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INTERNATIONAL JOURNAL OF
Oral and Craniofacial Science OPEN ACCESS JOURNAL

ISSN: 2455-4634 DOI: https://dx.doi.org/10.17352/ijocs

Observational study

Correlation between temporomandibular disorders and malocclusions: A retrospective observational study-can malocclusions or previous orthodontic treatments affect Temporo-Mandibular Disorders?

Alessandro Marchesi*, Dorothea Bellini, Andrea Sardella, Giulia Fornarelli and Tomson Zefi

Department of Gnathology, ASST Santi Paolo e Carlo, University of Milan, Milan, Italy

Received: 27 January, 2022
Accepted: 16 February, 2022
Published: 18 February, 2022

***Corresponding author:** Alessandro Marchesi, Department of Gnathology, ASST Santi Paolo e Carlo, University of Milan, Milan, Italy,
E-mail: marchesidottalessandro@gmail.com

Keywords: TMD; Malocclusions; Orthodontic treatment; Midline deviation

Abstract

Background: The purpose of this article is to verify the possible correlation between TMD (Temporomandibular Disorders) and different types of malocclusions in adult subjects and subsequently that between TMD and previous orthodontic treatment.

Materials and methods: A retrospective observational study was conducted in San Paolo e Carlo Hospital, associates of the University of Milan, for a period of 2 years (1st February 2019 – 3rd March 2020), on 374 adult patients (244 females and 130 males). The subjects underwent an intraoral examination with a gnathological assessment, in order to distinguish those who suffered from TMD and those who did not. Secondly, the patients were subjected to orthodontic examination to identify those who had previously undergone orthodontic treatment, assessing through an extraoral and intraoral examination, the dental class, the type of dental bite and the presence or absence of a midline deviation.

Results: The data analysis revealed a statistically significant association between TMD and gender (p= 0.023, OR= 1.66). The association between class I, II, III malocclusions and the presence of TMD was found to be statistically significant: p<0.0001 (OR= 4.04) and that between open/deep bite and the presence of TMD too: p= 0.003 (OR= 1.89). Moreover, the correlation between midline deviation and the presence of TMD was statistically significant: p<0.0001 (OR=7.48). On the other hand, no correlation was found between TMD and previous orthodontic treatment (p= 0.918).

Conclusions: The available data revealed a statistically significant association between TMD and malocclusions, related to dental class and bite and midline deviation, although the existing results in the literature are controversial regarding this association.

While no statistically significant correlation was found between TMD and previous orthodontic treatment. Orthodontic therapy, therefore, by correcting occlusion anomalies, could reduce the risk of TMD incidence. Finally, longitudinal studies with adequate statistical power are needed to clarify the possible interrelationships between TMD and malocclusions.

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Abbreviations

TMJ: Temporomandibular Joint; TMD: Temporomandibular Disorders; EMG: Electromyography

Introduction

The study of occlusion and its relationship with the function of the chewing system has been for many years a topic of interest in dentistry. The enormous curiosity in this field in association with the lack of complete knowledge led to the formulation of numerous concepts, theories, and methods of treatment.

The first supposition of a possible relationship between occlusion and TMJ function was suggested by Costen [1], who hypothesized that changes in dental conditions (e.g. loss of vertical dimension or deep bite) can lead to temporomandibular disorders and eventual otological symptoms.

Michelotti [2] proposed that occlusal interference may increase the habitual activity of the jaw muscles and consequently lead to TMD. By means of electromyography (EMG), the effects of an acute occlusion disturbance on habitual muscular activity were investigated. The masticatory system response revealed a reduction in the activity of the masseter muscle, and none of the test subjects showed signs and/or symptoms of TMD. Considering that healthy subjects without parafunctional activity were included in this study, it was hypothesized that the reaction to occlusal disturbances differs in patients with TMD.

Le Bell [3] used the same method implemented in Michelotti's study to observe the reactions in a group of patients with myofascial pain. The results showed an increase in the habitual activity of the masseter muscle and an increase in masticatory muscle pain. This led to the belief that subjects who were occlusal altered and affected by interference, upped the activity of the masticatory muscles, which in turn led to pain and dysfunction.

Hirsch and John [4,5] investigated the association between overjet and overbite and TMD in a sample of more than 3000 subjects and found no correlation.

