A literature review on the causal relationship between Occlusal Factors (OF) and Temporomandibular Disorders (TMD) I: descriptive epidemiological studies

Una revisión de la literatura sobre la relación causal entre los Factores Oclusales (FO) y los Desórdenes Temporomandibulares (DTM). I: estudio epidemiológico descriptivo

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ABSTRACT

Temporomandibular disorders (TMD) are a group of musculoskeletal/rheumatologic disorders of the orofacial region that directly involve the masticatory system. TMD etiology is controversial, and even though different anatomical, psychological, traumatic, and pathophysiologic factors have been considered contributors to TMD development, the current evidence does not allow establishing a clear relationship with any factor. However, occlusal factors (OF) have been associated with TMD etiology throughout history, and many studies have been done to clarify the relationship between TMDs and OFs. Regarding the role of occlusion in TMD etiology, there is currently a disagreement between general dentists and TMD specialists but also among specialists themselves. This diversity of opinions shows the need to continuously analyze the possible relationship between OFs and TMDs. This first article presents a review of the descriptive epidemiologic studies found in the literature that have been carried out to study the relationship between TMDs and OFs. The analysis of these epidemiologic reports indicates that there is no tendency to consider any OF related to TMD etiology and that possibly other factors should be considered in the development of TMDs.

Keywords: *occlusion, temporomandibular disorders, etiology, occlusal factors, temporomandibular joint, epidemiologic studies.*

RESUMEN

Los desórdenes temporomandibulares (DTM) son un conjunto de desórdenes musculoesqueléticos/reumatológicos de la región orofacial que involucran directamente el sistema masticatorio. La etiología de los DTM es controversial y aunque diferentes factores como anatómicos, psicológicos, trauma o patofisiológicos han sido considerados como contribuyentes en el desarrollo de los DTM, la evidencia actual no permite establecer un factor o factores con una relación clara. A pesar de esto, los factores oclusales (FO) han sido tradicionalmente asociados a lo largo de la historia a la etiología de los DTM. Un sin número de estudios se han realizado tratando de aclarar la relación entre los DTM y los FO. Sin embargo, respecto a la importancia de la oclusión en la etiología de DTM, existe actualmente una discrepancia entre la opinión no solamente entre odontólogos generales y clínicos "especialistas" de DTM, sino también entre odontólogos de este último grupo. Esta diversidad de opiniones indica que hay la necesidad de seguir analizando la posible relación entre los FO y los DTM. En primer artículo se presenta una revisión de los estudios descriptivos encontrados en la literatura que se han realizado para estudiar la relación entre DTM y los FO. El análisis de estos reportes epidemiológicos indica que no existe tendencia a favorecer a ninguno de los FO de estar relacionado con la etiología de los DTM y que posiblemente otros factores deberían ser considerados en el desarrollo de ellos.

Palabras clave: *oclusión, desórdenes temporomandibulares, etiología, factores oclusales, articulación* temporomandibular*, estudios epidemiológicos.*

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INTRODUCTION

Temporomandibular disorders (TMD) are the most frequent cause of non-dental pain in the orofacial region. They are considered a set of musculoskeletal/rheumatological disorders of the orofacial region directly involving the masticatory system.[1-3] These are characterized primarily by pain —located in the masticatory muscles, preauricular area, and temporomandibular joint (TMJ)— and dysfunction —noises in the TMJ and mandibular movement limitation and irregularity— of the masticatory system.[1-3] TMD etiology is controversial, and although different anatomical, psychological, trauma or pathophysiological factors have been considered as contributors in its development, current evidence does not allow establishing a clear relationship with any of these factors.[3-5] Despite this, occlusal factors (OF) have been associated with TMD etiology throughout history. Countless studies have been conducted trying to clarify the relationship between TMDs and OFs, both morphologically (static) and functionally (dynamic) (Table 1). Nevertheless, there is currently a disagreement regarding the role of occlusion in TDM etiology not only between general dentists and clinical TMD "specialists" but also among specialists themselves.[6-10] Many recent literature reviews have reported there is not strong support for the idea of occlusion as an etiological factor in TMDs.[11-14]

Despite this, many dentists believe that occlusal problems can cause TMDs to develop or are intimately related to them. Therefore, they resort to occlusal therapies such as occlusal adjustment by selective carving as first-line treatment, although many experts and the literature do not appear to support this clinical choice[6-8, 15] This variety of opinions indicates that is necessary to analyze further the possible relationship between OFs and TMDs. In order to determine the existence of a cause-effect relationship, all available data from epidemiological research must be used and evaluated so that the validity of the reported information is subsequently considered.[16-19]

Epidemiology is defined as the study of the distribution, determinants, and natural history of diseases. One of the general purposes of epidemiology is to help clarify the etiology of diseases, and different levels of epidemiological studies are used for this purpose in an orderly manner.

This paper aims to review different epidemiological studies and their validity to weigh the current scientific evidence supporting the possible relationship between TMDs and OFs. The first part will only present and analyze descriptive epidemiological studies.

