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Can temporomandibular dysfunction signs be predicted by early morphological or functional variables?

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SUMMARY The aim of the present study was to establish whether the early signs of various orofacial dysfunctions, malocclusions, or occlusal interferences can predict the development of temporomandibular dysfunction (TMD) in young adults. Forty-eight subjects referred for speech therapy and 49 controls participated in all four stages of this longitudinal study. The subjects were examined at the ages of 7, 10, 15, and 19 years. The phoniatrician diagnosed errors in place of articulation and problems in the movement and co-ordination of the speech articulators. Occlusion, TMD signs (palpatory tenderness of the masticatory muscles, and of temporomandibular joints (TMJ), jaw deviation on opening, and clicking), mandibular movement capacity and occlusal interferences were registered by the orthodontist. Multiple logistic regression models were applied in order to evaluate whether single signs of TMD at the age of 19 years were related to previous/present malocclusions or interferences, to misarticulations of speech, problems in oral motor skills, or other signs of TMD. The effect of gender was also considered.

The results showed that excessive overjet was the only variable which seemed to consistently increase the risk of TMD. In addition, girls seemed to be more prone to the development of TMD than boys. Although, during growth, there were both local and central factors associated occasionally with TMD development, the predictive value of those variables in the estimation of the individual risk of TMD was rather small.

Introduction

More than one-third of children and adolescents are reported to have temporomandibular dysfunction (TMD) (Magnusson *et al.*, 1985; Kirveskari *et al.*, 1986; Egermark-Eriksson *et al.*, 1990). Approximately one-third of all Finnish-speaking schoolchildren and university students have articulatory speech disorders (Laine *et al.*, 1987; Qvarnström *et al.*, 1991). Mastication, speech, and swallowing are physiological functions of the masticatory system which are closely related to each other (Närhi, 1984). Furthermore, disorders in various orofacial functions tend to occur in the same children (Laine *et al.*, 1992; Qvarnström *et al.*, 1993a; Pahkala *et al.*, 1995). It is well accepted that the aetiology of TMD is multifactorial, but there is still a need to describe the development of TMD signs and symptoms with increasing age, and to elucidate some aspects of the aetiology of TMD.

Clinically, the risk of TMD is alleged to be one indication for orthodontic treatment in children. From a therapeutic point of view, the most important question regarding the development of TMD is whether certain traits of morphological malocclusions, when observed in childhood, could be expected to predispose to functional disorders in adulthood. There are studies reporting that orthodontically treated individuals have less signs and symptoms of TMD than controls (Egermark and Thilander, 1992; Henrikson, 1999), while other reports suggest that signs and symptoms may ensue from treatment (Pullinger and Monteiro, 1988; Nielsen *et al.*, 1990), and in some studies no association between TMD and orthodontic treatment has been found (Sadowsky and Polson, 1984; Pilley *et al.*, 1997). It has also been demonstrated that some patients with TMD can be successfully treated by occlusal adjustment (Magnusson and Carlsson, 1983).

The aim of this study was to test the following hypotheses: (1) single malocclusion traits in childhood and adolescence can be considered as risk factors for TMD development with age, and (2) different orofacial dysfunctions such as articulatory speech disorders, problems in oral motor skills, and signs of TMD are related to each other in young adulthood.

Subjects and methods

The present investigation was a longitudinal study on the associations among different orofacial dysfunctions, namely speech misarticulations, problems in oral motor skills, and TMD. The original study group consisted of 157 6–8-year-old schoolchildren, who were diagnosed by special education teachers as having articulatory speech disorders and, therefore, referred for phoniatric consultation at Kuopio University Hospital. The controls were 130 first-graders of two elementary schools. As the controls represented one age cohort, some of them also had articulatory speech disorders, the prevalence of which corresponded to the number of misarticulations found in the age cohort of Finnish children. The subjects were re-examined at the ages of 10, 15, and 19 years. During the first examination, the mean age of the children was 7.6 years [standard deviation (SD) 0.4], at the second examination 10.6 years (SD 0.4), at the third examination 15.4 years (SD 0.5) and at the fourth examination 19.2 years (SD 0.5). There were 23 girls and 25 boys in the original hospital referral group and 31 girls and 18 boys among the controls, who attended all four examinations. As there were no significant differences between the original groups in the prevalence of articulatory speech disorders or TMD at the ages of 19 years (Tables 1 and 2), the groups were combined for the present statistical analyses. This study was approved by the Ethical Committee of the University of Kuopio in 1986.

With the patient in a supine position, clinical signs of TMD were examined by the same dentist (RP) as follows.

