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REVIEW ARTICLE

Temporomandibular disorders in growing patients after treatment of class II and III malocclusion with orthopaedic appliances: a systematic review

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ABSTRACT

Objective: To determine if the use of orthopaedic appliances in growing patients applied to correct Class II and III malocclusion is related to the development of temporomandibular disorders (TMD).

Material and methods: A systematic review was conducted between 1960 and July 2017, based on electronic databases: PubMed, Cochrane Library, Embase, Medline, Scopus, EBSCOhost, Scielo, Lilacs and Bireme. Controlled clinical trials (CCTs) and randomized controlled trials (RCTs) were identified. The articles were selected and analyzed by two authors independently. The quality of the evidence was determined according to the guidelines of the Cochrane Risk Bias Assessment Tool and the Cochrane Quality Study Guide.

Results: Seven articles were included, four CCTs and three RCTs. The studies were grouped according to malocclusion treatment in (a) class II appliances ($n = 4$) and (b) class III appliances ($n = 3$). The quality of evidence was low due to the high risk of bias, independent of the association reported. All studies concluded that the use of orthopaedic appliances would not contribute to the development of TMD.

Conclusions: The quality of evidence available is insufficient to establish definitive conclusions, since the studies were very heterogeneous and presented a high risk of bias. However, it is suggested that the use of orthopaedic appliances to correct class II and III malocclusion in growing patients would not be considered as a risk factor for the development of TMD. High-quality RCTs are required to draw any definitive conclusions.

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Class II; class III; temporomandibular disorders; temporomandibular joint; dentofacial orthopaedics

Introduction

'Temporomandibular disorders (TMD) are defined as a group of disorders involving the masticatory muscles, the temporomandibular joint (TMJ) and associated structures' [1]. The aetiology of TMD is multifactorial and poorly understood [2,3]. TMD may be associated with some types of malocclusions, and with skeletal class II and III [2,4,5]. The literature also suggests that the development of TMD may be related to the use of orthodontic appliances [6].

The relationship between occlusion and TMD is still considered as a controversial topic in dentistry. For years, some professionals were based on the evaluation and correction of occlusal anomalies to treat patients with TMD [7]. In the past, the evidence suggested that malocclusion was considered as the main factor for predisposition, initiation and perpetuation of TMD [8–10]. In 1990s some studies showed that some occlusal and skeletal characteristics as anterior open bite, unilateral posterior crossbite, overjet greater than 6 to 7mm and centric relation (CR) to maximum intercuspation (MI) discrepancy >2 mm could be considered occlusal risk factors for TMD [2,11,12]. Current evidence based on Systematic Reviews of observational studies would not support an association for dental occlusion in the pathophysiology of TMD [13,14]. Therefore, malocclusion would not be present, but the rapid change and stress applied in the system that would exceed the physiological tolerance threshold are being unfavourable for the TMJ [15–19]. In addition to the psychological factors, some studies indicate the importance of the role that would have stress, anxiety and depression in children along with TMD [20–23].

For class II malocclusion treatment in growing patients, removable and fixed orthopaedics appliances are used with two approaches. The first approach aims to restrict the forward position of the maxilla [24], and second approach, using functional appliances displacing the mandible forward, which would transfer the condyle out of the mandibular fossa transmitting the forces to the dentition and basal bone [25]. This sagittal change in the intermaxillary relationship due to anterior displacement of the mandible would generate TMD [26].

For class III malocclusion treatment in growing patients, the therapy is aimed to modify growth using orthopaedic appliances as the Petit's and Delaire's facemasks in patients with maxillary deficit, which act by pulling the maxilla and

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the maxillary dentition with the intention of improving the maxillo-mandibular relationship and rotating the jaw clockwise [27–30]. Chin cup treatment and functional class III appliances are used in patients with this malocclusion with greater growth of the mandible [31,32]. The use of chin cup or mandibular cervical headgear (MCH) would be associated with an increased risk of joint disorders by locating the condyle posteriorly [19,33,34], generating disc displacement [35].

The relationship between orthodontic treatment and TMD is still controversial, and although most recent reviews indicate that there is no cause-and-effect relationship between orthodontic treatment and TMD [36–38], these studies do not analyze the effect of orthopaedic treatment in growing patients.

Due to the lack of reviews that determine the relationship between the use of orthopaedic appliances and TMD during and after the treatment, the objective of this study was to establish a systematic review in order to find out if the use of fixed or removable orthopaedic appliances to correct class II and III malocclusion are associated with the development of TMD.

Materials and methods

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [39].

To answer the research question according to the PICO (Population, Intervention, Control groups and Outcome) scheme: 'Do growing Class II and Class III patients under (P) orthopaedic treatment (I) show an association between TMD onset and treatment (O), as opposed to an untreated growing class II and class III patients (C)?', an electronic search was conducted on 31 July 2016, updated on 23 August 2017. The databases used were PubMed, Cochrane Library, Embase, Medline, Scopus, EBSCOhost, Bireme, Lilacs and Scielo.

Type of studies

Randomized controlled trials (RCTs) or controlled clinical trials (CCTs) that aimed to determine whether orthopaedic appliance used in the treatment of class II and III malocclusion in growing patients develops TMD.

Language studies

The search was conducted without limitation of language.