Table 1. Occlusal factors

Morphological (static)	Functional (dynamic)
Angle's class I, II, and III malocclusions	Mandibular retruded contact position
Overjet	Premature anterior or posterior contact
Overbite	Working and non-working interference or contact (scale)
Open bite	Displacement between centric relation and centric occlusion
Crossbite	Disocclusion types (anterior, canine, or group)
Dental malposition (crowding)	Protrusive interference
Occlusal plane discrepancies	
Occlusal stability (bilateral-balanced occlusal contacts)	
Dental interdigitation (number of teeth in contact)	Wear facets (especially when related to mandibular movements).
Posterior occlusal support	
Arch asymmetry	
Face or jaw asymmetry	

Source: by the authors

METHODS

The literature review was performed using diverse sources of information:

1. The Ovid database (from 1966 to 2005). The abstracts of articles in English and whose titles suggested the study of the relationship between occlusal factors and TMDs were reviewed. In order to narrow the search, the different occlusal factors and relevant terms under the occlusion/malocclusion heading were used as keywords and cross-referenced with relevant terms under the TMJ heading (temporomandibular joint (TMJ), temporomandibular joint disorders).

2. The bibliography of the articles initially found in the Ovid database search.

3. The bibliography of different books about TMDs and occlusion.

4. The bibliography of several literature reviews on this topic from the Ovid database.

The articles that were ultimately collected were organized and analyzed along the different levels of epidemiological studies (Table 2). The reviewed information from each study was organized in different tables, including the sample's age and origin and the type of clinical evaluation used in the study. Additionally, we looked for the OFs evaluated in the study and whether or not they correlated with TMDs. This first article included only descriptive studies in which an association can be established at an individual level: case-series analysis and cross-

sectional studies. Analytical studies will be presented in the second part of this series of articles. Different studies were validated following the parameters recommended by Mohl20 applicable to the type of studies presented in this article. According to this author, validity is guaranteed in studies when the following aspects are considered:

1. Definition of the "gold standard". The gold standard is the main procedure, finding, indicator, or criterion for diagnosing a disease. In the case of TMDs, like other musculoskeletal disorders, the gold standard is clinical evaluation.

2. Establishment of an acceptable system of diagnostic classification. In order to establish the TMD subgroups, the used classification system must have good inclusion and exclusion diagnostic criteria. Moreover, this will allow determining the differential diagnosis and severity levels.

3. Use of clearly defined measures. Everything used to measure or describe observations or phenomena must be objective, quantifiable, and described within operational terms. That is the only way to ensure acceptable reliability for examiners and will subsequently make the studier easier to replicate.

4. Intra- and inter-examinators acceptable reliability. This means that the measured procedure or phenomenon must be reliable or repeatable in clinical evaluation in the same examiner and likewise among examiners. To achieve this goal, examiners must be adequately trained, and the use of clearly defined measures must be considered.

5. Use of suitable samples. Samples used in the studies must have three main characteristics: A) Appropriate sample size. A sufficient number of subjects serves to assess the wide variability occurring in biological systems. This significant variability is due to anatomical, functional, and behavioral differences between individuals, which could influence the results and conclusions of the study. B) Different levels of the disease. The population in which a phenomenon or disorder is to be measured should be studied with patients who have different degrees of severity of the same disorder. Proceeding this way ensures that the study's conclusions address the disorder in its different severity levels (from mild to complex cases), which allows making distinctions between the possible associated factors in relation to different levels of the condition. C) Representativeness. A good number of subjects is important, but they must also be representative of the general population and not samples from specific populations or groups (students, military, etc.).

6. Data collection by "blind" examiners. Data from the clinical evaluation of subjects and patients, as well as from measurements, procedures, or strategies, should be collected and

evaluated by researchers unaware of any characteristics that might lead to an impartial performance from the examiners. It is the only way to eliminate the bias that could appear due to the preconceived ideas that examiners may have regarding the occurrence of the event.

7. Study replicability. Studies should be repeated in other laboratories or clinics to ensure that the phenomenon is not particular to the researcher or their environment so the validity of the research hypothesis or clinical premise can be accepted as real scientific evidence. Replicability is ensured when measurements are clearly defined, and examiners have had adequate reliability in relation to what they are measuring.

8. Consideration of alternative hypotheses. Researchers must be prepared to propose other possible hypotheses that explain the phenomenon to ensure acceptance or non-acceptance of the research hypothesis. They must also answer questions such as: which experiment could disprove the hypothesis being measured? What hypothesis makes the experiment disproved?

Table 2. Epidemiological studies

Descriptive	Analytical
Case series	Observation (cases and controls and "retrospective and prospective" cohorts).
Cross-sectional	Intervention (randomized clinical studies)
Correlational (of the population)	

Source: by the authors

RESULTS

The descriptive studies included 30 cross-sectional studies in children and adolescents [21-51] (table 3), [54] in adults [52-106] (table 4), and 15 case series studies, out of which only one was conducted in children and adolescents [107-122] (table 5).