Palpation of muscles

Tenderness of the masticatory muscles was recorded as 'yes' if pain was reported by the patient during palpation. The following muscles were palpated: the anterior and posterior parts and the insertion area of the temporal, superficial, and deep parts of the masseter, the lateral and medial pterygoids, the sternocleidomastoid, and the posterior digastric.

Clicking/crepitation of the temporomandibular joint (TMJ) and TMJ tenderness on movement

TMJ sounds were reported if clicking or crepitation could be heard during active opening and closing of the mouth. A stethoscope was not used. TMJ tenderness was examined on opening and closing and was recorded as 'yes' if pain was noted during palpation. The structures were palpated from the lateral direction.

Deviation of the mandible

Deviation of the mandible on maximal opening and closing was recorded by the naked eye if it was more than 2 mm from the midline during movement.

Mandibular movement capacity

Recordings were made for maximal interincisal distance on opening, maximal lateral movements to the right and left, and maximal protrusion. The distance was measured in millimetres. For maximal protrusion, overjet was added to the measurement.

Occlusal contacts/interferences and slide

Different types of occlusal contact/interference were recorded with Hanel GHM occlusal test foil. Mediotrusive

Table 1 Prevalence (%) of articulatory speech disorders in 97 Finnish children at 7, 10, 15, and 19 years of age.

Articulatory speech disorder	Hospital referral group ($n = 48$)				Control group ($n = 49$)			
	7 years	10 years	15 years	19 years	7 years	10 years	15 years	19 years
Sounds produced too far anteriorly	50	52	46	48	35	45	33	39
Sounds produced too far posteriorly	27*	21*	10	13	2*	2*	4	2
Sounds produced laterally	0	2	2	4	0	0	0	2
Unclassified variants	19*	10	6	8	0*	2	6	6

*Statistically significant difference ($P < 0.05$) between hospital referral group and control group.

Table 2 Prevalence (%) of signs of temporomandibular dysfunction in 97 Finnish children at 7, 10, 15, and 19 years of age.

Signs of temporomandibular dysfunction	Hospital referral group ($n = 48$)				Control group ($n = 49$)			
	7 years	10 years	15 years	19 years	7 years	10 years	15 years	19 years
Deviation on opening	10	29	35	31	16	31	27	31
Palpatory tenderness of muscles	15	29	17	21	14	25	16	14
Palpatory tenderness of temporomandibular joint	2	10	0	0	2	10	0	0
Clicking	8	19	6	13	8	14	6	16

contact was recorded if there was any mediotrusive contact(s) when the laterotrusion ended with contact just between the canines. Protrusive interference was recorded if there were any post-canine contacts preventing symmetric interincisal contact during protrusive movement. The sagittal and lateral slide between the retruded contact position (RCP) and the intercuspal position (ICP) was recorded in millimetres.

Occlusion

Occlusion was registered clinically in the ICP according to the criteria described by Björk *et al.* (1964), but with slight modifications as described by Laine (1984). In summary, distal or mesial molar occlusion was recorded when there was a deviation of at least one-half cusp width bilaterally. Overjet and overbite were measured in millimetres. Lateral open bite, determined as a visible space between one or more antagonistic buccal teeth in ICP, lateral crossbite, and scissors bite (buccal crossbite) were registered for the premolars and molars. Table 3 shows the prevalence of malocclusions at the ages of 7, 11, 15, and 19 years in the subjects studied.

Prevalence of articulatory speech disorders and problems in oral motor skills

Articulatory speech disorders were clinically diagnosed by the phoniatrician according to the criteria described by Laine *et al.* (1987). Based on errors in place of articulation, misarticulations were categorized into too anteriorly, too posteriorly and laterally produced sounds. All other misarticulations were categorized as unclassified variants. Functioning of the muscles of the tongue, lips, and circumoral muscles during 19 different tasks was judged to be accurate, inaccurate, or failed. The co-ordination of repeated movements was assessed to be accurate if the subject was able to repeat the movement more than five times in 10 seconds. The methods and the data have been reported (Qvarnström *et al.*, 1991, 1993a).

Table 3 Prevalence (%) of different occlusal anomalies in 97 Finnish children at 7, 10, 15, and 19 years of age.