Among the various malocclusions, it has been suggested that posterior crossbite may be an important risk factor for TMD [6].

According to Pullinger [7], the possibility of a person with a posterior crossbite having a disc dislocation with reduction ranges from 3.3 to 1 in comparison to the population without crossbite. This does not seem to be true for young patients, in fact, there appears to be no correlation between crossbite and disc dislocation because initially there is a good adaptation [8,9].

Manfredini [10] and his colleagues studied a sample of approximately 400 subjects affected by TMD and did not find an association between malocclusions and TMD.

Evidence of a link between malocclusions and TMD should meet certain criteria. First of all, the causes must precede the effects, whereas, in the literature, we find studies demonstrating the opposite, i.e. that muscular pain causes changes in occlusion [11]. Furthermore, if there is an association, the more severe the malocclusion the more severe the pathology should be. In contrast, the previous studies suggest that the risk of TMD may only be associated with certain malocclusions. The results of the scientific community must be consistent over time, as an increasing number of studies reduce the importance of the role of occlusal factors in the etiology of TMD.

In the light of these considerations, it may be thought that occlusion is not currently to be considered the main risk factor for TMD.

Although there are many conflicting opinions, it was decided to carry out a retrospective observational study to continue investigating in this field [12,13].

In the last decade, in fact, temporomandibular disorders have increased in number and severity, presenting themselves in an even more complex way by being always linked to multifactorial etiopathogenesis. This constituted a reason for a daily confrontation with the patient and an even more accurate anamnesis and first visit.

The primary objective of this study is to investigate the existence of a possible correlation between TMD and different types of malocclusions in adult subjects, focusing on class I malocclusion, which differ from the normal occlusion only in the position of the teeth in relation to the occlusal line but not in the molar relationship [14-16], II and III malocclusions (sagittal plane); open or deep anterior bite (vertical plane); midline deviation.

The secondary objective is to investigate the correlations between the various types of orthodontic treatment and TMD. Orthodontic treatment is usually long-lasting and patients may complain of TMD symptoms before, during, or after treatment. Therefore, interest in the relationship between orthodontic treatment and TMD has grown, and many studies have been conducted on this topic without any solid evidence.

The need to investigate this relationship emerged from the occurrence of legal cases in which patients undergoing orthodontic treatment reported the onset of symptoms and signs of TMD during or after the course of treatment.

A 1995 review by McNamara, Sclingun, and Okeson [17] came up with eight conclusions that refuted this possible association.

The hypothesis that various orthodontic techniques may be involved as etiological factors in TMD has also been tested in recent decades by Dibbets and van der Weele [18], who have concluded that there is no causal relationship between the two.

According to current knowledge, the role of orthodontic treatment in the onset of TMD is not confirmed and the conclusions indicated by McNamara et Al. are still valid.

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A meta-analysis in regards identified no studies that indicated a link between traditional orthodontic treatment and an increase in the prevalence of TMD [19].

Other studies have also shown that there is no variation in the incidence of TMD symptoms or signs depending on whether functional or fixed orthodontic therapy is used [20-23].

A review [24] of the international literature has shown that orthodontic treatment, regardless of the technique used and regardless of premolar extraction during treatment, does not increase the signs and symptoms of TMD and is therefore not a risk factor for its development. Orthodontic treatment does not appear to be a valuable resource for treating or preventing the onset of TMD signs and symptoms. There is a need to improve the methodology used in the attempt to demonstrate a possible association between TMD and orthodontic treatment, to resolve the current contradictions.

Materials and methods

This is an observational study, conducted in the Complex Operative Unit of Stomatology and Oral Prevention of the San Paolo e Carlo Hospital, associates of the University of Milan, for a period of 2 years (1st February 2019 – 3rd March 2020) on 374 adult patients (244 females and 130 males). The sequential recruitment of patients attending the examination was carried out according to eligibility criteria. Inclusion criteria were age between 18 and 65 years; non-syndromic patients (patients without chromosomal, monogenic, epigenetic diseases); absence of any cause of intraoral pain (dental, periodontal, etc.).

Exclusion criteria were patients with partial (Class 1 and 2, according to the classification of the American College of Prosthodontists [25]) or total edentulism; patients with removable total dentures, partial dentures, and/or dental implants; patients with tumors in the head and neck region; patients with mandibular fractures; patients who have undergone previous orthognathic surgery.