Table 3. Cross-sectional studies in children and adolescents

First author & year	Sample (F/M)	Age range	Population and method for TMD clinical evaluation	Occlusal factors positively correlated with TMD (diagnosis, signs, or symptoms)			Occlusal factors reported without correlation to TMD
				Morphological	Functional	TMD	
Grosfeld, 1977	500 (269/231)	6-15	Randomly selected schoolchildren evaluated with an-interview and a physical examination	NR	NR	NR	Malocclusion and edentulism
Williamson, 1977	304 (175/129)	6-16	Pre-orthodontic patients evaluated with a physical examination	Overjet, Deep bite and open bite	NR	Muscle tenderness of the lateral pterygoid muscle	Angle's classes
Egermark-Ericsson, 1983	402 (194/208)	7-15	Randomly selected people evaluated with a questionnaire and a physical examination*	Crossbite, open bite, Angle's class II, III, tooth wear, and number of contact teeth	Occlusal interference and displacement in anteroposterior centric	Di Muscle tenderness on palpation, headaches	Non-working contacts
Gatzi, 1984	369 (181/188)	10-18	Schoolchildren evaluated with a questionnaire and physical examination	Malocclusion (crossbite, open bite, Angle's class II, III, and crowding) and tooth wear	NC	Muscle tenderness Articular noises	Occlusal interferences (premature and non-working contacts) and displacement in centric
Lieberman, 1985	369 (181/188)	10-18	Schoolchildren evaluated with a questionnaire and a physical examination	Deep bite > 5 mm and severe tooth wear	NR	Muscle tenderness of the TMJ and articular noises	Angle's classes, open bite, and crossbite
Brandt, 1985	1342 (669/673)	6-17	Schoolchildren evaluated with an-interview and a physical examination*^	Overbite, open bite, overjet, crossbite, and Angle's class II	Displacement in absent centric < 1 mm	Limitation of mouth opening, muscle tenderness, TMJ tenderness, articular noises	Angle's class III
Bernal, 1986	149 (70/79)	3-5	Schoolchildren evaluated with an-interview and a physical examination*^	Anterior crossbite	NR	TMJ clicking	Posterior crossbite, open bite, deep bite
Nilner, 1986	749 (380/369)	7-18	Randomly selected schoolchildren evaluated with an-interview and a physical examination	Angle's class II	Premature contacts, non-working contact	Mandibular movement, articular noises, deviation on opening, TMJ tenderness, muscle tenderness	Class III, open bite, deep bite, and tooth wear
Woman, 1986	285	17	Dental patients evaluated with a questionnaire and a physical examination*	NC	Non-working contact	Limitation of mouth opening Muscle tenderness	Angle's class, open bite, deep bite, crossbite, tooth wear, and displacement in centric
Kampe, 1987	225 (NR)	13-15	Randomly selected children evaluated with an interview and a physical examination*	NC	Non-working interference	Di	Tooth wear, displacement in centric, working interference, crossbite, overjet, and overbite and Angle's classes
Meng, 1987	173 (96/77)	6,8-27,7	Pre-orthodontic patients evaluated with an interview and a physical examination	NC	NC	TMD signs and symptoms	Tooth wear, displacement in centric, and number of teeth
Riolo, 1987	1342 (668/667)	6-17	Schoolchildren evaluated in an interview and a physical examination	Angle's class II, overjet and overbite, crossbite	Displacement in centric	TMJ tenderness Muscle tenderness Articular noises	Angle's class III
James, 1988 & Kirveskari, 1986	383 (196/187)	5-15	Randomly selected children evaluated with a physical examination*	Open bite	Phantom bite	TMD signs	Angle's class, overjet, overbite, deep bite, crossbite, and non-working contacts
Gunn, 1988	151 (85/67)	6-18	Immigrant population evaluated with an interview and a physical examination	Angle's class II	NC	Articular noises, earache, or headache	Displacement in centric, Angle's class III, overbite, overjet, crossbite, tooth wear
Mohlin, 1991	1018 (509/509)	12	Randomly selected children evaluated with an interview and a physical examination*^	Overjet	NC	Limitation of jaw movement	Overbite, crossbite, open bite and crowding, premature contacts, displacement in centric, non-working interferences
Kritsineli, 1992	80 (32/48)	NR	Pediatric dentistry patients evaluated with a physical examination	Overjet, overbite, crossbite and open bite	NR	Articular noises, deviation on opening	Angle's classes, dental midline coincidence, overbite, crowding, dental midline coincidence
Montego, 1992	7337 (4118/3219)	6-18	Randomly selected children evaluated with an interview and a physical examination	Crowding and excessive overjet	NR	TMD signs and symptoms	Posterior and anterior crossbite, deep bite, open bite

