Association between posterior crossbite, masticatory muscle pain, and disc displacement: a systematic review

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SUMMARY
BACKGROUND Among different malocclusions, posterior crossbite is thought to have a strong impact on the correct functioning of the masticatory system.

OBJECTIVE To assess, by systematically reviewing the literature, the association between posterior crossbite and different temporomandibular disorder (TMD) diagnosis: disc displacement and masticatory muscle pain.

MATERIALS AND METHODS A literature survey covering the period from January 1965 to April 2012 was performed. Two reviewers extracted the data independently and assessed the quality of the studies.

RESULTS The search strategy resulted in 2919 citations, of which 43 met the inclusion criteria. The scientific and methodological quality of these studies was found to be medium-low, independently by association reported. In several studies, posterior crossbite is reported to be associated to the development of disc displacement, muscular pain, and tenderness, possibly linked to a skeletal and muscular adaptation of the stomatognathic system. However, the lack of consistency of the results reported deeply reduces the external validity of the studies, with a consequent impossibility to draw definite conclusions.

CONCLUSIONS It is not possible to establish an association between posterior crossbite, muscle pain, and disc displacement because the distribution of the studies supporting or not supporting the association is similar. The consequences of posterior crossbite on the development of TMDs deserve further investigations, with high sample size, well-defined diagnostic criteria, and rigorous scientific methodologies. Finally, long-term controlled studies are needed to identify posterior crossbite as a possible risk factor for TMDs.

Introduction

Posterior crossbite is defined as the presence of one or more teeth of the posterior group (from canine to second molar) in an irregular (at least one cusp wide) bucco-lingual or bucco-palatal relationship, with one or more opposing teeth in centric occlusion (Daskalogiannakis, 2000). It is one of the most prevalent malocclusions in the primary and early mixed dentition and is reported to occur in 8–22% of orthodontic patients (Sonnesen et al., 1998) and in 5–15% of the general population (Thilander and Myrberg, 1973; Helm and Prydsø, 1979; Ciuffolo et al., 2005; Farella et al., 2007).

Among different malocclusions, posterior crossbite is thought to have a strong impact on the correct functioning of the masticatory system (Proffit, 2000; McNamara, 2002). It has been suggested that the altered morphological relationship between the upper and lower dentition may result in right-to-left-side differences in masticatory muscles and condyle–fossa relationship. The asymmetric work of the masticatory muscles could determine tenderness of the masticatory muscles (Sonnesen et al., 2001) and headache (Sonnesen et al., 1998), occurring more frequently in the crossbite group than in the control group. Furthermore, according to the proposed causal chain of events, the alterations of the disc–condyle relationship consequential to posterior crossbite may be responsible for disc displacement and temporomandibular joint (TMJ) clicking (Wilkinson, 1991; Pullinger et al., 1993; Egermark et al., 2003; Buranastidporn et al., 2006; Michelotti and Iodice, 2010).

However, a significant association between posterior crossbite and temporomandibular disorders (TMDs) is not consistently reported in the literature across time (Seligman and Pullinger, 1991; Vanderas, 1993; McNamara et al., 1995; Sonnesen et al., 1998; Sari et al., 1999; Alamoudi, 2000; Sonnesen et al., 2001; Thilander et al., 2002; Vanderas and Papagiannoulis, 2002; Egermark et al., 2003; Pereira et al., 2009; Marklund and Wänman, 2010; Tecco et al., 2011) and definitive conclusions cannot be drawn. Therefore, a systematic review addressing a carefully formulated question (List
and Axelsson, 2010) is needed. Hence, we carried out a systematic review focusing specifically on the association between posterior crossbite, muscular pain, and disc displacement, analysing the quality of the methodological soundness of the studies.

Materials and methods

To identify the studies that examined the correlations between posterior crossbite and different TMD diagnoses, a literature survey was carried out through the Medline database (Entrez PubMed, http://www.ncbi.nlm.nih.gov). The survey covered the period from 1 January 1966 to 30 April 2012 and used the medical subject heading term: ‘crossbite’, which was crossed with the keywords ‘Temporomandibular disorder*’, ‘disc displacement’, ‘click*’, ‘masticatory muscle pain’, ‘masticatory myofascial pain’, ‘muscular pain’, and ‘myalgia’.