Table 1 shows the socio-demographic and clinical characteristics of the subjects at recruitment.

The selected subjects underwent a detailed gnathological examination in order to distinguish those with TMD from those without.

Among the 374 subjects examined, 188 subjects did not present TMD at the time of the first visit whereas 186 subjects suffered from TMD.

In addition, all patients were assessed from an orthodontic point of view to distinguish those who had previously undergone orthodontic treatment from those who had not undergone any kind of orthodontic treatment.

A questionnaire was designed to assess the presence or absence of mobile or fixed orthodontic treatment and the age at which this treatment had been carried out, with age ranges of 6-12, 12-19, and >19 years. The questionnaire showed that among the 374 subjects in the sample, 191 had not previously undergone any type of orthodontic treatment, representing the control group, and 183 had, of whom 58 had undergone fixed treatment; 63 had undergone removable treatment; 62 had combined fixed and removable orthodontic treatment.

Finally, they underwent a thorough extraoral, intraoral, and functional clinical examination to assess their dental class, the type of dental bite, and the presence or absence of midline deviation.

During the gnathological examination, the TMJ disorders were analyzed according to the Helkimo clinical dysfunction index [26], which provides specific classifications and scores in order to homogenize and rationalize the various findings and make them comparable with the existing literature.

Table 1: Socio-demographic and clinical characteristics of the sample subjects (n=374).

Variable		
Age(years)		
Mean	36,8	
SD	13,5	
Median	35	
Min-Max	18-65	
Gender	**n**	***(%)***
Female	244	*(65,2)*
Male	130	*(34,8)*
DTM		
No	188	*(50,3)*
Yes(a)	186	*(49,7)*
Helkimo Index		
D.0	188	*(50,3)*
D.I	79	*(21,1)*
D.II	50	*(13,4)*
D.III	57	*(15,2)*
Orthodontic Treatment		
No	191	*(51,1)*
Fixed	58	*(15,5)*
Removable	63	*(16,8)*
Fixed and Removable	62	*(16,6)*
Dental Class		
Class I Normal	115	*(30,7)*
Malocclusion Class I	133	*(35,6)*
Malocclusion Class II	77	*(20,6)*
Malocclusion Class III	49	*(13,1)*
Dental Bite		
Normal	214	*(57,2)*
Open Bite	79	*(21,1)*
Deep Bite	81	*(21,7)*
Midline deviation		
< 3 mm	304	*(81,3)*
≥ 3 mm	70	*(18,7)*

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This index assesses the functional status of the masticatory system, considering: the decreased extension of the measured mandibular movements (opening, protrusion, right and left laterality), noises or joint blocks, deviations in the mandibular pathway, spontaneous pain in one or more movements, palpatory muscle pain (one or more painful points) and palpatory joint pain (lateral pole and posterior pole of the condyle).

For each of these clinical signs, a score of 0, 1, or 5 points was assigned according to their presence and severity. The classification of clinical dysfunction, based on the collected scores, includes the absence of dysfunction (D.0): 0 points, mild dysfunction (D.I): 1-4 points, moderate dysfunction (D.II): 5-9 points, severe dysfunction (D.III): 10-25 points.

The orthodontic examination was carried out first by an extra-oral clinical examination, which consisted in observing the face from a frontal view identifying the reference midlines (horizontal and vertical).

Subsequently, an intra-oral examination was conducted, assessing intraoral health (general dental condition; periodontal condition; presence of signs of parafunction). The intraoral examination was completed by the observation of common orthodontic parameters: molar and canine class, overjet, overbite, crossbite, midlines, mandibular deviations in opening and closing.

For overbite, deep bite, and open bite, the US values were taken into account: an overbite value of up to 3mm was considered normal and regarding the open bite and deep bite values, measurements lower than 0mm and greater than 3mm, respectively, were taken into consideration [27].

Incisive and canine guides were also analyzed to assess whether they were well represented or absent.

Regarding the midline, in maximum intercuspation, the upper midline was assessed to the lower midline and vice versa and the position of the single midlines of the two jaws to the facial midline. Assessing the midline coincidence during the opening permits a differential diagnosis between a functional asymmetry and a true asymmetry (skeletal or dental) [28,29].