Howell, 1993	154 (76/78)	13-17	Dental patients evaluated with a questionnaire and a physical examination^	NC	NR	TMD signs and symptoms	Angle's class III, crossbite and tooth wear
Tanne, 1993	305 (186/119)	NR	Pre-orthodontic patients evaluated with a questionnaire and a physical examination	Crossbite, open bite, deep bite, and crowding	NR	TMD signs and symptoms	Overjet
Keeling, 1994	3428 (1789/1639)	6-12	Schoolchildren evaluated with a physical examination^	NC	NC	Articular noises	Facial profile, Angle's classes, overbite, overjet, and crowding
Banderas, 1994	386 (NR)	6-12	Randomly selected people evaluated with an interview and a physical examination^	Crossbite	Premature contacts	Muscle tenderness, TMJ tenderness, limitation of mouth opening	Open bite, deep bite, and overjet
Verdonck, 1994	1182 (F)	12-15	Schoolchildren evaluated with an interview and a traditional physical examination	Dental crowding, deep bite	NR	Deviation on opening, pain	Crossbite, open bite, overjet, crowding, overbite, and non-working contacts
Westling, 1995	193 (96/97)	17	People evaluated with a questionnaire and a physical examination	NR	Premature contacts and displacement in centric	Articular noises in the contralateral TMJ	NR
Henrikson, 1997	183 (F)	11-15	Schoolchildren on the waiting list for orthodontic treatment evaluated with a questionnaire and a physical examination	Overjet > 6 mm, anterior open bite, number of contacts, and dental crowding	Non-working interferences and displacement in lateral centric >0.5 mm	Headaches, TMD signs, and symptoms	Crossbite, open bite, Angle's class I, II, tooth wear, midline discrepancy, and working interferences
Sonnesen, 1998	104 (56/48)	7-13	Pre-orthodontic patients with severe malocclusions evaluated with an interview and a physical examination*^	Angle's class II, overjet, open bite, unilateral crossbite, midline discrepancy, disturbances in tooth development	NR	Headaches Neck and shoulders tenderness Tenderness on muscles of mastication Jaw lock	Crowding, deep bite, overbite
Alamoudi, 2000	532 (288/244)	3-7	Schoolchildren evaluated with a questionnaire and a physical examination^	Posterior crossbite, edge-to-edge bite, anterior open bite, and canine class III	NC	TMD signs	Angle's classes, overjet, crowding, tooth wear, anterior crossbite, midline discrepancy, and displacement in centric
Thunder, 2002	4724 (2353/2371)	5-17	Randomly selected people evaluated with an interview and a traditional physical examination*^	Tooth wear, crossbite, anterior open bite, Angle's class III, overjet	Displacement in centric and non-working contacts	Articular noises, TMJ tenderness, muscle tenderness, Di	Angle's class II and midline discrepancy
Banderas, 2002	314 (153/161)	6-8	Schoolchildren from public schools evaluated with an interview and a traditional physical examination^	Posterior crossbite with lateral displacement in center overjet	NC	Deviation on opening, TMJ tenderness, articular noises, muscle tenderness	Deep bite, open bite, anterior crossbite, displacement in centric, premature contacts, non-working interference
Demir, 2004	716 (361-355)	10-19	Randomly selected schoolchildren evaluated with an interview and a physical examination^	Angle's classes, anterior crossbite, overjet, open bite, deep bite and crowding	NC	Muscle tenderness	Posterior crossbite and displacement in centric
Sterling, 2004	136 (66/70)	6-12	Pre-orthodontic patients evaluated with a physical examination	Angle's and canine classes, overjet	NC	Mandibular movements	Premature contacts, occlusal interferences, overbite, open bite, deep bite, and crowding

* Application of the Helkimo index (HI).
^ Reported reliability of examiners.
Helkimo anamnestic index (Ai); Helkimo dysfunction index (Di); no correlation (NC); not reported (NR); female (F), male (M); disc displacement without reduction (Deworm); magnetic resonance imaging (MRI); temporomandibular disorder (TMD); temporomandibular joint (TMJ).

Table 4. Cross-sectional studies in adults

First author & year	Sample (F/M)	Age range	Population and method for TMD clinical evaluation	Occlusal factors positively correlated with TMD (diagnosis, signs, or symptoms)			Occlusal factors reported without correlation to TMD
				Morphological	Functional	TMD	
Posselt, 1971	269 (F)	19-22	Nursing students evaluated with an interview and a physical examination	NC	NC	TMD signs and symptoms	Angle's classes, premature contacts, overjet, overbite, displacement in centric, non-working interference

