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Review Article

Effectiveness of different surgical modalities in the management of temporomandibular joint ankylosis: a meta-analysis

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Abstract: Background: A meta-analysis was conducted to evaluate the effectiveness of three surgical modalities-gap arthroplasty (GA), interpositional gap arthroplasty (IPG) and joint reconstruction (AR)-in treating temporomandibular joint (TMJ) ankylosis. Methods: A systematic review was performed using the PUBMED, EMBASE and OVID search engines in February 2015 to identify cohort studies with no restrictions, with the aim of evaluating the three surgical modalities. The outcome was the change between the pre- and postoperative maximal incisal opening (MIO). Analyses of category, heterogeneity, sensitivity and publication bias were performed. A fixed-effects model was used to compute the pooled weighted mean difference in the MIO among the different groups. Result: Seventeen studies with 740 participants were included in the final analysis. The IPG therapy showed a significantly greater MIO when compared to GA (WMD=1.16 mm; 95% CI, 0.15-2.16) and AR (WMD=0.99 mm; 95% CI, 0.05-1.92) therapies. The weighted mean difference between the AR and GA modalities was 2.94 mm (95% CI, 0.12-5.75). The pooled odds ratios (ORs) of the recurrence rate for IPG, GA and AR were 0.01 (95% CI, 0.00-0.03), 0.03 (95% CI, 0.00-0.07) and 0.06 (95% CI, 0.04-0.09), respectively. Conclusion: The analysis showed that IPG was more effective and displayed a lower recurrence rate, followed by AR and GA, in treating TMJ ankylosis. Thus, this analysis provides strong evidence supporting IPG as a first-line therapy for TMJ ankylosis.

Keywords: Temporomandibular joint ankylosis, meta-analysis, gap arthroplasty, joint reconstruction, interpositional gap arthroplasty

Introduction

Ankylosis of the temporomandibular joint (TMJ) is a major distressing disease that is mainly caused by trauma, infections, and systemic disorders such as arthritis and otitis, among others [1]. Several classifications have been proposed based on the location (intra- or extra-articular), type of tissue involved (fibrous, fibro-osseous or osseous) and extension of the fusion (complete or incomplete) [2]. Patients suffering from TMJ ankylosis usually present with an inability to open the mouth, accompanied by problems with speech, mastication, digestion and oral hygiene [3]. When occurring in children and adolescents, growth is affected tremendously, resulting in mandibular underdevelopment and facial deformity, which may also cause physiological and psychological problems [2, 4].

Accordingly, early interventions are necessary once the condition is recognized. These treatments include three different surgical modalities: gap arthroplasty, interpositional gap arthroplasty, and joint reconstruction [5]. Gap arthroplasty (GA) with simple osseous resection was first advocated by Abbe in 1880 [6]; however, this surgery has been reported to have various complications and is associated with a high recurrence rate [7]. Joint reconstruction (AR) with autologous or alloplastic techniques is also an alternative treatment for TMJ ankylosis, especially in end-stage TMJ disease [8]. Nevertheless, due to its technical limitations, higher cost and unpredictable complications, AR is not

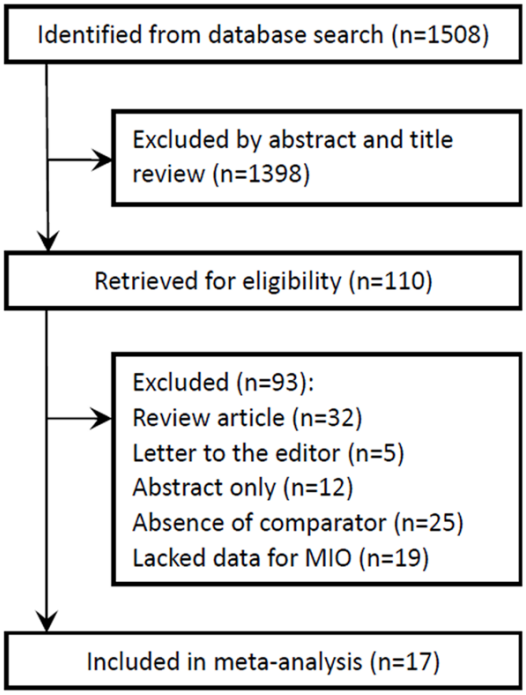

Figure 1. Flow chart of study selection.