The studies were selected on the basis of specific inclusion and exclusion criteria by three researchers, reading the titles, and the abstracts. The inclusion criteria were human studies, posterior crossbite, lateral crossbite, TMDs, retrospective studies with and without controls or reference group, and prospective studies. Exclusion criteria were articles not in English language, case reports and case series, reviews, studies with unclear diagnosis or poorly defined samples, treatment strategies and appliances, craniofacial syndrome diagnosis possibly influencing the prevalence of TMD, full text not available, and experimental animal studies. All the studies not pertinent with the aim of the review (i.e. not investigating on the relationship between posterior crossbite and TMD symptoms) and the studies analysing the anterior crossbite were excluded. Furthermore, some studies retrieved more times by using different keywords were counted only once. Finally, two researchers analysed the full-text version of all included studies independently, and the studies were catalogued on the basis of the associations between crossbite and ‘muscular pain’, ‘disc displacement’, or the generic term ‘TMD’. When the full-text version of the study was not directly available, the manuscript was requested to the corresponding author by email. Some studies investigating on more items were reported in two or more groups of associations. Afterwards, the researchers independently evaluated the scientific and methodological soundness of each study using a published quality score (Figure 1; Andrade et al., 2009). Each study was categorized as low (0–5 points), medium (6–8 points), or high (9 or 10 points). The data were extracted from each article, studies’ authors were not blinded to the examiners, and intra-examiner conflicts were resolved by discussion of each article to reach a consensus.

Data were analysed by conventional descriptive statistics. Pearson product-moment correlation supplemented by linear regression and unpaired Student’s two-tailed t-test were used for statistical analysis. Statistical significance was set at \( P < 0.05 \). All the statistical procedures were performed with the Statistical Package for the Social Sciences (SPSS 20.0, SPSS Inc., Chicago, Illinois, USA).

Results

A flow chart of the search strategy is represented in Figure 2. Initial search yielded 2919 citations. Screened on the basis of the inclusion and exclusion criteria, 43 articles were analysed.

Crossbite and disc displacement

On the basis of the inclusion/exclusion criteria, the search strategy resulted in 27 articles investigating specifically the relationship between crossbite and disc displacement. The scientific and methodological evaluation was high in 3 (11.2%) studies, medium in 12 (44.4%), and low in 12 (44.4%; Table 1 and Supplementary Table 1, available online).

Fifteen studies (55.5%) reported a significant association between posterior crossbite and disc displacement (‘association’) with a mean score of 5.5: 2 (13.3%) with a high score, 7 (46.7%) with a medium score, and 6 (40%) with a low score. Twelve studies (44.5%) did not find any significant association between posterior crossbite and disc displacement signs and symptoms (‘no association’) with a mean score of 5.7: 1 (8.3%) with a high score, 5 (41.7%) with a medium score, and 6 (50%) with a low score. Mean years of publication for the articles were, respectively, 14.7 years for the ‘association’ and 12.6 years for the ‘no association’ articles. Both scientific and methodological quality assessment and studies years of publication were not statistically different between groups (\( P = 0.71 \) and \( P = 0.55 \), respectively). Six out of 27 studies used research diagnostic criteria (RDC)/TMD for the evaluation of click, 2 reporting ‘association’ with a mean score of 7.5 (by the same authors in different years: Marklund and Wänman, 2007, 2010),
and 4 reporting 'no association' with a mean score of 6.2. Eight studies were based on adolescent samples (2 reporting 'association'; 6 reporting 'no association'), 5 studies on adult samples (4 reporting 'association'; 1 reporting 'no association'), and 11 on samples including both adolescent and adult subjects (8 reporting 'association'; 3 reporting 'no association'). Three studies did not report the age of the sample (2 reporting 'association'; 1 reporting 'no association').

Crossbite and masticatory muscle pain

On the basis of the inclusion/exclusion criteria, the search strategy resulted in 19 articles investigating specifically the relationship between crossbite and masticatory muscle pain. The scientific and methodological evaluation was high in 1 (5.3%) study, medium in 10 (52.6%) studies, and low in 8 (42.1%) studies (Table 2 and Supplementary Table 2, available online).

### Table 1  Crossbite and disk displacement.

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<td>Marklund</td>
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<td>Miyawaki</td>
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<td>Berg</td>
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<td>Corvo</td>
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<td>Miyazaki</td>
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<td>Roberts</td>
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### Table 2  Crossbite and masticatory muscle pain.