Types of participants

The articles selected included experimental studies in growing patients from both genders, with class II and III malocclusion.

Intervention type

Treatment or active therapy: fixed or removable appliances, extraoral or intraoral appliances for class II and III malocclusion treatment.

Control group: without treatment, other therapies (active or placebo)

Type of results

Primary outcomes: to determine the association between treatment with orthopaedic appliances for class II and III malocclusion and the development of TMD.
Secondary outcomes: to determine (1) psychosocial problems; (2) association between the use of orthopaedic appliance and development of TMD by gender.

Data collection

For TMD: not limited to any method, with a clear reference of the concept and diagnosis of temporomandibular pathology. Diagnostic criteria for TMD based on Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) and Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) are restricted only to clinical methods to establish a clear diagnosis of TMD. The RDC/TMD and DC/TMD were published in 1992 and 2014, respectively, which would limit the search only from 1992 and would be restricted to clinical methods of diagnosis for TMD. Due to the limited evidence and the evolution of the concept and diagnostic criteria regarding TMD, we decided to include any diagnostic method, such as clinical, imaging, among others.
For Class II and III malocclusion: data were collected based on cephalometric, imaging, occlusal relationship with increased overjet, retrognathic mandible (class II) and anterior crossbite (class III) according to clinical study and/or plaster casts.

Search strategy and study selection

For the identification and selection of the number of potentially eligible studies for this systematic review (N), a specific and individualized search strategy for each database was developed. A semantic field was determined for the term 'Class II and III orthopaedic appliances' and another semantic field related to the term 'Temporomandibular Disorders' (Table 1).

Electronic databases used:

- PubMed database. Filters used: Article types: Clinical Trial, randomized controlled trial, controlled clinical trial/ Publication dates: 1966- to 31-7-2017
- Cochrane Library: Filters: Database: Trials/Publication Year: 1966-2017
- Embase: Article Type: Controlled clinical trial - Randomized clinical trial/Publication date: 1966-2017
- Medline: Article Type: Controlled clinical trial - Randomized clinical trial/Publication date: 1966-2017
- EBSCOhost: Publication type: Academic journal/Publication date: 1963 to 2017-07-31
- Scopus: Document type: Article/publication dates: 1960 to-2017
- BIREME: Publication date: to-2017
- Lilacs: Publication date: to-2017
- Scielo: Publication date: to-2017.

Table 1. Search strategy and terms used for the search.

	Search strategy and terms		
Database and limits	Semantic fields: "Class II and III orthopaedic appliances"		Semantic field: "Temporomandibular disorders"
PubMed (*n* = 915) Limits Article types: Clinical Trial, randomized controlled trial, controlled clinical trial Publication dates: 1966 to 2017-07-31	Functional appliance [tiab] OR functional class II appliance [tiab] OR functional class III appliance [tiab] OR orthopedic class II appliance [tiab] OR orthopedic class III appliance [tiab] OR frankel [tiab] OR frankel-2 [tiab] OR frankel-3 [tiab] OR bionator [tiab] OR twin block [tiab] OR forsus [tiab] OR herbst [tiab] OR delaire mask [tiab] OR facial mask [tiab] OR jasper jumper [tiab] OR headgear [tiab] OR mandibular headgear [tiab] OR chin cup [tiab] OR mandibular advance appliance [tiab] OR MARA [tiab] OR MAA [tiab]	AND	Temporomandibular disorders [tiab] OR temporomandibular joint disorders [tiab] OR TMJ disorders OR temporomandibular diseases [tiab] OR TMD OR craniofacial disorders [tiab] OR craniomandibular dysfunction [tiab]
The Cochrane Library (*n* = 720) Limits: Database: Trials Publication Year: to-2017	Functional appliance OR functional class II appliance OR functional class III appliance OR orthopaedic class II appliance OR orthopaedic class III appliance OR frankel OR frankel-2 OR frankel-3 OR bionator OR twin block OR forsus OR herbst OR delaire mask OR facial mask OR jasper jumper OR headgear OR mandibular headgear OR chin cup OR mandibular advance appliance OR MARA OR MAA	AND	Temporomandibular disorders tiab OR temporomandibular joint disorders tiab OR TMJ disorders tiab OR temporomandibular diseases tiab OR TMD tiab OR craniofacial disorders tiab OR craniomandibular dysfunction tiab
Scielo (n = 5)	(Frankel OR bionator OR twin block OR herbst OR jasper jumper OR headgear)	AND	(Temporomandibular disorders)
Lilacs-Bireme (*n* = 259) Limit Document type: article	(Frankel OR bionator OR twin block OR herbst OR jasper jumper OR headgear)	AND	(Temporomandibular disorders)
EBSCOhost (*n* = 343) Publication type: Academic journal Publication date: 1963 to 2017-07-31	Functional appliance OR functional class II appliance OR functional class III appliance OR orthopaedic class II appliance OR orthopedic class III appliance OR frankel OR frankel-2 OR frankel-3 OR bionator OR twin block OR forsus OR herbst OR delaire mask OR facial mask OR jasper jumper OR headgear OR mandibular headgear OR chin cup OR mandibular advance appliance OR MARA OR MAA OR mentonera OR mascara traccion frontal OR activador clase II OR activador clase III		Temporomandibular disorders OR TMD OR temporomandibular joint OR arthralgia OR myofascial pain OR Costen's syndrome OR dolor miofascial OR Temporomandibular Joint Dysfunction Syndrome OR Transtornos da Articulação Temporomandibular OR Trastornos Craneomandibulares OR synovitis OR osteoarthritis OR osteoarthrosis OR Myofascial Pain Syndromes OR Myalgia OR Myofascial Pain Dysfunction OR craniomandibular pain OR craniomandibular disorders OR disc displacement with reduction OR disc displacement without reduction OR luxation TMJ OR TMJ pain OR TMJ disease OR TMJ disorder OR TMJ Syndrome OR Musculoskeletal Diseases OR Musculoskeletal Pain
Scopus (*n* = 159) Limits: Document type: Article Publication date : 1960 to 2017	Mandibular advance appliance OR headgear OR frankel OR herbst OR forsus	AND	Temporomandibular disorders OR craniomandibular disorders OR TMD
Embase (*n* = 107) Article Type: Controlled clinical trial Randomized controlled trial Article Clinical study Publication date: 1966–2017	Functional AND appliance OR functional AND class AND ii AND appliance OR functional AND class AND iii AND appliance OR orthopaedic AND class AND ii AND appliance OR orthopaedic AND class AND iii AND appliance OR frankel OR 'frankel 2' OR 'frankel 3' OR bionator OR 'twin' OR 'twin'/exp OR twin AND block OR forsus OR herbst OR delaire AND ('mask' OR 'mask'/exp OR mask) OR facial AND ('mask' OR 'mask'/exp OR mask) OR jasper AND jumper OR headgear OR mandibular AND headgear OR 'chin' OR 'chin'/exp OR chin AND cup OR mandibular AND advance AND appliance OR mara OR maa AND temporomandibular AND disorders OR temporomandibular AND ('diseases' OR 'diseases'/exp OR diseases) OR tmd AND ([controlled clinical trial]/lim OR [randomized controlled trial]/lim) AND [<1966-2017]/py AND [clinical study]/lim AND [article]/lim		
Medline (*n* = 399) Article Type: Controlled clinical trial Randomized controlled trial Publication date: 1966–2017			