considered as a routine treatment in some countries [9]. Recently, interpositional gap arthroplasty (IPG) has been developed and has become the primary surgical management of TMJ ankylosis [10]. Different interpositioning grafts have been introduced, including autogenous materials (temporalis myofascial flap, fascia lata, auricular cartilage, dermis and full-thickness skin), alloplastic materials (gold foil, tantalum foil, Silastic and Proplast) and xenografts [11].

This meta-analysis was performed with the following objectives: (1) to compare the effectiveness of GA, IPG and AR in treating TMJ ankylosis and (2) to evaluate the recurrence rate of these procedures.

Materials and methods

Study selection

A literature search was performed in February 2015 using PUBMED, EMBASE and OVID as search engines. The search was executed using medical subject headings (MeSH) or free text words. One or a combination of the following terms was used in the search: TMJ ankylosis, gap arthroplasty, interpositional gap arthroplasty, joint reconstruction, alloplastic material, and autogenous material. The reference lists were also searched to identify all of the relevant publications.

Selection criteria

The studies that met the following criteria were included in this meta-analysis: (1) randomized controlled trails, controlled clinical trails or retrospective studies; (2) number of participants ≥10; (3) surgical treatments for TMJ ankylosis (GA, IPG and AR); and (4) well-reported pre-/postoperative maximal inter-incisal opening (MIO). The studies that did not meet the selection criteria were thus excluded in the initial review.

Data extraction

Two reviewers (XHL and PS) performed the search independently and blindly. For each study identified, the following data were collected: last name of the first author, year of publication, country, design of the study, number of patients, gender (male/female ratio), mean age, etiology of the disease, pre- and postoperative MIO, recurrence, and follow-up period. If there was a disagreement between the reviewers, a third physician (SYZ, with more than 10 years of experience in TMJ disorders) was consulted to obtain a consensus.

Statistical analysis

This meta-analysis was performed in accordance with the guidelines in PRISMA statement [12]. The outcome variable was evaluated by the mean change between the pre- to postoperative maximum inter-incisal opening (MIO) [7]. A conservative approach was used to estimate the standard deviation (SD) of the mean difference between the baseline and post-treatment: SD (change from baseline) [13]

$$= \sqrt{\frac{(preoperativeSD)^2 + (postoperativeSD)^2}{2}}$$

Weighted mean differences (WMDs) or standard mean differences were used to construct forest plots of continuous data. For binary outcomes, the odds ratio (OR) was used to measure the recurrence rate of different surgical treatments. The random-effects model was used if heterogeneity was detected; otherwise, the fixed-effects model with a 95% confidence interval (CI) was performed. Cochran Q and I^2 statistics were used to assess the heterogene-

Table 1. Characteristics of the included studies: gap arthroplasty (GA) versus interpositional gap arthroplasty (IPG)