Type of occlusal anomaly	7 years	10 years	15 years	19 years
Sagittal				
Distal molar occlusion	32	39	31	34
Mesial molar occlusion	3	2	3	6
Overjet ≥ 5 mm	16	23	19	21
Overjet ≤ 0 mm	6	1	2	3
Vertical				
Overbite ≤ 0 mm	19	3	4	6
Overbite ≥ 5 mm	4	13	18	17
Lateral open bite	9	4	2	1
Transversal				
Crossbite	10	5	6	9
Scissors bite	0	2	1	2

Statistical analysis

Multiple logistic regression models were used to establish if any of the morphological or functional variables expressed at 7, 10, 15, and 19 years of age were related to any signs of TMD at the age of 19 years, and thus could be considered as a risk factor of that disorder. The following dichotomized (0 = no, 1 = yes) variables were included in the analyses: palpatory tenderness of the masticatory muscles, jaw deviation on opening, clicking, protrusive interference, mediotrusive contact, long (greater than or equal to 2 mm) sagittal RCP–ICP slide, lateral (greater than or equal to 0.5 mm) RCP–ICP slide, any articulatory speech disorder, any problems in movement or co-ordination of the speech articulators, distal and mesial molar occlusion, lateral crossbite, and lateral open bite. Maximal opening, maximal laterotrusive, and protrusive movements (mm), and overjet and overbite (mm) were included in the analyses as continuous independent variables. The effect of gender was also considered. Variables for which the prevalence was less than 5 per cent (palpatory tenderness of the TMJ at the ages of 7, 15, and 19 years, scissors bite at all examinations, RCP–ICP slide and lateral open bite at the ages of 10, 15, and 19 years, mesial molar occlusion at the ages of 7, 10, and 15 years, and lateral slide at the age of 19 years) were excluded from the models. For all comparisons, $P < 0.05$ was considered to be statistically significant.

Results

Logistic regression analyses regarding malocclusions (Tables 4–7) showed that lateral open bite at the age of 7 years and excessive maxillary overjet at the ages of 10, 15, and 19 years had a positive relationship with muscle tenderness in young adulthood. An association between mesial molar occlusion and deviation on opening at the age of 19 years was also positive. Mediotrusive contacts were negatively but protrusive interferences positively related to clicking among 19 year olds.

The risk of muscle tenderness was higher in those whose lateral movements had been large at the ages of 7 and 15 years. However, those with reduced protrusive movement capacity in the first-grade were likely to have TMD signs, especially muscle tenderness and clicking, in young adulthood. In addition, clicking, jaw deviation on opening, and muscle tenderness seemed to be associated with each other from time to time during growth, but none of the single signs proved to be a persistent risk factor of another sign. Furthermore, girls seemed to be more prone to the development of certain clinical signs of TMD, such as muscle tenderness at all stages of the

Table 4 Associations between temporomandibular dysfunction signs (muscle tenderness, clicking, deviation on opening) in 19 year olds ($n = 97$) and morphological and functional variables for the same children at 7 years of age, considering the effect of gender (0 = girls, 1 = boys), as estimated by the logistic regression model. Only statistically significant variables are listed.

Dependent variable (at the age of 19 years)	Independent variable (at the age of 7 years)	Regression coefficient	*P*
Muscle tenderness*	Lateral open bite	5.523	0.047
	Muscle tenderness	4.613	0.019
	Protrusive movement	–1.697	0.021
	Laterotrusive movement	1.032	0.022
	Articulatory speech disorder	3.654	0.024
	Problems in co-ordination of speech articulators	4.291	0.047
	Gender	–6.189	0.007
Clicking†	Protrusive movement	–0.381	0.049

*$R^2 = 0.421$. †$R^2 = 0.055$ (Cox and Snell, 1989).

Table 5 Associations between temporomandibular dysfunction signs (muscle tenderness, clicking, deviation on opening) in 19 year olds ($n = 97$) and morphological and functional variables for the same children at 10 years of age, considering the effect of gender (0 = girls, 1 = boys), as estimated by the logistic regression model. Only statistically significant variables are listed.

Dependent variable (at the age of 19 years)	Independent variable (at the age of 10 years)	Regression coefficient	*P*
Muscle tenderness*	Maxillary overjet	0.925	0.001
	Problems in co-ordination of speech articulators	1.554	0.043
	Gender	–3.208	0.003
Clicking†	Clicking	1.861	0.017
	Problems in co-ordination of speech articulators	1.531	0.036
	Gender	–1.463	0.046
Deviation on opening‡	Gender	–0.946	0.046

*$R^2 = 0.188$. †$R^2 = 0.037$. ‡$R^2 = 0.087$ (Cox and Snell, 1989).

Table 6 Associations between temporomandibular dysfunction signs (muscle tenderness, clicking, deviation on opening) in 19 year olds ($n = 97$) and morphological and functional variables for the same children at 15 years of age, considering the effect of gender (0 = girls, 1 = boys), as estimated by the logistic regression model. Only statistically significant variables are listed.