Table 2. Studies retrieved in full text and excluded from the review.

First author and year	Reason for exclusion
Wiedel, 2016 [42]	Discomfort in patients using removable and fixed appliances for anterior crossbite correction.
Pancherz, 2015 [43]	It is not a CCT or RCT.
Aidar, 2013 [44]	It is not a CCT or RCT.
Aidar, 2009 [45]	Same data as Aidar, 2013. [44]
Cacho, 2007 [46]	Cases series.
Kinzinger, 2006 [47]	It is not a CCT or RCT.
Kinzinger, 2006 [48]	It is not a CCT or RCT.
Kinzinger, 2006 [49]	It is not a CCT or RCT.
Ruf, 2002 [50]	It is not a CCT or RCT.
Ruf, 2000 [51]	It is not a CCT or RCT.
Deguchi, 1998 [52]	It is not a CCT or RCT.
Owen, 1998 [53]	Retrospective study.
Ruf, 1998 [54]	Cases series.
Peltola, 1995 [55]	It is not a CCT or RCT.
Dibbets, 1992 [56]	It is not a CCT or RCT.
Hansen, 1990 [57]	Cases series.

CCT: controlled clinical trial; RCT: randomized controlled trial.

Study selection and data collection

In the first screening, the title and abstract of all potentially eligible articles were listed and evaluated by two researchers independently (J.A., C.R.). In the second stage, the full text of articles that potentially met eligibility criteria based on the first screening was assessed independently by the same two researchers (J.A., C.R.) according to inclusion criteria (study design: RCTs, CCTs; study objective: to determine whether the use of orthopaedic appliances for treatment of class II and III malocclusion develops TMD; type of participants: patients treated in the growth stage). When no agreement was found, the inclusion of the article within the sample was discussed with a third researcher (P.H.), who acted as an arbiter. Articles that met inclusion criteria were selected in the review for the final analysis. The reasons why some studies were excluded were recorded in an adjacent column and presented in the results (Table 2). The quality of assessment according to the guidelines of the Cochrane Risk Bias Assessment Tool [40], and the Cochrane Quality Study Guide [41] was performed by two independent reviewers (V.M., T.J.).

Extracting data from studies

The PICO criteria (Population, Intervention, Control groups and Outcome) was used to make the tables of analyzed articles. *Population* (sample size, distribution by gender, age range and standard deviation); *Intervention*: (Orthopaedic appliances, type of method for the diagnosis of TMD and skeletal and occlusal class II and III, statistical analysis); *Comparison criteria or control:* (presence of any control group with and without intervention) and *Outcomes* (including the answer to the hypothesis, relationship between the use of orthopaedic appliances and development of TMD).

Quality assessment

The quality of the evidence was established through the risk of bias, carried out by two researchers (V.M and T.J). The risk of bias was determined according to the guidelines of the Cochrane Risk Bias Assessment Tool [40], and the Cochrane Quality Study Guide [41], which recommends reporting the following elements:

1. Random sequence generation.
2. Allocation sequence concealment.
3. Blinding (outcome assessment).
4. Completeness of outcome data.
5. Selective outcome reporting.
6. Other sources of bias: Time of use of the orthopaedic appliance (hours per day), amount of force applied and diagnostic method for TMD.