Finally, during the functional examination, the presence of vicious habits (present or past), the type of breathing, and swallowing was assessed.

Regarding the statistical analysis, descriptive data are expressed as mean, standard deviation (SD), median, range of variability (min-max) for continuous variables, several subjects, and percentage for discrete variables. The comparison between subjects with and without TMD was conducted based on the age by means of Student's t-test for independent samples, chi-square test or Fisher's exact test for discrete variables, or the non-parametric Mann-Whitney test. The Odds Ratio (OR) and its 95% confidence interval (95% CI) were also estimated. The association between the degree of TMD severity and the presence of malocclusion and/or previous orthodontic treatment was assessed using the chi-square test or the Kruskal-Wallis test, when appropriate. Finally, a multivariate logistic analysis, adjusted according to sex and age, was conducted to assess whether and which occlusal and orthodontic variables studied were independently associated with TMD. Values below 0.05 of the p-significance level were considered statistically significant (two-tailed test). The SPSS program version 24.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

Results

Among the 374 subjects examined, 50.3% (188 subjects) did not present TMD at the time of the first visit whereas 49.7% (186 subjects) suffered from TMD.

The prevalence of TMD in the sample was therefore 49.7%, with a confidence interval of 44.7-54.8%.

Figure 1 compares subjects free of TMD (D.0) with subjects affected by TMD. The latter is distributed by the degree of severity, based on Helkimo's clinical dysfunction index.

Out of the 186 subjects presenting a TMD: 79(21.1%) had mild dysfunction (D. I); 50(13.4%) had a moderate dysfunction (D.II); 57(15.2%) had severe dysfunction (D.III).

Among the 374 subjects in the sample: 191(51.1%) had not previously performed any type of orthodontic treatment; 58(15.5%) had undergone fixed treatment; 63(16.8%) had undergone removable treatment; 62(16.6%) had combined fixed and removable orthodontic treatment.

The prevalence of previous orthodontic treatment in our sample was 48.9% with a confidence interval of 43.9-54%.

The statistical analysis revealed a significant association between TMD and gender.

Of the 244 female subjects: 112(45.9%) had no TMD and 132(54.1%) had TMD. The prevalence of TMD in females was therefore 54.1% with a confidence interval of 47.8-60.2%.

Of the 130 male subjects: 76(58.5%) had no TMD; 54(41.5%) had TMD. The prevalence of TMD in males was 41.5% with a confidence interval of 33.4-50.1%.

Stratified analysis by gender showed a statistically

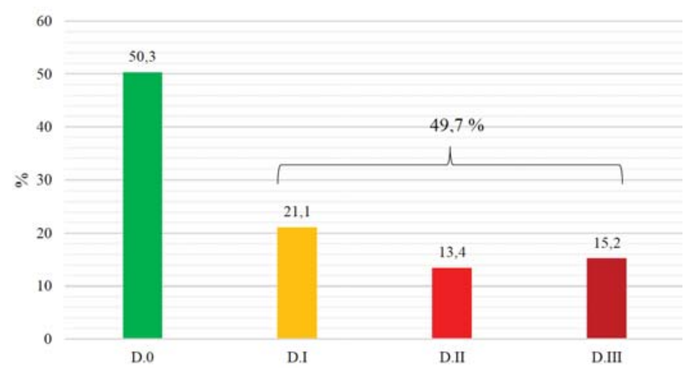

Figure 1: Percentage distribution of sample subjects with respect to the Helkimo index.

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significant difference in the prevalence of TMD between females and males (p= 0.023). The risk of having TMD in females compared to males is thus 1.66 times higher.

On the other hand, the age-stratified analysis showed no statistically significant difference in the prevalence of TMD.

By examining the numerical and percentage distribution of subjects in the sample with or without TMD in relation to orthodontic treatment, no statistically significant association was found (p= 0.918). The evaluation was based on a binomial distribution and a 95% confidence interval (Table 2).

Table 3 shows the distribution of subjects in the sample with and without TMD compared to the presence or absence of malocclusions in the sagittal plane.

69.3% of the subjects in the sample presented a Class I, II, or III malocclusions (according to Angle's classification). The association between these malocclusions and the presence of TMD was found to be statistically significant: p<0.0001 (OR= 4.04).

The presence of class I, II, and III malocclusions is approximately 50% higher in subjects with TMD than in those without TMD.