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Nine studies reported a significant association between posterior crossbite and masticatory muscle pain (‘association’) with a mean score 5.6: none with a high score, 6 (66.7%) with a medium score, and 3 (33.3%) with a low score. Ten studies did not find a significant association between posterior crossbite and masticatory muscle pain (‘no association’) with a mean score of 5.8: 1 (10%) with a high score, 4 (40%) with a medium score, and 5 (50.0%) with a low score. Mean years of publication for the articles were, respectively, 17.2 years for the ‘association’ and 11.6 years for the ‘no association’ articles. Both scientific and methodological quality assessment and studies years of publication were not statistically different between groups (P = 0.77 and P = 0.20, respectively). Three out of 19 studies used RDC/TMD for the evaluation of muscle pain, 1 reporting ‘association’ (mean score: 6) and 2 reporting ‘no association’ (mean score: 5). Eleven studies were based on adolescent samples (6 reporting ‘association’; 5 reporting ‘no association’), 4 studies on adult samples (1 reporting ‘association’; 3 reporting ‘no association’), and 5 on samples including both adolescent and adult subjects (2 reporting ‘association’; 3 reporting ‘no association’).

Crossbite and TMD

On the basis of the inclusion/exclusion criteria, the search strategy resulted in 20 articles investigating specifically the relationship between crossbite and the generic term ‘TMD’.

The scientific and methodological evaluation was high in 1 (5%) study, medium in 10 studies (50%), and low in 9 studies (45%; Table 3 and Supplementary Table 3, available online).

Nine studies reported a significant association between posterior crossbite and TMD (association) with a mean score of 5.6: none with a high score, 5 (55.6%) with a medium score, and 4 (44.4%) with a low score. Eleven studies did not find a significant association between posterior crossbite and TMD (no association) with a mean score of 5.7: 1 (9%) with a high score, 5 (45.5%) with a medium score, and 5 (45.5%) with a low score. Mean years of publication for the articles were, respectively, 10.8 for the association and 13.4 for the no association articles. Both scientific and methodological quality assessment and studies years of publication were not statistically different between groups (P = 0.84 and P = 0.47, respectively). Two out of 20 studies used RDC/TMD for the evaluation of TMD symptoms, 1 reporting ‘association’ (mean score: 5) and 1 reporting ‘no association’ (mean score: 9). Eleven studies were based on adolescent samples (7 reporting ‘association’; 4 reporting ‘no association’), 8 studies on adult samples (4 reporting ‘association’; 4 reporting ‘no association’), and 10 on samples including both adolescent and adult subjects (7 reporting ‘association’; 3 reporting ‘no association’). One study did not report the age of the sample, reporting ‘no association’.

Table 3 Crossbite and temporomandibular disorder.

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<td>Somesen</td>
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Discussion

This systematic review aimed to select all prospective and retrospective observational studies with or without control groups verifying the association between posterior crossbite and specific TMD signs and symptoms, such as masticatory muscle pain and TMJ disc displacement. Forty-three studies were retrieved. Some of them were included in more than one group of association.

From a methodological point of view, the scientific quality of most part of the studies analysed in this review was medium-low, deeply influencing the importance and reliability of their relative results. Though the poor quality of the studies affects the current knowledge on the relationship between posterior crossbite and TMD signs and symptoms, no significant difference was found in terms of quality between articles reporting association or not. Moreover, no significant association was found between the year of publishing of the studies and the associations found. Indeed, the association (or not) between posterior crossbite and TMDs seems to be transversal across time and not influenced by trends of the moment.

Nevertheless, publication bias, that is the likelihood that negative findings on the outcome of a particular treatment may be published less frequently than association ones, may represent a problem given the nature of the issue under review. Furthermore, even if we excluded studies using the same research sample, redundancy concerns, that are the problem of duplication studies on the same study populations, cannot be ruled out. This problem could be mainly ascribed to the relatively few groups involved in this clinical research field, some of them contributing with multiple papers on populations of different size (Egermark-Eriksson et al., 1983, 1987, 1990, Egermark et al., 2003; Seligman...

The representativeness of a sample to its disease/disorder target population is important when the sample is being used to draw generalized conclusions or to estimate the strength of possible risk factors (Farella and Palla, 2009). This is often the case with the vast majority of studies on the aetiology of TMD and is the main cause for the still present confusion that is apparent over the role of occlusion in TMD.

The inclusion criteria we used were limited to the articles in peer-reviewed journal and in English language to enhance the methodological rigor of the studies examined and the conclusion drawn. However, this strategy did not exclude the possibility that some publications in other languages and/or publications included only in other databases were unjustly excluded and should be considered in future reviews.

According to our review, results of the scientific literature are not consistent, and different opinions have been presented across time. Consistency of the observed association across studies represents the fifth criterion of the Hill’s suggestions (Hill, 1965; Gordis, 2009). It means that the association should be repeatedly observed in independent studies, that is, in different individuals and settings under different methods. Lack of consistency may imply that the observed association between two variables appeared because of chance or error (Türp and Schindler, 2012).