Each category was assigned according to the following grades: *High, Low or Unclear* risk of bias. The studies were considered as being exposed to a high risk of bias if they had a 'High' or 'Unclear' risk of bias for random sequence generation or allocation sequence concealment.

Results

2907 potentially eligible articles were identified in the first approach in the databases used (Table 1). However, 487 of these articles were excluded because they were duplicated. After reviewing the title and abstract of the remaining 2420 studies, 2397 articles were excluded due to their nonrelevance. Of the 23 articles left, 16 were eliminated in the reading of the full text for not meeting the inclusion criteria for this systematic review (Table 2). Finally, seven studies were analyzed (Tables 3, 4 and 5). Figure 1 summarizes the results described.

Characteristics of studies

Seven articles were included in this systematic review. Three RCTs and four CCTs were identified. The articles were grouped according to skeletal and occlusal anomaly in Class II orthopaedic appliances ($n = 4$); Class III orthopaedic appliances ($n = 3$). None of the reviewed articles established a relationship between the use of orthopaedic appliances and development of TMD (Tables 3, 4 and 5).

Characteristics of participants

The age range of patients was between 7 and 24 years old. When studies were grouped according to the type of malocclusion, the age range was 7 to 14 years old for Class II orthopaedic appliances, 8 to 24 years old for Class III orthopaedic appliances. Of the seven articles analyzed, six exclusively included growing patients and one article included growing patients and young adults without distinguishing between them, which explains the age range in the class III malocclusion group [33].

It was neither possible to determine psychosocial problems nor the higher prevalence of TMD according to gender, because the studies did not address this objective.

Table 3. Summary of orthopaedic appliances articles in patients with class II malocclusion and TMD.

First author and year	Population	Intervention	Comparison (control group)	Outcome	Conclusions
Conti, 2008 [58]	60 subjects. Average age 12.58 years ±3.72 years. Range 7 to 23 years.	Bionator appliance in patients with class II malocclusion. Diagnosis of TMD: questionnaire (10 questions and the TMD index was calculated). Clinical examination to evaluate mandibular movements, TMJs and presence of pain in TMJs with 900 gr of pressure and muscular evaluation with 1500 gr of pressure. ANOVA test and Kruskal–Wallis.	Group 1: subjects without treatment. Group 2: under treatment with Bionator. Group 3: already treated with Bionator.	There was no difference in the presence of TMD in the studied group. No association between discrepancy of centric relationship and MI and TMD severity.	The orthopaedic protrusion, in spite of altering the position of the condyles, does not increase the prevalence of TMD. There was no relationship between condilar centricity with signs and symptoms of TMD.
Franco, 2002 [59]	56 children. 29 males, 27 females. age range 8.8 to 12.6 years. Starting pubertal growth peak.	Fränkel appliance (FR-II) in class II-1 for 18 months. Performing 112 initial MRI (T1) and another18 ± 1 months after (T2) (parasagittal and coronal views) Evaluated: - Disc position at closed mouth - Functional disc position at open mouth - Disc shape (biconcave/non biconcave) Chi square test.	Group 1: FR-II appliance ($n = 28$; age 10.3 ± 0.9 years old) Group 2: No intervention ($n = 28$; age 10.9 ± 0.7 years old).	At T1, there was no significant difference in disc position between the two groups. At T2, there was no difference in disc location between groups. There was no alteration in disc position between T2 and T1. No difference in disc shape between the two groups in T1. At T2 significant difference was found in both groups (G1 = 100% biconcaves; G2 = 82.1% biconcaves)	There were no changes in the position of the disc; 100% of the patients treated with FR-II had a high and interposed position of the disc in closed and open mouth, respectively. On the contrary, the use of FR-II would avoid internal degenerative pathology in the TMJs at the beginning of the pubertal growth peak.
Chintakanon, 2000 [60]	40 white children class II-1. 27 males, 13 females. age range 10–14 years.	Clark Twin-Block for 6 months in class II-1 patients with mandibular retrognathism, decreased lower facial height and overjet >5 mm. (Method of diagnosis and evaluation are not explained). MRI of the right TMJs to evaluate disc-fossa relationship in sagittal and coronal view; axial angle of condyle and eminence; and sagittal concentricity. *T*-student and chi-square tests.	Group 1 (CTB): treated with CTB at R1: beginning and R2: 6 months ($n = 19$; 14 males, 5 females; 11.7 ± 1.3 years old) Group 2: no treatment ($n = 21$; 8 females, 13 males; 11.5 ± 1.3 years old).	Sagittal position of the disc: no significant differences between groups at R1. Reference line, PC: difference in the posterior margin of the disc in the group 1 at R2. Prevalence of the anterior disc displacement depended on the chosen baseline. Coronal disc position: no difference in disc position between groups.	The use of CTB caused the mandibular condyle to be located anteriorly in the fossa at R1, however, at R2 it turned back, but occupying a more anterior portion than group 2. There is no evidence of disc recapture in children with disc displacement at the end of CTB treatment.
Keeling, 1995 [61]	191 patients. 119 males, 72 females. average age 9.8 years, SD (0.9).	Bionator and Headgear/biteplane appliances in class II patients. Class II: bilaterally equal to or greater than ½ molar cusp or one side less than ½ cusp class II if the other side is greater tan½ cusp class II. Overjet and positive overbite. Stages of evaluation: early treatment, retention/no-retention and follow-up (6 months intervals). Diagnosis of TMD: clinical examination: signs and symptoms. Chi-square test, ANOVA test, logistic regression test with $p < .05$.	Bionator group ($n = 60$; 38 males, 22 females), age 9.8 years old, SD (1.1). Headgear group ($n = 71$; 41 males, 30 females), age 9.93 years old, SD (0.82). Control group ($n = 60$; 40 males, 20 females), age 9.71 years old, SD (0.75).	Early use of Bionator and Headgear is not a risk in healthy children. The increase in age (10.3 average age) was related to the development of sounds in TMJs ($p < .04$), the failure to achieve class I molar and muscular pain development ($p = .034$). Subjects with TMDs at the beginning of treatment had seven times more possibility of pain if they were treated with Headgear ($p = .007$).	There is no benefit or risk in children receiving early treatment with Bionator and Headgear regarding to TMJ function. Most subjects with sounds and pain in TMJs and initial muscular pain maintain their condition during and after treatment. Class II children with TMJ capsular pain may benefit from using Bionator.