Dependent variable (at the age of 19 years)	Independent variable (at the age of 15 years)	Regression coefficient	*P*
Muscle tenderness*	Maxillary overjet	0.600	0.011
	Clicking	3.714	0.003
	Muscle tenderness	1.787	0.045
	Laterotrusive movement	0.585	0.049
	Gender	–2.186	0.033
Clicking†	Deviation on opening	1.275	0.035
Deviation on opening‡	Deviation on opening	2.892	<0.001
	Articulatory speech disorder	1.358	0.021

*$R^2 = 0.285$. †$R^2 = 0.088$. ‡$R^2 = 0.313$ (Cox and Snell, 1989).

study, deviation on opening at the ages of 10 and 19 years, and clicking at the age of 10 years, than boys.

Articulatory speech disorders among 7 and 15 year olds increased the risk of TMD development, e.g. muscle tenderness and jaw deviation on opening, respectively. Also problems in the co-ordination of speech articulators at all stages of the study except among 15 year olds, proved to predispose to TMD signs, mainly muscle tenderness, in young adulthood.

Discussion

During this study, the same children were examined four times between 7 and 19 years of age. Drop-out

Table 7 Associations between temporomandibular dysfunction signs (muscle tenderness, clicking, deviation on opening) in 19 year olds ($n = 97$) and morphological and functional variables for the same children at 19 years of age, considering the effect of gender (0 = girls, 1 = boys), as estimated by the logistic regression model. Only statistically significant variables are listed.

Dependent variable (at the age of 19 years)	Independent variable (at the age of 19 years)	Regression coefficient	*P*
Muscle tenderness*	Maxillary overjet	0.452	0.015
	Problems in co-ordination of speech articulators	1.722	0.016
	Gender	–1.611	0.047
Clicking†	Mediotrusive contact	–1.968	0.021
	Protrusive interference	2.008	0.007
	Muscle tenderness	1.877	0.007
Deviation on opening‡	Mesial molar occlusion	2.454	0.012
	Clicking	1.391	0.026
	Gender	–1.150	0.032

*$R^2 = 0.215$. †$R^2 = 0.183$. ‡$R^2 = 0.139$ (Cox and Snell, 1989).

of the subjects was mainly due to relocation away from the district, and partly to unwillingness to come to the examinations. Between the first and second examinations, the largest drop-out was from the group referred for speech articulatory problems, which is a possible source of error when the follow-up data were analysed. With age, the differences in the prevalence of misarticulations between the groups levelled off; certain misarticulations tended to reduce (substitutions changed into distortions, which are considered to be milder misarticulations) or improve, but there was also an increase, especially in /s/-sounds, among the controls, probably reflecting the manner of speech in this age group (Qvarnström *et al.*, 1993b). Considering the fluctuation in speech misarticulations with age, and the length of the follow-up period, it is unlikely that the drop-outs will have seriously influenced the findings.

The present results regarding malocclusion show that a lateral open bite at 7 years of age, mesial molar occlusion at 19 years of age, and excessive overjet at 10, 15, and 19 years of age seem to increase the risk of TMD signs (mainly muscle tenderness) in young adulthood. Excessive overjet predisposes to large mandibular movements, most probably for functional reasons, speech articulation, and bite, which may stress the masticatory muscles. In other longitudinal studies it has been found that distal molar occlusion in combination with a deep bite, especially Angle's Class II division 2 (Helm and Petersen, 1989), and extreme maxillary overjet (Egermark-Eriksson *et al.*, 1990) are positively correlated to TMD. In the latter study, inversion of incisors, anterior open bite, and lateral crossbite were also revealed to be potential risk factors of TMD signs and symptoms, but no such association was found in the present investigation. In the present sample there was only a few individuals with mesial molar occlusion, anterior open bite, anterior crossbite, and scissors bite, and thus those malocclusion traits could not be considered in every analysis.

When evaluating possible causality between malocclusions and TMD, the severity of the malocclusion and the age of the subject should be considered, as most individuals with (mild) malocclusions may experience beneficial remodelling changes in TMJ components, but with a long exposure to severe malocclusions there are likely to be extensive TMJ changes (Solberg *et al.*, 1986). This makes the analyses more complicated. Interestingly, however, studies on orthognathic patients have shown that pre-operatively the prevalence of TMD does not seem to exceed that in non-patient populations (Kerstens *et al.*, 1989), and post-operatively the reduction in subjective pain and discomfort is not related to the severity of the pre-treatment malocclusion (Rodrigues-Garcia *et al.*, 1998).