Study	Mean Age (yr)	Etiology (n)	GA group					IPG group					Follow-up (yr)
			Patient (n)	MIO (mm)			Recurrence (n)	Patient (n)	MIO (mm)			Recurrence (n)	
				Pre-op.	Post-op.	Improvement			Pre-op.	Post-op.	Improvement		
Tanrikulu et al. 2005 (Turkey)	12.40	Trauma17	8	2.50	31.00	28.50±4.50	0	9	3.00	32.11	29.11±4.40	1	1.04
Danda et al. 2009 (India)	9.56	Trauma13; Infection2; Unknown1	8	3.75	29.88	26.13±8.88	1	8	3.50	31.44	27.94±10.35	1	1.69-1.93
Zhi et al. 2009 (China)	22.25	Trauma32; Otitis3; Pneumonia1; Unknown3	25	7.00	25.58	18.58±6.48	3	17	9.00	29.57	20.57±7.86	0	1-11
Elgazzar et al. 2010 (Egypt)	19.43	NC	11	5.30	29.10	23.80±5.02	2	25	5.30	33.90	28.60±4.89	0	2.41
Holmlund et al. 2013 (Sweden)	48.56	Arthritides36	14	19.29	30.86	11.27±10.67	0	22	20.18	36.68	16.5±6.19	0	2.36
Bhatt et al. 2014 (India)	12.90	Trauma214; Infection31; Idiopathy17	207	3.55	33.31	29.76±7.07	26	55	3.33	33.87	30.54±6.59	2	3.78
Güven et al. 2008 (Turkey)	6.93	Trauma11; Otitis2; Unknown1	6	11.33	37.67	26.34±1.37	0	8	7.88	37.25	29.37±5.13	0	2.79
Ramezanian et al. 2006 (Iran)	19.50	NC	22	8.70	32.10	23.40±3.55	7	26	10.30	33.90	23.60±3.41	0	4
Mansoor et al. 2013 (Pakistan)	13.33	NC	30	6.47	30.80	24.33±4.78	0	30	8.43	32.20	23.77±5.05	1	0.5
Shaikh et al. 2013 (India)	15.15	Trauma20	10	3.9	33.30	29.40±6.53	0	10	0.50	33.40	32.90±6.53	0	1

MIO: maximal inter-incisal opening; NC: not clear.

Table 2. Characteristics of the included studies: interpositional gap arthroplasty (IPG) versus joint reconstruction (AR)

Study	Mean Age (yr)	Etiology (n)	IPG group					AR group					Follow-up (yr)
			Patient (n)	MIO (mm)			Recurrence (n)	Patient (n)	MIO (mm)			Recurrence (n)	
				Pre-op.	Post-op.	Improvement			Pre-op.	Post-op.	Improvement		
Tanrikulu et al. 2005 (Turkey)	12.40	Trauma16	9	3.00	32.11	29.11±4.40	1	7	2.14	28.58	26.43±7.32	1	1.04
Elgazzar et al. 2010 (Egypt)	19.43	NC	25	5.30	33.90	28.60±4.89	0	20	5.30	33.80	28.50±4.89	0	2.41
Qudah et al. 2005 (America)	8.40	Trauma22	8	6.60	31.00	24.40±2.28	1	14	6.50	29.90	23.40±1.68	1	3.71
Souza et al. 2003 (Brazil)	19.70	Trauma4; Infection3; Idiopathy1; Unknown6	5	9.00	33.00	24.00±8.97	0	9	6.56	32.78	26.22±10.93	1	2.35
Balaji et al. 2003 (India)	22.78	NC	22	0.95	36.7	35.75±1.94	0	9	1.30	34.00	32.70±1.67	0	1.67
Sahoo et al. 2012 (India)	13.16	Trauma54; Infection2	19	3.11	35.21	32.10±6.92	1	37	3.97	36.08	32.11±7.09	2	1.78
Dimitroulids et al. 2004 (Australia)	32.55	Trauma5; Iatrogenicity6	9	15.78	35.78	20.00±5.74	0	2	15.00	35.50	20.50±0.71	1	3.46

MIO: maximal inter-incisal opening; NC: not clear.