Table 4. Summary of orthopaedic appliances articles in patients with class III malocclusion and TMD.

First author and year	Population	Intervention	Comparison (control group)	Outcome	Conclusions
Kurt, 2011 [62]	46 subjects. Females: 23; Males: 23. Age range 8–11 years.	Treatment of class III patients with maxillary retrognathia with two appliances: 1. Modified Jasper Jumper (JJ) 2. Delaire-type facial mask. Diagnosis of class III: (a) Skeletal relationship: maxillary retrognathia (SNA $\leq 79°$); ANB $-1°$; horizontal growth pattern (S–N/Go–Me: 30–32°) (b) Dental relationship: angle class III with an anterior crossbite. The patients could achieve an edge-to-edge incisor position. TMD: RDC/TMD prior to appliance placement and removal. Evaluation performed in control group before and after 6 months. Chi-square, McNemar, Mann–Whitney *U*, Kruskal–Wallis and Wilcoxon tests.	1. Treatment group: $n = 33$. Females: 15; males:18. Age range 8–11 years old. (a) Modified JJ: $n = 16$. Females :8; males: 8. Average: 9.67 ± 0.95 years old. (b) Delaire-type facial mask: $n = 17$; Females:7; males:10. Average: 9.55 ± 0.97 years old. 2. Control group: $n = 13$. Females: 8; males:5. Average: 9.14 ± 0.40 years old.	The most diagnosed disorder was arthralgia. A significant decrease was found in mean number of painful muscles after treatment in the modified JJ group ($p<.05$). A significant reduction of arthralgia was observed in post-treatment vs pre-treatment between treatment and control groups ($p<.001$).	The Delaire-type facial mask and the modified JJ used in the early treatment of class III malocclusions have no effect on the occurrence of TMD.
Rey, 2008 [33]	75 subjects. Females: 43; males: 32. Age range: 12-24 years. Average age: 16.7 ± 2.8 years.	Mandibular cervical headgear (MCH) in class III patients worn by 14 h daily with a force of 300 g per side followed by fixed appliances. Treatment duration: 2–3 years. Diagnosis of class III: Wits appraisal <-2, ANB $<0°$, class III molar relationships, negative overjet. TMD: Helkimo index. Signs and symptoms. *Z* score on proportions test.	1. Control group: $n = 25$; no previous orthodontic treatment. 2. Class I group: $n = 25$; prior fixed appliances without extractions. 3. Dentoskeletal Class III group: $n = 25$; prior treatment with MCH and fixed appliances.	No significant difference among the three groups in Helkimo index ($p=.367$). Most patients had no signs and symptoms of TMD (66.7%). Most prevalent TMD was clicking (92%)	There was no high prevalence of signs and symptoms of TMD in Class III malocclusion patients treated with MCH and fixed appliances compared to Class I malocclusion treated with fixed appliances and subjects without orthodontic treatment.
Arat, 2003 [63]	124 patients. Age range: 8.3–31.1 years. Pre-treatment: mean 11.2 years; age range: 8.3–14 year. Post-treatment: mean 13.4 years; age range:9.7–16.8 years.	Skeletal class III malocclusion treated by Chin-cup therapy. Average treatment time was 1.8 years. 500 g force used for 14 h/day. Diagnosis of TMD: functional examination of signs and symptoms performed by one investigator according to the Okeson and Graber criteria (Clicking at open and/or closed mouth; pain of masticatory muscles and joints, opening Deviation). Analysis by a *Z*-test.	1. Control group 1: skeletal class III malocclusion ($n = 39$, mean age 15.5 years) 2. Control group 2: acceptable normal occlusion ($n = 53$;mean age 19.2 years). 3. Treatment group: Chin cup ($n = 32$; mean age 18.4 years).	The distribution of symptomatic subjects in the treatment and Class III malocclusion groups was found to be statistically similar ($Z = 0.19$). The distribution of symptomatic subjects was found to be statistically similar between the treatment and normal groups ($Z = 1.54$). The occurrence rate of clicking and deviation did not differ among groups.	Chin-cup therapy is neither a risk factor nor a prevention of TMD.