Helkimo, 1974	321 (165/156)	15-65	Randomly selected people evaluated with an interview and a physical examination*	NC	NC	Ai, Di	Premature contacts, displacement in centric, non-working interference, and number of teeth
Mohlin, 1976	253 (M)	18-25	Randomly selected people evaluated with an interview and a physical examination^	NC	Non-working interferences	TMJ pain on movement and palpation	Posterior support, premature contacts, and displacement in centric
Solberg, 1979	739 (370/369)	19-25	University students evaluated with a questionnaire, an interview, and a physical examination^	NR	Displacement in asymmetrical centric	TMD signs	Distance of the displacement in centric, overbite
Williamson, 1979	53 (27/26)	9-20	Pre-orthodontic patients evaluated with a physical examination	NC	NR	Pain	Jaw asymmetry
Wigdorowicz-Makowerowa, 1979	4829	10-45	Schoolchildren, students, and soldiers evaluated with an interview and a physical examination	Malocclusion	NR	TMD signs and symptoms	NR
Osterberg, 1979	384 (198/186)	70	Randomly selected people evaluated with an interview and a physical examination*	NC	NC	Di	Occlusal support zones, number of dental contacts, displacement in centric
Ingervall, 1980; Mohlin, 1980	398 (M)	21-54	Randomly selected people evaluated with an interview and a physical examination*	Angle's class III	Working interference, non-working interference, premature contacts, displacement in centric	Di, movement limitation, mandibular luxation	Deep bite, open bite, crossbite, overjet
Kayser, 1981	118 (NR)	19-71	Prosthodontic patients evaluated with an interview and a physical examination	NC	NC	Dysfunction's signs or symptoms	Occlusal support zones, number of dental contacts, overjet, tooth wear
Mohlin, 1983	272 (F)	20-45	Randomly selected people evaluated with an interview and a physical examination*	NC	NC	Di	Deep bite, open bite, crossbite, overjet, working interference, non-working interference, premature contacts, displacement in centric
Abdel-Hakim, 1983	215 (M)	17-65	Medical patients evaluated with an interview and a physical examination	Posterior occlusal support	NR	Muscle pain	Tooth wear
Kirveskari, 1985	521 (NR)	17-62	Metalworkers evaluated with an interview and a physical examination	NC	NR	Dysfunction's signs or symptoms	Tooth loss
Nesbitt, 1985	81 (43/38)	22-43	Individuals taking part in a growth study evaluated with an interview and a physical examination*	Angle's class II, deep bite, overjet	NR	Ai, articular noises, TMJ pain	Crossbite, overbite, open bite
Thilander, 1985	661 (272/389)	20-54	Men serving military service and randomly selected women evaluated with an interview and a traditional physical examination*	Crossbite, Angle's class III, open bite	Non-working contacts	Di	Displacement in centric, tooth wear, deep bite, overjet
Budtz-Jorgenson, 1985	146 (81/65)	> 70	Dental patients evaluated with an interview and a traditional physical examination*	Dental support zones	NC	Di, TMJ tenderness, muscle tenderness	Displacement in centric
Grosfeld, 1985	800 (395/405)	15-22	Schoolchildren evaluated with an interview and a physical examination	Crossbite, tooth loss	Occlusal interferences	TMD signs and symptoms	Angle's classes, tooth wear
De Laat, 1986	121 (50/71)	22-28	Dentistry students evaluated with an interview and an examination*	Fewer number of teeth, overjet and overbite, tooth wear, Angle's class, and occlusal contacts	Displacement in centric, non-working interferences and disocclusion type (group or canine)	TMJ noises, muscle pain, HI	NR
McEntee, 1987	596 (392/204)	> 54	Individuals in retirement homes evaluated with an interview and a physical examination*	NC	NR	HI	Posterior support, displacement in centric
Szentpetery, 1987	600 (315/285)	11 > 71	Randomly selected people evaluated with an interview and a physical examination*	Deep bite, Angle's class II, tooth wear, edentulism	NC	HI	Non-working interferences
Witter, 1988	132 (72/60)	NR	Dental patients evaluated with an interview and a physical examination*	Posterior occlusal support	NR	Mild and infrequent TMJ pain	Tooth wear
Pullinger, 1988	222 (102/120)	19-41	Dentistry and Dental Hygiene students evaluated with an interview and a physical examination	Angle's class II, deep bite	Displacement in short centric	Muscle tenderness of the TMJ, articular noises	Deep bite, crossbite, premature contacts, overjet open bite
Seligman, 1988 (a, b)	222 (102/120)	19-41	Dentistry and Dental Hygiene students evaluated with an interview and a physical examination	Angle's class II	Displacement in short centric	Muscle tenderness	Crossbite, premature contacts, overjet, open bite, tooth wear

Harriman, 1990	117 (F)	75-94	Nuns evaluated with an interview, craniomandibular index, and a physical examination	Molar support	NR	TMD signs and symptoms	NR
Minagi, 1990	430 (132/332)	19-30	Dentistry and Dental Hygiene students evaluated with a questionnaire and a physical examination	NR	NC	TMJ noises	Working and non-working contacts, disocclusion type (canine or group)
Huber, 1990	434 (217/217)	18-76	Dental patients evaluated with a physical examination	NR	NC	Maximum mouth opening, TMJ noises, deviation on opening	Displacement in centric, non-working interferences and disocclusion type (group or canine)
Woman, 1991	264 (126/138)	19	People evaluated with an interview and a physical examination*	Decrease in the number of contacts in IM	Occlusal interference, displacement in centric	Mandibular pain, headache, jaw fatigue, Di, muscle tenderness	Premature contacts, overjet, overbite
Mango, 1991	100 (39/61)	35-74	Randomly selected people evaluated with an interview and a physical examination	NR	Occlusal interferences	Pain or noise in the TMJ	NR
Glaros, 1992	81 (48/33)	17-32	Individuals from a dental school evaluated using radiography	NC	NR	TMJ Questionnaire	Overbite
Shiau, 1992	2033	17-32 (872/1161)	University students evaluated with an interview and a physical examination^	NC	Non-working contacts on group function, displacement in vertical centric	TMD signs and symptoms	Angle's classes, crossbite, open bite, deep bite, edentulism
Schiffman, 1992	269 (F)	NR, Average 23	Nursing students evaluated with an interview and a physical examination* ^	Jaw asymmetry	Unilateral premature contact	HI and craniomandibular index, TMD subgroups	Angle's classes, facial asymmetry, crossbite, open bite, edentulism, occlusal support, displacement in centric, working, and non-working interference
Al Hadi, 1993	600 (189/311)	18-22	University students evaluated with an interview and a physical examination	Overjet > 6 mm	Group function, non-working interference	TMD signs and symptoms	Angle's classes
Bid, 1995	429 (248/181)	66-90	Medical patients evaluated with an interview and a physical examination	NC	NR	TMD signs and symptoms	Posterior occlusal support
Miyazaki, 1994	532 (353/179)	6-32	Pre-orthodontic patients evaluated with an interview and a physical examination	Posterior crossbite, open bite		Articular noises, jaw pain, abnormal jaw movements	Overjet, deep bite, crowding, anterior crossbite
Castro, 1995	63 (34/29)	NR	Non-patient population of a university center. Evaluation method NR	NR	Protrusive interference	Articular noises and muscle pain, and TMJ	Laterality interference, canine relationship, premature contacts
Hochman, 1995	96 (NR)	20-31	Dentistry and Dental Hygiene students evaluated with an interview and a physical examination	NR	NC	TMD signs and symptoms	Non-working contacts and interferences, displacement in centric
Sato, 1996	643 (345/298)	NR, > 70	People evaluated with an interview and a physical examination	NC	NR	Osteoarthritis	Occlusal support absence
Conti, 1996	310 (160/150)	NR, Average 20	Students evaluated with an interview and a physical examination*	NC	NC	TMD signs and symptoms	Overjet, overbite, premature contacts, displacement in centric, non-working interferences
Hiltunen, 1997	364 (262/102)	76-86	Randomly selected people evaluated with an interview and a physical examination* ^	NC	NR	HI	Occlusal support zones
Ciancaglini, 1999	483 (300/183)	18-75	Randomly selected people evaluated with an interview and a physical examination*	NC	NR	Mandibular stiffness and tiredness, difficulty in mandibular movement, Di	Occlusal support zones
Matsumoto, 2002	60 (NR)	20-27	Class I and II dental patients evaluated with a questionnaire and a physical examination	NC	NC	TMD signs and symptoms	Angle's classes, overjet, overbite, open bite, deep bite, crossbite, tooth crowding
Celic, 2002	230 (NR)	19-28	Dental patients evaluated with a questionnaire and a physical examination	Overjet and overbite > 6 mm	NR	TMD subgroups	NR
Celtic, 2002	230 (M)	19-28	Dental patients evaluated with a questionnaire and a physical examination^	Angle's classes, overjet > 5 mm, midline discrepancy, number of contacts < 10 in IM	Premature contacts, non-working interferences	TMD signs and symptoms	Displacement in centric, working interference, overbite, crowding, and tooth loss