Table 3. Characteristics of the included studies: joint reconstruction (AR) versus gap arthroplasty (GA)

Study	Mean Age (yr)	Etiology (n)	AR group					GA group					Follow-up (yr)
			Patient (n)	MIO (mm)			Recurrence (n)	Patient (n)	MIO (mm)			Recurrence (n)	
				Pre-op.	Post-op.	Improvement			Pre-op.	Post-op.	Improvement		
Tanrikulu et al. 2005 (Turkey)	12.40	Trauma15	7	2.14	28.58	26.43±7.32	0	8	2.50	31.00	28.50±4.50	0	1.04
Elgazzar et al. 2010 (Egypt)	19.43	NC	20	5.30	33.80	28.50±4.89	0	11	5.30	29.10	23.80±5.02	2	2.41
Vasconcelos et al. 2009 (Brazil)	22.21	Trauma5; Infection9; Idiopathy1	5	10.00	30.00	20.00±8.10	0	10	8.00	26.64	19.67±6.97	2	3.35
Mabongo et al. 2013 (India)	8.00	Trauma4; Infection2; Idiopathy7	4	6.80	32.90	26.10±8.92	0	9	6.80	27.00	20.20±4.88	2	5.58

MIO: maximal inter-incisal opening; NC: not clear.

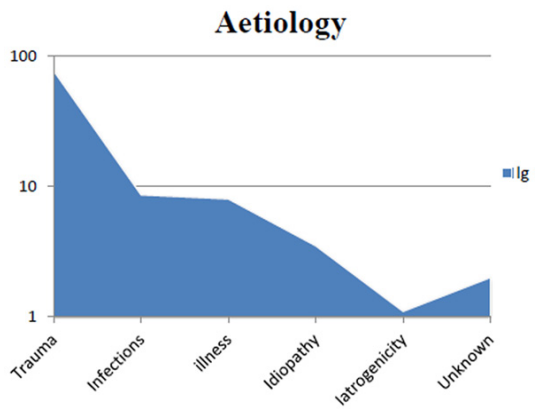

Figure 2. Data sets by etiology factors of TMJ ankylosis. The most common etiology is trauma (76.8%).

ity among the studies [14]. Based on the Cochrane guidelines, I^2 values of 0-40%, 30-60%, 50-90% and 75-100% were defined as low, moderate, substantial and high heterogeneity, respectively [15]. Heterogeneity was considered statistically significant if the probability values were <0.05 [16]. Egger and Begg's tests were used to measure the funnel plot asymmetry, which indicates publication bias [17]. All of the data were analyzed using Stata 10 (StataCorp, College Station, TX, USA).

Results

Studies selection process

The process of study selection is presented in **Figure 1**. A total of 1508 studies of potential interest were identified in the initial database search. After title and abstract evaluations, 1398 studies were excluded for being out of the scope of the topic of the meta-analysis. The remaining 110 studies were further reviewed in full text, and an additional 93 studies were excluded for the following reasons: review article (n=32), letter to the editor (n=5), abstract only (n=12), absence of comparator (n=25), lacking data for the MIO (n=19). As a result, 17 studies were included in the meta-analysis [18-34]. The two observers reached an agreement on which studies should be included (Cohen's unweighted k=0.87).

Characteristics of the included studies

The extracted data and the characteristics of the studies included in the final analysis are summarized in **Tables 1-3**. The analysis included 17 studies with 740 participants of TMJ ankylosis treated with surgical approaches (gap arthroplasty, interpositional gap arthroplasty, and joint reconstruction) [18-34]. The cohorts were from nine different countries, with seven from India, two from Turkey, two from Brazil, and one each from the United States, China, Sweden, Egypt, Iran and Pakistan. Within the 740 participants (ratio of male/female: 333/351), the age ranged from 6.93 to 48.56 years (mean, 18.05 years) and the follow-up ranged from 0.50 to 5.58 years (mean, 2.77 years). The primary etiological factor of the TMJ ankylosis was trauma (76.8%), followed by infection (8.6%), illness (8%) and idiopathy (3.5%) (**Figure 2**). Of the 17 studies, ten studies [18-27] compared IPG to GA, seven [20, 25, 28-32] compared IPG to AR and four [20, 25, 33, 34] compared AR to GA. Two studies [20, 25] were used in all of the comparisons for assessing the three treatment modalities for the MIO and recurrence. All of the studies measured the values of the pre- and postoperative MIO and recorded the recurrence rate. The overall study quality, evaluated by the STROBE score, averaged 8.3 (range 6-9) on a scale of 1 to 10.