MI: maximum intercuspation; MRI: magnetic resonance imaging; RDC/TMD: research diagnostic criteria for temporomandibular disorders; SD: standard deviation; TMD: temporomandibular disorders; TMJ: temporomandibular joint.

Table 5. Summary of studies analyzed according to study design, type of malocclusion, appliances used and whether these appliances allowed the development of TMD.

Author, year	Study design	Type of malocclusion	Orthopaedic appliances	Fixed/removable	Development of TMD (yes/no)
Kurt, 2011 [62]	RCT	Class III	Jasper Jumper Delaire facemask	Fixed Removable	No
Conti, 2008 [58]	CCT	Class II	Bionator	Removable	No
Rey, 2008 [33]	CCT	Class III	Cervical Headgear	Removable	No
Arat, 2003 [63]	CCT	Class III	Chin cup	Removable	No
Franco, 2002 [59]	RCT	Class II	FR-II	Removable	No
Chintakanon, 2000 [60]	CCT	Class II	Twin-Block	Removable	No
Keeling, 1995 [61]	RCT	Class II	Bionator Headgear	Removable Removable	No

CCT: clinical controlled trial; RCT: randomized controlled trial; TMD: temporomandibular disorders.

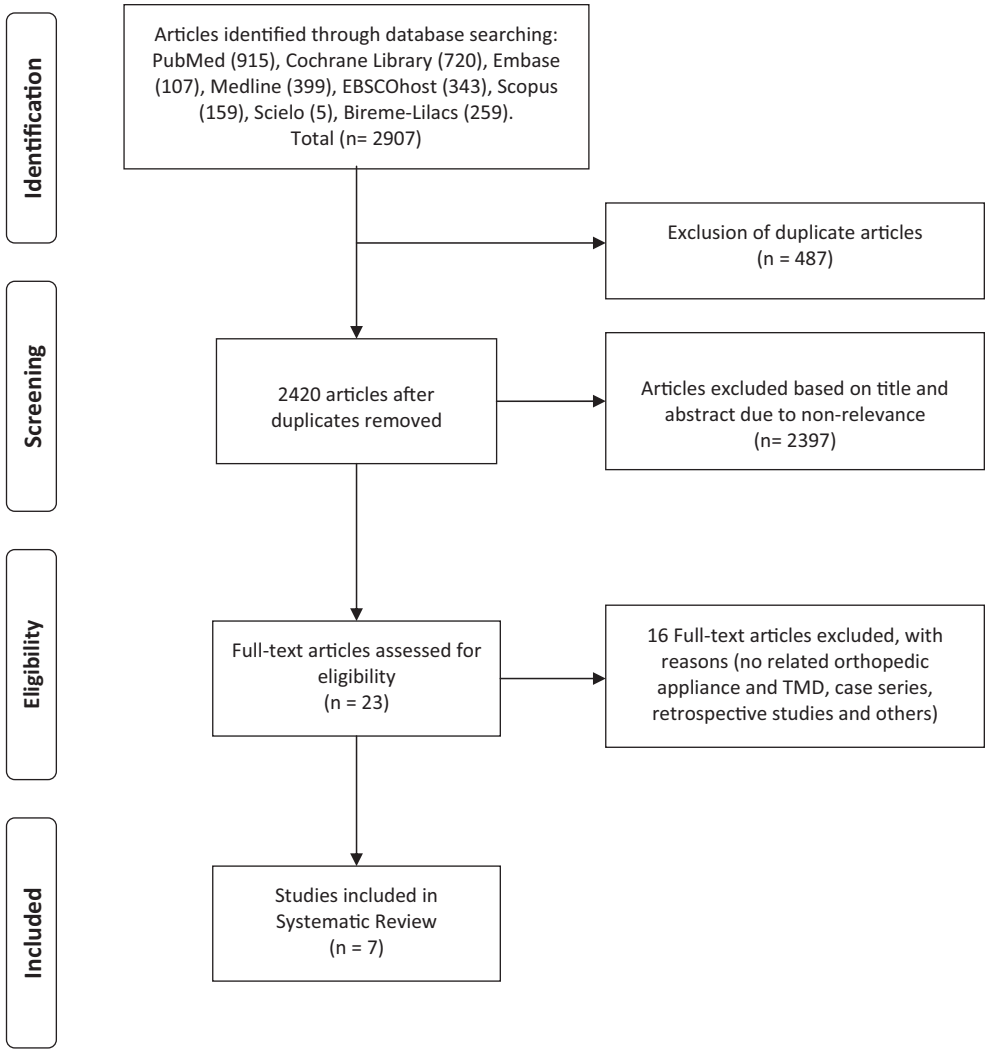

Figure 1. Search method, identification, selection and inclusion of articles.

Quality assessment

When the quality of the studies based on the risk of bias was analyzed according to the Cochrane Risk of Bias Assessment Tool and the Cochrane Quality Study Guide, it was determined that all studies were exposed to a high risk of bias (Table 6). None of the studies presented adequate sequence generation (randomization). The RCTs analyzed did not provide any information on the randomization process. For CCTs, it was considered that their design had a high risk of bias inherent to the study design. No study adequately addressed allocation concealment. The item 'blinding of outcomes' took place in only two studies (Kurt 2011, Keeling 1995) [61,62].