Uhac, 2002	100 (M)	24-52	General population and physical examination	Loss of > 5 teeth and overjet > 7,5 mm	NC	TMJ crackling (no correlation with clicking)	Number of teeth in occlusion, overbite, disocclusion type (canine or group), displacement in centric and non-working interferences
John, 2002	3033 (NR)	10-74	Schoolchildren and general population evaluated with a questionnaire and a physical examination ^	Overbite and overjet	NR	Report of jaw pain, articular noises, and movement limitation	Angle's classes, overjet, overbite, open bite, deep bite, crossbite, premature contacts, displacement in centric, non-working interferences
Sarita, 2003	850 (NR)	> 20	Randomly selected people evaluated with an interview and a physical examination ^	NC	NR	Articular noises	Posterior occlusal support, tooth wear
Buranastidp-orn, 2004.	31 (20/11)	18-46	Pre-orthodontic patients evaluated with TMJ images^	Asymmetry	NR	Disc displacement in the TMJ	NR
Ahn, 2004	58 (F)	18-43	Class II pre-orthodontic patients evaluated with MRI	Angle's class II	NR	Disc position on the MRI of the TMJ	Positive
Bernhardt, 2004	2529 (1309/1220)	20-81	Randomly selected people evaluated with a questionnaire, an interview, and a physical examination ^	Minor tooth wear	NR	Muscle tenderness on palpation	NR
Gesch, 2004	4289 (2180/2109)	20-81	Randomly selected people evaluated with a physical examination^	Bilateral open bite, edge-to-edge bite, Angle's class II, crowding	NC	TMD signs	Crossbite, tooth wear, non-working interferences, and protrusion
Gesch, 2004	4289 (2180/2109)	20-81	Randomly selected people evaluated with an interview and a physical examination ^	Diastemata	NC	TMD symptoms	All morphological and functional factors
Hirsh, 2005	3033 (NR)	10-75	Schoolchildren and general population evaluated with a questionnaire and a physical examination ^	NC	NR	Articular noises (clicking and crackling)	Overbite and overjet
Mundt, 2005	2963 (1493/1470)	35-74	Randomly selected people evaluated with an interview, a questionnaire, and a physical examination ^	NC	NR	Muscle or TMJ tenderness	Posterior occlusal support
Ikebe, 2005	850 (390/460)	> 60	Volunteer elderly students evaluated with a questionnaire and a physical examination	NC	NR	Noises in the TMJ, limitation of mouth opening	Posterior occlusal support, bite force

For abbreviations and symbols, see Table 3.

Table 5. Case series studies

First author & year	Sample (F/M)	Age range	Origin of patients and method for TMD clinical evaluation	Occlusal factors positively correlated with TMD (diagnosis, signs, or symptoms)			Occlusal factors reported without correlation to TMD
				Morphological	Functional	TMD	
Franks AST,	751 (NR)	NR	University health center, evaluated with an interview and a physical examination	Loss of occlusal support	Displacement in centric	TMD signs and symptoms, TMJ disorders	Tooth wear
Mohlin, 1978	56 (39/17)	16-62	University students evaluated with an interview and a physical examination*	NC	NC	Di	Midline discrepancy, crossbite, overjet, overbite, deep bite, Angle's classes, premature contacts, displacement in centric and non-working interferences
Rieder, 1983	1040 (653-387)	13-86	Private practice, evaluated with a questionnaire, an interview, and a physical examination	NC	Non-working and protrusive interferences	TMD signs and symptoms	Posterior occlusal support and displacement in centric
DeBoever, 1983	135 (102/33)	12-68	University health center, evaluated with an interview and a physical examination*	NC	Non-working interferences	Di	Dental support, premature contacts
Mejersjo C, 1984	154 (NR)	18-60	University health center, evaluated with an interview and a physical examination*	NC	NC	TMD signs and symptoms and Di	Displacement in centric, non-working interference and number of teeth in occlusion