A possible explanation to this controversial view could arise from the use of vague and unspecific terms as ‘malocclusion’ and ‘TMD’, instead of specific and validated diagnosis (i.e. crossbite, TMD diagnoses, etc.). Indeed, a major shortcoming of most studies seems to be focused on TMD as a whole. On the other hand, several studies, even though evaluating TMD signs and symptoms during the clinical examinations, pooled them in a unique variable (‘with TMD’ versus ‘without TMD’) in the statistical analysis and in the results (Motegi et al., 1992; Alamoudi, 2000; List et al., 2001; Gesch et al., 2005; Godoy et al., 2007). However, TMDs are actually considered not a single pathology but a heterogeneous group of different diseases involving the stomatognathic system (De Boever et al., 2000). Furthermore, the use of ‘TMD’ as a collective term of all TMD signs and symptoms may mislead the reader to incorrect conclusions. This could be the case of Tecco et al. (2011), who found an important association between posterior crossbite and TMD symptoms ($P = 0.000$), without any significant association between posterior crossbite, TMJ sound ($P = 0.22$), and myofascial pain ($P = 0.97$). Similarly, a significant association between posterior crossbite and TMD signs and symptoms has been reported, when only headache was significantly associated (Sonnesen et al., 1998).

Moreover, it has to be remarked that only in the last 10–15 years, the introduction of validated diagnostic criteria, calibrated examiners, and appropriate imaging as in the RDC/TMD and DC/TMD has improved the reliability of investigations and of classification systems (Ahmad et al., 2009; Anderson et al., 2010; List and Greene, 2010; Schiffman et al., 2010). According to our opinion, the spreading of its use in the research and clinical settings will improve the methodological and scientific soundness and appropriateness of the future surveys.

Another important confounding factor in the analysis of the association between crossbite and TMDs may be represented by the selection of the samples. Indeed, most of the studies are based on orthodontic patients or selected controls among dental students or staff members that are not representative of the general population. In such cases, for instance, patients could seek orthodontic treatment because they are alerted on the potential role of malocclusion as risk factor of TMD, and on the other side, dental students and/or staff members can be aware of oral behaviours being considered TMD risk factors and avoid it. The consequence is a selection bias leading to unreliable results (Farella and Palla, 2009). Furthermore, many studies suffer from samples barely described (Seligman et al., 1988), small sample size (Miyawaki et al., 2004; Pahlaka and Qvarnström, 2004; Pellizoni et al., 2006; Berg et al., 2008) or investigated features poorly represented in the sample (i.e. only 16 of 106 patients presented crossbite in Corvo et al., 2003 and 2 of 127 in List et al., 2001), and predetermined sample sizes are reported in very few studies (Farella et al., 2007). Similarly, the age of the sample used influence the associations found, preventing the comparison between results of studies on children and on adults (Thilander and Bjerklin, 2012).

The main limitation of investigations evaluating the relative importance of single risk factors for disorders having a multifactorial aetiology is the difficulty in controlling for all of the other variables (Slade et al., 2008; Greene 2011). Consequently, TMDs, as the other multifactorial complex pathologies, should be evaluated using multivariate statistical analyses, as univariate models may overestimate some resulting associations (Pullinger et al., 1993; Landi et al., 2004). Even though the harmful/detrimental effects of unilateral versus bilateral crossbite on single signs/symptoms of TMD could be particularly interesting to be investigated, it was not possible to draw conclusions because it was analysed in very few studies. Finally, very few studies on the topic reported long-term data (Egermark-Eriksson et al., 1987, 1990, Egermark et al., 2003; Berg et al., 2008), deeply influencing the actual knowledge on the topic, and preventing to the elucidate if posterior crossbite is a cause, an effect, or unrelated to the temporomandibular muscular and articular disorders.