The items 'Completeness of outcome data' and 'Selective outcome reporting' were largely addressed in all studies analyzed. The other risks of bias presented in the studies were related to the time of use of the orthopaedics appliances (hours per day reported), amount of force applied [58], and diagnostic method for TMD that were replicable and reliable [58,61,63].

Table 6. Risk of bias according to Cochrane Risk of Bias Assessment Tool.

First author, year	Sequence generation	Allocation concealment	Blinding of outcome	Incomplete outcome data	Selective reporting	Other sources of bias
Orthopaedics appliances for class II malocclusion						
Conti, 2008 [58]	High	High	High	Low	Low	High
Franco, 2002 [59]	Unclear	Unclear	Unclear	Low	Low	Unclear
Chintakanon, 2000 [60]	High	High	High	Low	Low	Unclear
Keeling, 1995 [61]	Unclear	Unclear	Low	Low	Low	High
Orthopaedics appliances for class III malocclusion						
Kurt, 2011 [62]	High	High	Low	Low	Low	Unclear
Rey, 2008 [33]	High	High	High	Low	Low	Unclear
Arat, 2003 [63]	High	High	High	Low	Low	High

Discussion

The relationship between orthodontic/orthopaedic treatment and development of TMD is a topic of great interest that has generated an extensive discussion in dental literature, where its influence as an aetiological factor in the TMD has not been established yet.

The objective of this systematic review was to analyze all RCTs and CCTs to determine whether the use of orthopaedics appliances to correct class II and III malocclusion in growing patients would be considered as a risk factor for the development of TMD (Table 5). Seven studies were analyzed, all considered growing patients. However, one article did not discriminate children and adolescents from young adults [33].

From a methodological point of view, the quality of evidence of the analyzed studies was low, mainly influenced by the exposure to the high risk of bias, the lack of replication of the methods used for the diagnosis of TMD and great variability of orthopaedic appliances that does not allow in establishing comparisons between the studies. In relation to the risk of bias according to the Cochrane Risk of Bias Assessment Tool and the Cochrane Quality Study Guide, all included articles had a high exposure to risk of bias; both the RCTs and the CCTs were analyzed. Recurring methodological flaw in items: random sequence generation, allocation sequence concealment and blinding outcome.

Regarding the lack of clinical methods with adequate sensitivity for diagnosis of TMD observed in this systematic review, one of the methods used for the diagnosis of evidence-based TMD is the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), created with the purpose of clinical and epidemiological research [64], and the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), which results in an evidence-based system with greater validity for clinical use [64]. Although these methods are widely used in clinical research, they only have validity in adults. This presents a difficulty for studies in growing subjects.

Class II orthopaedic appliances in growing patients and temporomandibular disorders

In this systematic review, four articles were analyzed in order to determine if the use of class II orthopaedic appliances to correct class II malocclusion in growing patients would develop TMD. All studies were exposed to a high risk of bias according to The Cochrane Quality Study Guide and none determined that the use of removable appliances (Bionator, Fränkel II appliance, Twin-block and headgear) is related to the development of TMD (Table 5 and 6).

Despite the controversy surrounding the possible TMD generated by the use of class II orthopaedic appliances, due to the sagittal change of the mandible when the condyle is displaced from the fossa, the analyzed evidence in this systematic review shows that the treatment with these appliances would not have any influence on the development of muscular and joint disorders. However, the heterogeneity in the design and the diagnostic methods, the quality of the evidence and the lack of sensitivity for the diagnosis of TMD in growing subjects do not allow to establish definitive conclusions.

Some studies in adolescents show an association between disc displacements in the TMJ in subjects with class II morphological characteristics, such as a decrease in mandibular length, clockwise rotation mandible and retruded position of mandible [65]. They concluded that a class II profile and a hyperdivergent growth pattern could be associated with an increase in the frequency of disc displacement and degenerative joint disorders [65]. Although the devices for mandibular advancement would have a dentoalveolar effect, they would not correct the skeletal abnormality [66], so it is not possible to determine if it is the use of the orthopaedic appliance or the facial morphology that contributes to the development of TMD.

Regarding muscles disorders, there would be a decrease in muscle activity due to occlusal instability and changes in the intermaxillary relationship due to the mandibular protrusion caused by the appliance [67]. A study performed by Sood et al. [67], concluded that the use of Forsus Fatigue Resistant in class II division 1 patients decreased the muscle activity and the number of posterior occlusal contacts, leaving them in inocclusion. This would lead to a change of sensorial information in the receptors of the masticatory muscles, altering the position of muscular balance, resulting in the presence of pain in patients when retracting the mandible [68], causing changes in the neuromuscular response, decreased ability of lateral movements and increased muscle sensitivity, which would continue during the first months of treatment. Muscle balance would be re-established when this new position, as a result of the orthopaedic appliance, is maintained. Finally, after 6 months

using the device, muscle activity returns to pre-treatment levels as a result of neuromuscular adaptation [67].