Roberts, 1987	205 (NR)	NR	University health center, evaluated with a physical examination and articulation radiography	NC	NC	Disc position on the TMJ	Angle's classes, overjet, overbite, posterior occlusal support, tooth wear, disocclusion type, displacement in centric and non-working interference
Linde, 1990	158 (122/36)	15-76	University health center, evaluated with an interview and a physical examination	NC	Premature contacts and displacement in asymmetrical centric	Muscular TMD, DDwoR, NC with other TMD diagnoses	Angle's classes, crossbite, open bite, premature contact, working, and non-working interference
Ai, 1992	210 (166/44)	12-70	Prosthodontics university health center, evaluated with an interview and a physical examination	Tooth loss, occlusal stability	Occlusal interferences	Signs of muscle tenderness on palpation	NR
Scholte, 1993	193 (152/41)	NR, average 33	University health center, evaluated with a questionnaire and a physical examination*	Molar support loss	NC	Osteoarthritis, NC with other TMD subgroups	Working interference, non-working interference,
Scholte, 1993	522 (423/99)	NR, average 34	University health center, evaluated with a questionnaire, an interview, and a physical examination*^	Occlusal support absence	Non-working interferences	Osteoarthritis, TMD, muscular, and NC with other TMD subgroups	Premature contacts and displacement in centric
Watanabe, 1998	143 (105/38)	NR, average 34	University health center, evaluated with an interview and a physical examination	NR	Working and non-working contacts	Signs of muscle tenderness to palpation with other TMD subgroups	NR
Ohta, 2003	41 (33/8)	16-66	University health center, evaluated with a physical examination and MRI	NR	Working and non-working contacts	Disc position on the TMJ	NR
Fui, 2003	71 (45/26)	NR, average 27	Prosthodontics university health center, evaluated with an interview and a physical examination	NR	NC	TMJ pain and articular noises	Premature contacts, number of working and non-working interferences, and occlusal contacts in IM
Yamada, 2003	25 (19/6)	NR	Pre-orthodontic patients with radiographic evidence of osteoarthritis	NR	Displacement in centric	Bone changes in TMJ interpreted as osteoarthritis	NR
Corvo, 2003	106 (74/32)	10-18 average NR	University health center, evaluated with an interview and a physical examination*	Angle's class II	NR	Di and TMD signs and symptoms	NR
Takaya, 2004	61 (44/17)	20-58	Oral surgery university health center, evaluated with an interview and a physical examination	NR	Group function, non-working interferences	Disc displacement	Canine disocclusion and working interference

For abbreviations and symbols, see Table 3.

Analysis of the factors guaranteeing the validity of the collected studies

1. Definition of the "gold standard". In most studies, TMDs were defined by the presence or absence of one or more generally isolated signs or symptoms. Only a few studies attempted an analysis based on the presence or absence of the TMD diagnosis or TMD subgroups. [83, 89, 94, 100, 107, 112, 113, 115-118, 120, 122]

2. Diagnostic classification system. Only a few reviewed studies attempted to use a systematic diagnostic classification that would allow a differential diagnosis between the different TMDs [83, 94, 113, 115-117].

3. Use of clearly defined measures. In general terms, the criteria for identifying TMD signs were described similarly throughout the studies; however, the techniques used during the physical examination to establish its presence were different.

4. Intra- and inter-examinators acceptable reliability. Some studies did not report the number of examiners, while others used two or more. Some studies reported high reliability, while others only reported it as acceptable. Few studies reported training the examiners before data collection. [26, 34, 36, 39, 41, 42, 45-50, 55, 82, 83, 90, 95, 97, 99, 101-106, 116.]

5. Use of suitable samples. Most studies used more than 200 subjects for analysis. Factors such as the intensity, duration, or frequency of the subjects' signs and symptoms did not determine the cases' severity. Some studies [21, 23, 28, 48, 50, 66, 91, 92, 101-103, 107] took random samples from the general population. Conversely, most studies used specific populations such as students (schoolchildren, undergraduate dentists, nurses) or patients (general dentistry, pre-orthodontics).

6. Data collection by "blind" examiners. The vast majority of studies did not report considering this aspect, and only a few reported some form of control for this examiner's bias variable [29, 35, 42, 45, 77, 80, 83, 90, 101-103, 105, 117, 118]. As a measure to control this aspect, some studies reported different examiners: some to evaluate symptoms and others to evaluate signs. Alternatively, other studies prevented the examiners from knowing the patient's clinical condition or the patients' responses when questionnaires were used during the clinical evaluation.

7. Study replicability. In the descriptive studies, there was no tendency to favor any of the evaluated OFs. On the contrary, the studies displayed a high variability. Correlation between several OFs and TMDs was reported. However, it was also remarkable that many of the evaluated OFs did not report any correlation.

8. Consideration of alternative hypotheses. Important aspects of the descriptive studies make certain hypotheses possible, such as the tendency of the TMD signs and symptoms to occur more in women than in men. Is there a factor (other than occlusal ones) associated with female

were a factor associated with TMDs and these are more frequent in women, do women have more malocclusions than men? These are some of the hypotheses that could alternatively arise from the review results in these descriptive studies.