IPG versus GA

Ten studies [18-27] containing data on 551 participants compared the treatment of TMJ ankylosis with GA (n=341) to IPG (n=210). In these studies (5 CCTs and 5 retrospective studies), the age of the patients ranged from 6.93 to 48.56 years (mean, 18.00 years) and the follow-up ranged from 0.5 to 5.5 years (mean, 2.52 years). The analysis reported that the patients treated by IPG showed a significant increase in the MIO (fixed: WMD=1.16 mm; 95% CI 0.15-2.16), with moderate heterogeneity among the studies (P=0.33; I^2=12%) (**Figure 3**). Begg's (P=0.655) and Egger's (P=0.784) tests provided no evidence of publication bias. The sensitivity analysis showed that excluding any study from the pooled analysis did not substantially influence the results.

IPG versus AR

Figure 4 shows the results of 7 studies [20, 25, 28-32] with 195 participants treated by IPG (n=94) and AR (n=98). Among these studies, 1 was a CCT and 6 were retrospective studies. The age of the patients ranged from 8.4 to 32.55 years (mean, 18.35 years), and the follow-up ranged from 1.04 to 3.71 years (mean, 2.35 years). In the analysis, the participants with the IPG therapy had an extra 0.68 mm in

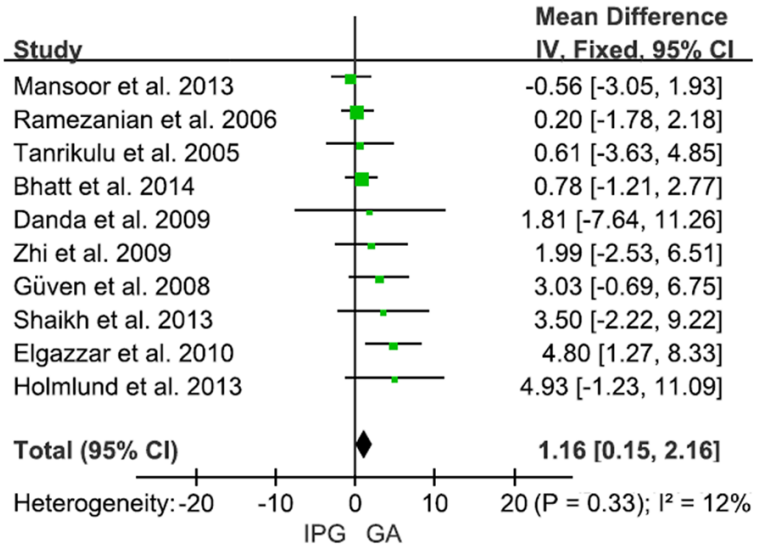

Figure 3. Pooled WMD of the MIO between IPG and GA.

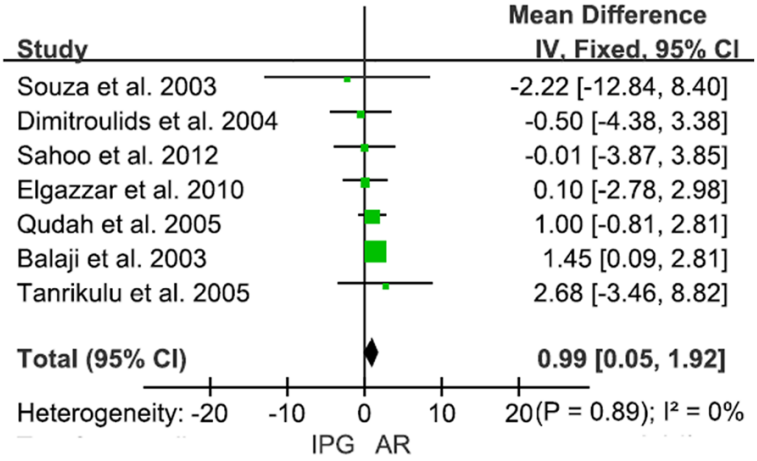

Figure 4. Pooled WMD of the MIO between IPG and AR.