Table 4 shows the distribution of subjects in the sample with and without TMD in relation to the dental bite; 42.8% of the subjects had an altered bite (open or deep bite). The association between open/deep bite and the presence of TMD was found to be statistically significant: p=0.003 (OR= 1.89).

The presence of an open or deep bite was approximately 45% greater in subjects with TMD than in those without TMD.

The distribution of subjects in the sample with and without TMD was also analyzed in relation to the deviation of the inter-incisive line (Table 5): 18.7% of the subjects had an inter-incisive line deviation greater than or equal to 3mm. The association between inter-incisive line deviation and the presence of TMD was found to be statistically significant: p<0.0001 (OR= 7.48). The presence of a deviation greater than or equal to 3mm was approximately five times greater in subjects with TMD in comparison to those without TMD.

Table 6 shows the distribution of the subjects in the sample with or without TMD, divided into subgroups, in relation to the four dental classes: Normal Class I, Malocclusion Class I, Malocclusion Class II, and Malocclusion Class III; 0.7% of the sample subjects presented a normal occlusion; 35.6% presented a Class I malocclusion; 20.6% presented a Class II malocclusion; 13.1% presented a Class III malocclusion. The stratified analysis by dental class showed a statistically significant difference in the prevalence of TMD compared to the different types of malocclusions. Respectively: Class I malocclusion: p<0.0001; OR= 2.75; CI 95%: 1.56-4.87. Class II malocclusion: p<0.0001; OR= 6.36; 95% CI: 3.21-12.72. Class III malocclusion: p<0.0001; OR= 6.14; 95% CI: 2.78-13.73.

Subjects with a Class II and III malocclusion had an approximately six-fold increased risk of having TMD.

Table 7 shows the distribution of the subjects in the sample with or without TMD, divided into subgroups, in relation to the three types of bite considered in our study: normal bite, open bite, and deep bite; 7.2% of the sample subjects had a normal bite; 21.2% had an anterior open bite; 21.6% had a deep bite. The stratified analysis by dental bite showed a statistically significant difference in the prevalence of TMD compared to the open and deep bite. Respectively open bite: p= 0.005; OR= 2.17; CI 95%: 1.24-3.81; deep bite: p= 0.067; OR= 1.66; 95% CI: 0.96-2.87.

Subjects with an anterior open bite were more likely to have TMD than those with a deep bite.

Finally, a multivariate logistic analysis, adjusted for gender and age, was conducted to assess whether and which occlusal and orthodontic variables studied were independently associated with temporomandibular disorders (Table 8). The multivariate logistic analysis confirmed an independent

Table 2: Age distribution of sample subjects with and without TMD versus orthodontic treatment.

	DTM NO			DTM YES		
Age (years)	NO Orthodontic treatment (n=97)	YES Orthodontic Treatment (n=91)	No DTM total (n=188)	NO Orthodontic Treatment (n=94)	YES Orthodontic Treatment (n=92)	DTM total (n=186)
Mean	37.3	35.8	36.6	38.1	35.7	37
SD	14.5	12.2	13.4	15.4	11.5	13.6
Median	34	33	33.5	38	35	37
Min-Max	18-65	18-65	18-65	18-65	18-64	18-64

Table 3: Numerical and percentage distribution of sample subjects with or without TMD with respect to the presence or absence of malocclusions on the sagittal plane.

	DTM no (n=188)		DTM yes (n=186)		OR(95% IC)	p
Dental class	n	%	n	%		
Class I normal (n=115)	84	(73.0)	31	(27.0)	4.04(2.43-6.73)	< 0.0001
Class I. II. III malocclusion (n=259)	104	(40.2)	155	(59.8)		

Table 4: Numerical and percentage distribution of sample subjects with or without TMD with respect to the presence or absence of malocclusions in the vertical plane.

	DTM no (n=188)		DTM yes (n=186)		OR(95% IC)	p
Dental bite	n	%	n	%		
Normal bite (n=214)	122	(57.0)	92	(43.0)	1.89(1.22-2.92)	0.003
Altered bite (n=160)	66	(41.2)	94	(58.8)		

Table 5: Numerical and percentage distribution of sample subjects with or without DTM with respect to the inter-incisive line.