DISCUSSION

The role of OFs in TMD etiology is undoubtedly controversial, and the possible relationship between them is not easy to analyze and interpret. When comparing tables 3, 4, and 5, where the studies of children and adolescents, adults, and case series are presented, respectively, studies in children and adolescents show a higher tendency to display a correlation between OFs and TMDs than studies in adults. Likewise, the correlation tendency is higher in adult studies when compared to case series studies. However, in general, the great variability of the results of the analyzed descriptive studies prevails, as well as the subsequent lack of a clear tendency to determine the possible OFs with less or more relationship with TMDs. This lack of uniformity could be explained by the divergence and inconsistency of the methodologies used in other research (poorly defined and differently performed measurements, the reliability of the examiners, etc.). This inconsistency, in turn, puts at risk the strength of factors that ensure the validity of the results [14, 123-125]. In only a few research studies, a clinical study of TMDs with certain reported reliability and validity was used to establish a correlation between OFs and TMDs. 126-129 A limited number of studies used the evaluation and diagnostic criteria for TMD research published by Dworkin (1992)[128, 129] This work aimed to standardize the different TMD studies to facilitate the comparison between them. In general, the descriptive research studies reported in this article define TMDs in terms of signs and symptoms, which usually occur in isolation and do not represent a disease state with the clinical characteristics of patients with TMDs. Prevalence studies have shown that TMD signs and symptoms are relatively common in the general population. Around 65% of the general population has at least one sign in the TMJ —abnormality in jaw movements, clicks, crackling, and muscle or joint tenderness on palpation— and 35% of it have at least one symptom —limitation of mandibular opening, muscle or joint pain.[1] However, only 7 to 10% are considered to have problems severe enough to require treatment.1

In many research studies, the Helkimo index[130] was used to establish the presence of signs and symptoms of TMDs and to determine their severity. However, this index tends to overestimate

the prevalence of TMDs when applied to the general population. Applying this index to the general population, Helkimo130 reported that only 12% of the population was free of signs and symptoms, while 47% had at least one severe symptom of a TMD. As mentioned above, the percentage of individuals seeking treatment is much lower (7-10%); therefore, this index overestimates the presence of TMDs, and a possible association with some OFs cannot be considered entirely valid.

The criteria for identifying TMD signs and symptoms were not completely similar throughout different studies. Likewise, the techniques used during the clinical examination were also different. For example, muscle tenderness on palpation was determined with different techniques and on different muscles. Some authors used stethoscopes to assess articular sounds, while others used audition or palpation of the TMJ. Sometimes, the articular sounds reported by the subjects participating in the study were also considered. It is noteworthy that articular sounds were a diagnostic criterion in most studies, although this isolated sign or symptom is not a good TMD indicator.[131, 132] Regarding OFs, some authors established a difference between occlusal contacts and interferences. The lateral movement distance obtained for the evaluation of occlusal interference varied throughout the studies. However, high variability in the number of contacts or interferences has been reported depending on the distance of lateral mandibular movement.[133] Likewise, throughout the studies, the evidence of the presence of TMD symptoms was collected using different methods such as interviews or questionnaires (answered by mail or in person by the patient). In the case of children, the information was obtained with the help of their parents.

Few studies reported examiner training and acceptable levels of intra- and inter-examiner reliability. The fluctuation that characterizes the TMD signs and symptoms, alongside the situation of the studies above, makes the reliability of the measurements quite low. There is a general tendency to compromise the validity of studies when the reliability of measurements and examiners is inadequate.

Several studies took samples from more than 200 subjects, but conventionally these samples were not randomly taken from the general population. This fact shows that in most studies, the population representativeness was not optimal, and therefore, generalizing or extrapolating the results to all subjects is debatable. In addition, the TMD levels of severity (or their signs or symptoms regarding intensity, frequency, or duration) were not reported in either cross-sectional or case-series studies. When establishing the severity of TDM cases, the Helkimo index was used, and as mentioned above, the diagnostic validity of this index is doubtful. Lastly, TMDs are more frequent in females than in males. Therefore, if there is any correlation between OFs and TMDs, one possible alternative hypothesis could be that

malocclusions or OFs would also be more frequent in females than in males. The existing epidemiological reports cannot support this hypothesis, suggesting that other factors should be involved in the development of TMDs.[77 134]

The lack of consistency in the research results was a constant when evaluating these reports. Likely, the lack of replicability of the studies is directly related to the methodological problems that have been discussed in this article. The analysis of these epidemiological reports shows that there is no tendency to favor the idea of any OF being related to the TMD etiology and that possibly other factors should be considered in their development.

CONCLUSIONS

The role of OFs in TMD etiology is certainly controversial; therefore, the possible relationship between them is not easy to analyze and interpret. Generally speaking, it can be said that one of the purposes of the information obtained with descriptive studies is to provide hypotheses about the first factors possibly involved in the etiology of diseases. However, due to the inherent limitations of descriptive studies, these hypotheses are not positive proof for any identified factor's causality and hence must be subsequently evaluated using analytical studies. Before considering evaluating or testing any particular hypothesis, there must be the concept of "association" between an exposure factor (OF) and a disease (TMD). The analysis of these epidemiological reports shows that there is no tendency to favor the idea of any OF being related to TMD etiology and that possibly other factors should be considered in the development of TMDs. Perhaps the improvement of the research designs will allow establishing more concrete hypotheses so that they can later be evaluated with analytical epidemiological studies.

CONFLICT OF INTEREST

The authors state that they have no conflict of interest.

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