the MIO compared to those with AR treatment (fixed: WMD=0.99; 95% CI 0.05-1.92). The test for heterogeneity across the studies showed homogeneity (P=0.89; I^2=0%) and no evidence of publication bias (Begg's test, P=0.293; Egger's test, P=0.213). The sensitivity analysis confirmed that excluding any one study from the pooled analysis did not vary the results substantially.

AR versus GA

Four retrospective studies [20, 25, 33, 34] including 74 patients evaluated the effectiveness between GA (n=38) and AR (n=36) in treating joint ankylosis (**Figure 5**). The age of the patients ranged from 8.00 to 22.21 years (mean, 15.51 years), and the follow-up ranged from 1.04 to 5.58 years (mean, 3.10 years). The data analysis showed that AR resulted in a wider MIO when compared to GA (fixed: WMD=2.94; 95% CI 0.12-5.75). The heterogeneity test showed no significant difference (P=0.25; I^2=27%). Begg's (P=1.000) and Egger's tests (P=0.798) provided no evidence of publication bias. The sensitivity analysis showed that excluding any study from the pooled analysis did not affect the results substantially.

Recurrence rate

The recurrence rate of each treatment was also evaluated. The results showed that management with IPG was associated with the lowest recurrence rate of 2.56% (OR=0.01; 95% CI, 0.00-0.03), followed by AR of 4.67% (OR=0.03; 95% CI, 0.00-0.07) and then GA with 11.94% (OR=0.06; 95% CI, 0.04-0.09).

Discussion

This meta-analysis including 17 studies [18-34] compared the effectiveness of the three surgical modalities in treating TMJ ankylosis. The results supported the view that IPG is more effective than the other two therapies, AR and GA, and presented a lower recurrence rate; however, due to the lack of comparative studies and data, more studies with a larger sample size and a longer period of follow-up (with an emphasis on the rate of reankylosis) are necessary.

In the included studies, articular trauma was the major etiological factor of TMJ ankylosis (76.8%) [35]. Local and systemic infections were the second most frequent after trauma (8.6%). In the series of the 740 cases, patients aged 10-20 years were the most affected age group (52.94%) and females were the more susceptible population (51.32%) [18-34].

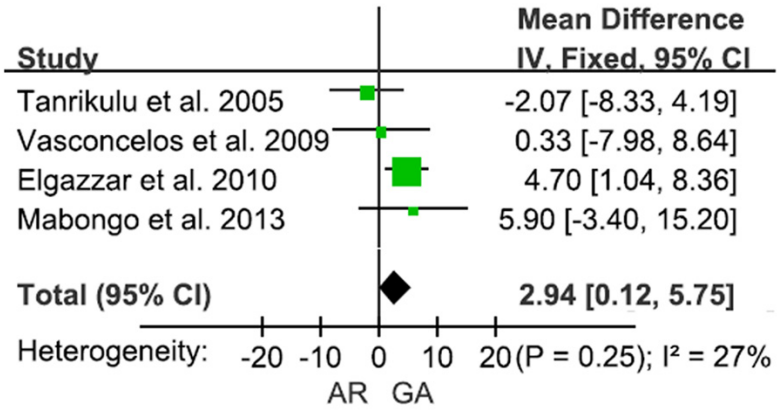

Figure 5. Pooled WMD of the MIO between AR and GA.

TMJ ankylosis is typically associated with difficulties in mastication, oral hygiene, facial growth disturbances, and possible pharyngeal narrowing, which invariably result in physical and psychological disabilities [36]; however, due to technical challenges, high technical demands and the high incidence of recurrence, the different modalities for treating TMJ ankylosis remain a topic of current interest.