Crossbite and disc displacement

Twenty-seven articles evaluate the association between posterior crossbite and TMJ disc displacement. The existing relationship
between posterior crossbite and TMJ disc displacement is still an unsolved question because several studies obtained different results (Keeling et al., 1994; Sonnesen et al., 2001; Farella et al., 2007). According to the most part of studies available at today, the altered morphological relationship between the upper and lower dentition seems to result in alterations of the disc–condyle relationship, which in turn are possibly responsible for disc displacement and TMJ clicking (Wilkinson, 1991; Pullinger et al., 1993; McNamara et al., 1995; Egermark et al., 2003). Indeed, positive associations between unilateral posterior crossbite and TMJ clicking are supported by several studies, suggesting that the crossbite increases the risk of disc displacement by a factor of up to 3 (Kritsineli and Shim, 1992; Pullinger et al., 1993; Tanne et al., 1993; McNamara et al., 1995; Thilander et al., 2002; Egermark et al., 2003). It must be stressed that, according to our findings, among the studies based on adolescent samples two out of eight (25%) reported a significant association, whereas, among the studies based on adult samples, four out of five (80%) reported significant association between posterior crossbite and disc displacement. The higher association between crossbite and disc displacement in adults than in adolescents could be explained by the adaptive of the stomatognathic system in adolescents. Consequently, the persisting exposition to the risk factor (i.e. posterior crossbite) could determine the development of disk displacement in the adult age. This chain of events represents only a hypothesis at today because long-term controlled studies are still lacking. Nevertheless, considering that the 80% of studies on adults and 25% of studies on adolescents reported significant association between posterior crossbite and disc displacement, the orthodontic correction of a posterior crossbite could be suggested to reduce the adaptation demands of the stomatognathic system in growing subjects (Thilander and Bjerkl, 2012), whereas it is not warranted in adults to prevent TMJ derangement because skeletal adaptation has already taken place.

**Crossbite and masticatory muscle pain**

Nineteen articles evaluate the association between posterior crossbite and masticatory muscle pain. The existing relationship between posterior crossbite and masticatory muscle pain is still an unsolved question too. Comparing normocclusive and posterior crossbite subjects, Alarcon et al. (2000) found that in the right posterior crossbite subjects, the left posterior temporal showed higher electromyographic (EMG) activity than the right posterior temporal, possibly consequent to the functional mandibular shift. Such a shift could act as a mechanism for reaching a certain degree of occlusal stability (Alarcon et al., 2000; Andrade et al., 2009). Nevertheless, the same authors found that the right anterior temporal demonstrated a higher EMG activity than the left anterior temporal in the normocclusive group, suggesting that some cases of muscular asymmetry could be considered as physiological and compatible with normal function (Alarcon et al., 2000; Andrade et al., 2009).

Moreover, tenderness of the anterior temporalis and superficial masseter muscles is reported to occur more frequently in the crossbite group than in the control group (Egermark-Erikssson et al., 1983, 1990; Sonnesen et al., 2001). Nevertheless, oral parafunctions, such as clenching and object biting, significantly increase the probability of having muscle tenderness independently from and more than malocclusion (Vanderas, 1993; Michelotti et al., 2010). Finally, psychosocial status of TMD patients could be a confounding factor because several studies showed an association between TMD pain and disorders such as depression, somatization, and anxiety (Rollman and Gillespie, 2000; Suvinen et al., 2005; Sonnesen and Svensson, 2008; Manfredini et al., 2011).

**Crossbite and TMD**

Twenty articles evaluate the association between posterior crossbite and TMD. Temporomandibular disorders is a term to define a number of clinical conditions that involve the masticatory muscles, the TMJs, or both (Oksens, 2008). These conditions include articular and/or muscular pain, alteration in mandibular dynamics, and TMJ noises (clicking and crepitus), recognizing different possible aetiologies and risk factors. On this basis, the introduction of tools, such as RDC/TMD (Dworkin and Le Resche, 1992) well defining the different categories of TMDs, has increased the level of consistency between studies. Nevertheless, some studies still continue to analyse TMD as a unique dependent variable, possibly producing misleading results. This approach, even if useful to increase the statistical power of the analysis, can be a confounder when investigating on risk factors. However, analysing the studies that investigated the TMD as a whole, the relationship between posterior crossbite and TMD signs and symptoms still remains a controversial issue. According to some studies (Egermark-Erikssson et al., 1990; Alamoudi, 2000), posterior crossbite is one of the most important occlusal features significantly associated to TMDs suggesting the importance of an early orthodontic intervention to prevent the development of TMDs. Conversely, according to some other studies (Gesch, 2004a; Godoy et al., 2007), no significant association was found between posterior crossbite and TMDs, suggesting caution when it is a matter of altering the existing occlusion to prevent or to treat temporomandibular dysfunction.

**Conclusions**

1. The relationship between posterior crossbite and articular and muscular disorders is still an unsolved issue.
2. The literature available on the matter suffers of medium-low scientific and methodological quality, independent of the association reported.
3. Definitive conclusions cannot be drawn, and the possible association should be addressed by future researches.
with rigorous scientific methodology (see Strobe-Statement checklist).

Very few studies on the topic reported long-term data, deeply influencing the actual knowledge on the topic, and preventing us from elucidating if the posterior crossbite is a cause, an effect, or unrelated to the temporomandibular muscular and articular disorders. Future surveys with long-term control are needed, especially in adolescent samples.

Supplementary material

Supplementary material is available at European Journal of Orthodontics online.

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