In relation to the effects of class II orthopaedic appliances on TMJ, the evidence shows that they would cause anterior displacement of the condyle in the glenoid fossa after the use of functional appliances, and in a second treatment phase with fixed appliance, the condyle would maintain a concentric position [69]. Pancherz et al. [70] Kinzinger et al. [49] and Wadhawan et al. [69] concluded that the joint disc would move to a posterior position when using functional appliances, but at the end of the treatment, the joint disc tends to be located in its original position. This would be explained by the anterior positioning of the condyle as a result of using the functional appliances that would produce the stretching of the retrodiscal tissues which in turn could cause a stretching of the articular disc or its displacement to a more posterior position. Despite the tension produced by retrodiscal tissues, the disc would not lose its morphology [69]. The evidence shows that the use of functional appliances such as the Activator, Fränkel, Twin-block, Bionator and Herbst would not cause changes in the position and shape of the articular disc [59,69,71,72].

Class III orthopaedic appliances in growing patients and TMD

Three studies aimed to establish the relationship between orthopaedic appliances to correct class III malocclusion in growing patients and the development of TMD, considering fixed appliances such as Jasper Jumper (JJ) and removable appliances as: Delaire facemask, cervical headgear and chin cup. It has been assumed that orthopaedic forces applied from the chin to the posterosuperior part of the condyle contribute to the development of TMD [19,73]. However, some TMJ elements, such as the temporomandibular ligament (TML) have not been considered. The backward and upward movement of the condyle generated by the chin cup is inhibited by the horizontal portion of the TML, so this ligament would act as a safety mechanism against this situation [74]. In addition, in a study performed by Gökalp et al. [18], they observed that if the chin cup is used during premature growth periods and if the magnitude of the forces does not exceed the physiological limits, there would be no changes in position and shape of the articular disc. When quality of the evidence was considered, all articles analyzed were exposed to a high risk of bias (Table 6).

Agreements and disagreements with other reviews

The reviews that analyze the effects of orthopaedic appliances in growing patients are limited. They mostly aim to determine the effect of treatment of orthodontic fixed appliances as a risk factor in the development of TMD. In the meta-analysis performed by Kim et al. [75], they concluded that traditional appliances used in orthodontic treatment would not increase the prevalence of TMD (Begg appliance, Herbst, class II elastics, Bionator, headgear, facemask and chin cup) and other appliances, such as Bionator and Herbst, would decrease the symptoms. Michelotti performed a review in 2010 to determine a possible association of orthodontic treatment in the development of TMD (including functional appliances, class II/III elastics, chin cup, headgear, fixed and removable appliances). The authors concluded that current evidence does not demonstrate the influence of orthodontic treatment as an aetiological factor in TMD [76]. In the systematic review conducted by Zurfluh et al. [77], they evaluated the effect of chin cup treatment on the TMJ, concluding that poor evidence and poor study quality do not allow to establish the influence of chin cup in the TMJ; however, studies show that chin cup would not be a risk factor for the development of TMD.

The discrepancies found with these reviews were related to the search methods, number of databases used, the language of the articles and the analysis of the evidence. In the meta-analysis performed by Kim et al. [75], the analysis of the studies did not determine the quality of the articles, and according to the authors, the high heterogeneity did not allow a true meta-analysis, which would be attributed to the lack of sensitivity of the diagnostic methods of TMD, the variability of study designs and the presence of bias.

Limitations

The lack of evidence and the low level found in the articles analyzed show a great limitation in this review. Only three RCTs and four CCTs were found, which presented high risk of bias. The large number of appliances used and the lack of methodologies with adequate sensitivity for the clinical diagnosis of TMD do not allow comparisons between the studies, making it difficult to determine an association between the use of orthopaedic appliances in growing patients and the development of TMD. For this reason, and although the evidence available does not allow to establish a causal relationship between the use of these devices and the development of TMD, the results of this systematic review should be interpreted with caution.

Despite the heterogeneity of the studies, the presence of bias, recurrent methodological flaws and the evidence that do not support the use of orthopaedic appliances in growing patients and their relationship with the development of TMD, it is possible to suggest that the use of orthopaedic appliances in growing patients with class II and III malocclusion would not be considered as a risk factor for TMD.

Given the heterogeneity in study designs and diagnostic methods for TMD, number of subjects, appliances used and treatment time, it was not possible to perform a meta-analysis.

Conclusions

Establishing the causal relationship between orthopaedic appliances and the development of TMD in growing patients is a controversial topic in dental literature, due to limited and inconclusive evidence.

Nonetheless, based on the findings in this systematic review, it is possible to conclude:

- The evidence linking the use of orthopaedic appliances in children and adolescents to correct class II and III malocclusion is limited and of low quality, with heterogeneous designs and methodologies.
- According to the studies analyzed, it is possible to suggest that the use of fixed or removable orthopaedic appliances used in the treatment of class II and III malocclusion in growing patients would not be considered as a risk factor for the development of TMD.
- Current literature only provides low levels of evidence, which is why it is necessary to decrease the risk of bias in future studies to allow more consistent comparisons and conclusions. Future research should focus on improving sensitivity for the diagnosis of TMD in growing patients, increasing the number of RCTs, improving random sequence generation, the allocation sequence concealment and blinding of outcome assessment to ameliorate the quality of the evidence.

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