GA, which is based on leaving the TMJ joint region empty by resecting the ankylotic bone, is a simple method with a short operating time [2]; however, because of the relatively little improvement between the pre- and postoperative maximum inter-incisal opening (compared to IPG: WMD=-1.16 mm; compared to AR: WMD=-2.94) and the relatively higher risk of re-ankylosis (4.67%), this method has been largely abandoned. In addition, GA leads to various complications such as the development of an open bite in bilateral cases, premature occlusion on the affected side and a suboptimal postoperative range of motion [37]. In 1934, the first interpositional arthroplasty was used by Risdon to treat TMJ ankylosis [38]. The IPG therapy places the emphasis on the application of interpositional materials in the ostectomy region. Interlaid in the distance between resected bone surfaces, the interpositional material is essential to prevent re-ankylosis (2.56%) and promote functional joint activity (compared to AG: WMD=1.16 mm; compared to AR: WMD=0.99). Additionally, autogenous and alloplastic materials including a temporalis myofascial flap, dermis, homologous cartilage, silicon sheets, titanium mesh, and acrylic implants have been used as interpositional materials [10, 11]. Among these materials, the temporalis muscle flap and its variations are widely adopted. According to Chossegros, the temporalis muscle flap has been reported with a satisfactory success rate, especially in children (over 83%), due to its rich blood supply and close proximity to the temporal site [39]. In the present analysis, 8 out of the 15 studies with IPG treatment utilized the temporalis muscle flap as an interpositional material and the mean change of the MIO went from 6.92 mm (preoperative) to 33.53 mm (postoperative). TMJ reconstruction is necessary for patients with extensive osteotomy and consequently insufficient ramus height [8]. Reconstruction may be performed with costochondral grafts, clavicular osteochondral grafts, iliac crest grafts, coronoid process grafts and alloplastic condylar implants (compared to GA: WMD=2.94; compared to IPG: WMD=-0.99) [2]; however, problems including technical limitations, high cost and potential complications (graft fracture, infection, over growth, donor site morbidity foreign body reaction, and dystrophic bone formation) make this surgery an irregular treatment, especially in certain less developed countries [9]. In this meta-analysis, costochondral is the major reconstruction graft because of the growth potential, which makes this method an ideal choice to ensure mandibular growth in children with TMJ ankylosis.

Compared with previously published meta-analyses on the same discussed topic, the current meta-analysis has a number of advantages [40-42]. First, a substantial number of studies and participants were included (17 studies with 740 participants). Therefore, the statistical power of the analysis was significantly enhanced. Second, the study selection, data extraction, and statistical analysis were performed independently and blindly by two investigators, and consistency was reached by an arbitrator, thus improving the accuracy and reliability of the data in the analysis.

Despite its strengths, the current meta-analysis has certain limitations. First, the quality of the individual studies varied, with some having limited adjustment for potential statistical con-

founders [43]. The meta-analysis was subject to the confounding factors within the included cohorts, which is an inherent limitation of all observational studies and meta-analyses. Thus, the results might be biased toward an exaggeration or underestimation of risk estimates. Second, publication bias is another potential concern when performing a meta-analysis of published studies. In the statistical tests used in this meta-analysis, no significant publication bias was observed, but it is still possible that smaller studies, which have null results, tend not to be published [7]. In other words, the statistical power of that particular aspect of the study might be limited.

Based on the findings from this analysis, additional questions remain to be answered. Do factors such as age, gender or etiology have any relationship with the option of treatment? To answer these questions, further well-designed RCT studies are mandatory.

In conclusion, interpositional gap arthroplasty (IPG) showed a preponderance in treating TMJ ankylosis with a lower recurrence rate followed by joint reconstruction (AR) and gap arthroplasty (GA). In addition, more well-designed and stratified cohort studies are needed to better understand the underlying biology.

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Disclosure of conflict of interest

None.

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