	DTM no (n=188)		DTM yes (n=186)		OR(95% IC)	p
Midline deviation	n	%	n	%		
<3mm(n=304)	177	(58.2)	127	(41.8)		
>3 mm(n=70)	11	(15.7)	59	(84.3)	7.48(3.63-15.74)	<0.0001

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Table 6: Numerical and percentage distribution of sample subjects with or without TMD. Divided into subgroups. With respect to dental class.

	DTM NO		Total NO DTM n=188	DTM YES		Total DTM YES n=186
Dental class	Orthodontc treatment **No** (n=97)	Orthodontc treatment **Yes**(n=91)		Orthodontic treatment **No** (n=94)	Orthodontc treatment **Yes** (n=92)	
Class I Normal (n= 115)	51(52.5%)	33(36.3%)	84(44.7)	19(20.2%)	12(13.1%)	31(16.7%)
Class I malocclusion (n= 133)	35(36.1%)	31(34.1%)	66(35.1)	39(41.5%)	28(30.4%)	67(36.0%)
Class II malocclusion (n= 77)	9(9.3%)	14(15.3%)	23(12.2)	24(25.5%)	30(32.6%)	54(29.0%)
Class III malocclusion (n= 49)	2(2.1%)	13(14.3%)	15(8.0%)	12(12.8%)	22(23.9%)	34(18.3%)

Table 7: Numerical and percentage distribution of sample subjects with or without TMD. Divided by subgroups. With respect to dental bite.

	DTM NO		Total NO DTM n= 188	DTM YES		Total DTM YES n= 186
Dental bite	Orthodontc treatment No (n= 97)	Orthodontc treatment Yes (n= 91)		Orthodontic treatment No (n= 94)	Orthodontc treatment Yes (n= 92)	
Normal bite (n= 214)	72(74.2%)	50(54.9%)	122(64.9)	47(50.0%)	45(48.9%)	92(49.5%)
Open bite (n= 79)	8(8.3%)	22(24.2%)	30(16.0)	23(24.5%)	26(28.3%)	49(26.3%)
Deepbite (n= 81)	17(17.5%)	19(20.9%)	36(19.1)	24(25.5%)	21(22.8%)	45(24.2%)

Table 8: Multivariate logistic analysis. Adjusted for age and gender. With DTM dependent variable and independent variable (covariates).

Variable	β	S.E	OR	(95% CI)	p
Age(years) _	0.003	0.009	0.99	(0.98-1.01)	0.752
Gender(F vs M) _	0.516	0.244	1.67	(1.04-2.70)	0.034*
Orthodontic treatment(NO vs YES)	0.193	0.224	0.83	(0.52-1.31)	0.415
Malocclusion Sagittal plane (no vs yes)	1.397	0.272	4.04	(2.37-6.98)	<0.0001*
Malocclusion Vertical plane (No vs yes)	0.220	0.243	1.25	(0.77-2.01)	0.365
Midline deviation (No vs yes)	2.035	0.368	7.65	(3.72-15.74)	<0.0001*

association of TMD with sagittal plane malocclusions (class I, II, and III malocclusions) and with midline deviation. On the contrary, the association with vertical malocclusions (open and deep bite) was not statistically significant.

Discussion

In similarity with our study, other research conducted [30-33] on the adult population estimated a prevalence of around 55% for women and around 40% for men. The stratified analysis by sex showed a statistically significant difference in the prevalence of TMD between females and males (p = 0.023) in which female subjects presented about twice the risk of TMD compared to male subjects.

This finding is in agreement with previous studies and confirms what others have already concluded [34,35].

Regarding the age of the subjects in the sample, no statistically significant difference was found in the prevalence of TMD (p=0.322), consistent with other international scientific studies, in which, although there was a trend of greater severity of TMD in young adults, no correlation was found between age and presence of TMD [36-38].

Young adults represent the life stage of greatest production and difficulty. With advancing age comes changes in the standard of living and adaptive capacity of individuals with TMD; signs and symptoms become subclinical and perceived at a lower intensity, resulting in less pronounced severity.

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The increasingly early onset of the first signs and symptoms of TMD is mainly due to parafunctional habits [39-41].

In this study, in contrast to what various scientific literature has shown, a statistically significant association emerged between TMD and the malocclusions considered.

Most of the scientific literature in fact shows a weak link between malocclusions and TMD [42] or a total absence of causal relationship [43].