In the present logistic regression analyses the explanatory values of malocclusions in the aetiology of TMD were rather small, varying from 3 to 11 per cent. This indicates that no single occlusal factor is of major importance for the development of TMD, corroborating the findings of other longitudinal studies (Helm and Petersen, 1989; Egermark-Eriksson *et al.*, 1990). However, the present findings do not detract from the importance of early orthodontic screening, as there are other functional indications for the correction of certain malocclusions, e.g. risk of asymmetric bicondylar growth (Pirttiniemi *et al.*, 1991), tissue damage (Järvinen, 1979; Helm, 1990), and possible predisposition to obstructive sleep apnoea later in life (Rintala *et al.*, 1991; STAKES, 2002).

Mediotrusive contact proved to decrease the risk of clicking among 19 year olds, which agrees with Minagi *et al.* (1990), who found this protective effect of mediotrusive contact to be evident especially during bruxism. Although functional occlusion is considered to be more important than malocclusion in the aetiology of TMD, studies on the association between interferences and TMD are contradictory (Egermark-Eriksson *et al.*, 1983; Ingervall *et al.*, 1991; Kirveskari *et al.*, 1992). In the present investigation, protrusive interference seemed to increase the risk for clicking in adulthood but not in childhood despite the high prevalence of interferences at the ages of 7, 10, and 15 years (Pahkala *et al.*, 1991; Pahkala and Laine-Alava, 2000). This may indicate that children can adapt better to peripheral factors compared with adults.

In order to evaluate the role of interferences in the aetiology of TMD, it should be remembered that a variety of occlusal contacts occur during functional jaw movements according to the craniofacial morphology of an individual, and thus, for example, mediotrusive contacts should be separated from mediotrusive interferences. However, vague associations between interferences and TMD is no excuse for introducing these suspected risk factors, such as occlusal interferences, as a side-effect of dental treatment (Kuttila *et al.*, 1996).

The results also showed that different signs of TMD were related to each other, but with an unpredictable pattern. As stated by Kirveskari (1991), 'TMD may just represent a loose conglomerate of signs and symptoms with no systematic causal relationships, or the signs and symptoms could represent different stages of a process progressing at different speeds'. Because the signs and symptoms of TMD fluctuate (Magnusson *et al.*, 1985; Pahkala and Laine-Alava, 2000), at the individual level it is not possible to explain why one individual will get TMD and another will not (Greene, 2001). The signs of TMD can quite often be found among children and adolescents, but only a very small minority of them will require treatment (Mohlin *et al.*, 1991). In fact, the signs and symptoms of TMD in growing individuals may be due in part to growth changes (Dibbets *et al.*, 1985; Pahkala and Laine-Alava, 2000). Thus, the predictive value of single TMD signs for the development of severe dysfunction later in life seems to be poor.

The present study showed that large lateral jaw movements at 7 and 15 years of age, and reduced protrusive capacity at 7 years of age were related to some TMD signs some years later. According to previous results, mandibular movement capacity partly reflects occlusal morphology (Pahkala and Laine-Alava, 2002; Pahkala and Qvarnström, 2002), and is partly associated with problems in other orofacial functions (Pahkala *et al.*, 1991). Thus, in growing individuals hypo/hypermobile movements of the mandible do not necessarily indicate TMD development. In addition, girls seem to be more prone to the development of TMD signs, especially muscle tenderness, than boys. It has been demonstrated that there are some gender differences in the fibre composition of the jaw musculature (Eriksson, 1982), as well as in EMG output (Visser and DeRijke, 1974), which might partly explain earlier exhaustion and pain in the musculature of females than in males (Krogstad *et al.*, 1992). The relationship between gender and TMD has been previously discussed (Pahkala and Laine-Alava, 2000).

Finally, the present results confirm previous findings (Laine *et al.*, 1992; Pahkala and Laine-Alava, 2002) that articulatory speech disorders produced in an incorrect place in the oral cavity and problems in oral motor skills are related to TMD, probably indicating an inadequate compensation mechanism or poor control of the neuromuscular system.

Conclusions

A large overjet was the only morphological variable which seemed to consistently increase the risk of TMD. Females were also more likely to suffer from TMD than males. Although, during growth, there were both local and central factors associated from time to time with TMD development, the predictive value of these variables in the estimation of individual risk of TMD seems to be at best modest. These findings strengthen the hypothesis that different orofacial dysfunctions are positively related, but the role of malocclusion in the aetiology of TMD in adolescence seems to be rather small.

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