the response of the TMJ to mandibular surgical advancement[45,87,99]. There was a more pronounced effect on the condyle (retrusion, erosion, flattening and osteophyte) when positional screws were used than when miniplates were used, suggesting that this was developed by the higher impact of the screws transmitted to the condyle. However, no evidence with clinical design has been published with respect to the TMJ response to the type of fixation, except studies which showed a greater skeletal long-term relapse rate in patients treated with bicortical screws than with miniplates[70,76].

The choice of type and design of mandibular synthesis should be based on the treatment planning rather than on the surgeon´s preference. The use of more rigid fixation techniques (positional screws) should be the choice for patients with greater bite force, larger advancements (>7 mm) and no preexisting active CR, while, on the other hand, a less rigid fixation (miniplates) would be a better choice in cases with a risk factor of CR. As is well known, relapse generally occurs with larger mandibular advancement and in response to CR. Before surgery, any signs of CR should also be studied to identify preexisting resorption.

Besides the mechanical aspects of surgical correction, the treatment of Class II malocclusions with severe mandibular retrognathism in association with a hyperdivergent skeletal pattern is considered a clinical challenge. This craniofacial morphology is considered a risk factor for disc displacement[100], painful TMJ before[71,93,100] and after[73,79] surgery, is subject to less painful improvement after surgery[33,141,142] and is prone to CR before and after surgery[23,33], especially if the condylar neck is posteriorly inclined[72,74], and results in higher frequency and greater magnitude of horizontal relapse[11,94].

CONCLUSIONS

Mandibular advancement surgery maintained the relationship between the articular disc and condyle; improved preexisting arthralgia without any individual guarantees or in any predictable manner; and, increased the risk of CR, especially in susceptible cases.

The amount of mandibular advancement, the degree of maxillomandibular counter-clockwise rotation and the increased joint loading due to the greater rigidity of the mandibular fixation technique contributed to influencing TMJ position and health.

Females with skeletal Class II malocclusion and a high mandibular plane angle pattern were subject to less improvement in painful TMD after surgery and were prone to CR before and after surgery, especially in cases associated with a posteriorly inclined condyle, which contributed to greater horizontal relapse.

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