The association between class I, II, and III malocclusions (according to the Angle classification) and the presence of TMD was found to be statistically significant ($p<0.0001$). According to the data obtained, subjects with a Class II and III malocclusion are six times more likely of having TMD than subjects with a normal class I. On the contrary, subjects with a Class I malocclusion are roughly three times more susceptible to having TMD than subjects with a normal Class I.

The association between malocclusions in the vertical plane (open and deep bite) and the presence of TMD was found to be statistically significant ($p=0.003$). According to the data obtained, subjects with an anterior open bite are more likely to have TMD than those with a deep open bite. These results support those obtained by Michelotti [2] (2005) and by LeBell [3] (2006) who both studied the muscle activity of the chewing system in patients with malocclusions.

The association between midline deviation greater than or equal to 3mm and the presence of TMD was found to be statistically significant ($p<0.0001$). The presence of a deviation greater than or equal to 3mm was approximately five times greater in subjects with TMD than in those without TMD.

No statistically significant correlation was found between TMD and previous orthodontic treatments, confirming the results reported by international literature and in particular, the results obtained in the study conducted by McNamara, Slingun, Okeson [17] in 1995, whose concepts are still considered clinically valid today.

Furthermore, as an observational study, it is not possible to draw any etiological conclusions on the possible relationship between TMD and malocclusions. Longitudinal studies with adequate statistical power and tools capable of diagnosing and dividing TMD into subtypes (such as muscular, articular, and mixed), appear to be necessary for a better understanding of this association.

Conclusion

In conclusion, the results of this retrospective observational study, conducted on an adult population, suggest the existence of a statistically significant association between TMD and malocclusions, related to dental class, type of dental bite, and midline deviation.

In contrast to the literature [44,45], in this study the open bite seems to be associated with TMD much more than the deep bite: this could be due to the lack of anterior guides in open bites, in which the mandible is freer to move, and this can more easily lead to the onset of TMD than in those who have a deep bite with canine and incisor guides that are more accentuated.

Furthermore, all malocclusions (class I, II, III) are associated with TMD and this could be explained by the lack of anterior guides (as in open bite), which leads to joint overloading and, consequently, to the onset of TMD. This hypothesis is strengthened by the fact that the correlation between malocclusions and TMD was not only associated with second and third-class malocclusions, where the problem would be only the sagittal defect, but also with first-class molars with dysfunction in the guides. Thus, guidance interference could play an important role in the occurrence of TMD.

The association that has been demonstrated between midline deviation >3mm and the onset of TMD could be due to a positional problem of the mandible and therefore to a discrepancy between centric relation and maximum intercuspation , with consequent later mandibular deviation, which could lead to the genesis of TMD [46].

The same correlation cannot be deduced for orthodontic treatment: although it overloads the TMJ during therapy, after some time it does not affect the TMJ and the genesis of TMD.

This could be a strong suggestion that orthodontic therapy should be used for the resolution of all types of malocclusions, in order to reduce the risk of incidence of TMD.

The strength of this study is that it significantly demonstrates that malocclusions are associated with TMD and orthodontic treatment can be a protective factors for the occurrence of TMD.

Nevertheless, it would be ideal to have an even larger sample available in order to better analyze the different severities of TMD and the different types of orthodontics (mobile/fixed) and ages of intervention.

Another limitation might be that no cases with aligner orthodontics were included, which should be investigated in further studies.

Authors' contributions

Dorothea Bellini, Giulia Fornarelli e Tomson Zefi have given substantial contributions to the acquisition of the data, Alessandro Marchesi and Andrea Sardella have contributed to the analysis and interpretation of the statistical data and to the conception of the manuscript. All authors have participated in drafting the manuscript, Alessandro Marchesi revised it critically. All authors read and approved the final version of the manuscript.

All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

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Citation: Marchesi A, Bellini D, Sardella A, Fornarelli G, Zefi T (2022) Correlation between temporomandibular disorders and malocclusions: A retrospective observational study-can malocclusions or previous orthodontic treatments affect Temporo-Mandibular Disorders? Int J Oral Craniofac Sci 8(1): 001-009.
DOI: https://dx.doi.org/10.17352/2455-4634.000051

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DOI: https://dx.doi.org/10.17352/2455-4634.000051