Original Article

Association of Malocclusion and Functional Occlusion with Subjective Symptoms of TMD in Adults: Results of the Study of Health in Pomerania (SHIP)

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Abstract: An analysis of exclusively representative population-based studies on adults has shown that only few and inconsistent associations could be detected between malocclusions and clinical signs of temporomandibular disorders (TMD)—and none for functional occlusion factors (occlusal interferences, non–working side contacts, etc). The aim of this study was to analyze associations between morphologic occlusion as well as factors of functional occlusion and subjectively perceived symptoms of TMD—again on the basis of the population-based Study of Health in Pomerania (SHIP), providing a sample of 4310 subjects (out of 7008 subjects yielding a response rate of 68.8%) aged 20 to 81 years, and other international representative studies from the systematic review. Besides occlusal factors also parafunctions and socioeconomic status (SES) were taken into account (including age and sex). Multiple logistic regression analysis was used—adjusted for SES. In this study, none of the occlusal factors were significantly associated with the indication of more frequent subjective TMD symptoms. However, the parafunction ''frequent clenching'' was connected with subjective TMD symptoms (odds ratio = 3.4). Compared with other population-based studies few and (across studies) inconsistent associations between malocclusions and subjective TMD symptoms could be ascertained. No significant associations of factors of functional occlusion with TMD symptoms were identifiable. (*Angle Orthod* 2005;75:183–190.)

INTRODUCTION

An analysis of exclusively representative population-based studies on adults has shown that only few and inconsistent associations could be detected between malocclusions and clinical signs of temporomandibular disorders (TMD).[1,2] For functional occlusion factors (occlusal interferences, non–working side contacts, both with or without wear facets, etc), no associations were found. The aim of this study was to analyze associations between morphologic occlusion as well as factors of functional occlusion and subjectively perceived symptoms of TMD—again on the basis of exclusively population-based studies on adults. These were the representative Study of Health in Pomerania (SHIP) in Germany[3,4] and other international representative studies from a systematic review on associations between occlusion and TMD.[2] Besides occlusal factors, also age, sex, and socioeconomic status (SES) were taken into account.

MATERIALS AND METHODS

Sample and study area

A representative random sample of 7008 women and men (aged 20 to 79 years) was drawn from three district towns Greifswald, Stralsund, Anklam and 29 communities in the surrounding region, which is part of West Pomerania and is the most northeasterly region of Germany. West Pomerania is the northeastern part of Mecklenburg-West Pomerania, one of the 16 federal German states. The sample selection was done in two steps. First, of the three districts in the region, three cities (17,076 to 65,977 inhabi-

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TABLE 1. Percentage Distribution of Prevalences of Subjective Symptoms of TMD in 4290 Adults Examined by Means of the Dental Interview

Symptoms of TMD[a]	Frequency	Prevalence %
TMJ sounds (clicking or crepitation)		
No	3913	91.2
Yes	377	8.8
Sometimes	307	7.2
Frequent	47	1.1
Always	23	0.5
TMJ pain		
No	4174	97.3
Yes	116	2.7
Sometimes	97	2.3
Frequent	14	0.3
Always	5	0.1
Pain in facial muscles		
No	4236	98.7
Yes	54	1.3
Sometimes	39	0.9
Frequent	13	0.3
Always	2	0.1
Subjective TMD symptoms total		
No	3832	89.3
Yes	458	10.7

[a] TMD indicates temporomandibular disorders; TMJ, temporomandibular joint.

tants) and 12 towns (1516 to 3044 inhabitants) were selected, and of the small towns (less than 1500 inhabitants), 17 out of 97 were drawn at random. Second, from each of the selected communities, subjects were drawn at random from official inhabitant data files proportional to the population size of each community and stratified by age and sex. From the entire population of 212,157 inhabitants, 7008 subjects were sampled, with 292 persons of each sex in each of the 12 five-year age strata. The examinations took place from October 1997 to May 2001. For a full description of the design of the study see John et al[3] and for the dental part see Hensel et al.[4]

Subjective TMD symptoms

To obtain a subjective evaluation of dysfunction symptoms, each participant was interviewed concerning recent unilateral or bilateral symptoms of dysfunction, such as joint sounds like clicking or crepitation, pain in the temporomandibular joints, and pain in the facial muscles (each: sometimes, frequently, always), according to the TMD diagnosis guidelines of the Academy of Orofacial Pain.[5] TMD symptoms and their prevalences are shown in Table 1. Together with prevalences of TMD signs, the prevalences of TMD symptoms have been described in detail elsewhere.[6] The dependent variable was defined the way that subjects with one or more symptoms belonged to the TMD symptom population. The distribution of TMD symptoms is presented in Table 2.

TABLE 2. Distribution of TMD Symptoms[a]

No. of TMD Symptoms	Frequency	Percentage
0	3832	89.3
1	377	8.8
2	73	1.7
3	8	0.2

[a] TMD indicates temporomandibular disorders.

Normal occlusion/malocclusions

Subjects with a defined loss of teeth (15+ teeth) were excluded from the analysis because it was not possible to adequately assess their morphologic occlusion (for full definition see Gesch et al[1]). Thirty-three variables of malocclusion and normal occlusion were clinically investigated (Table 3). An anatomically correct occlusion was considered as normal (ideal) occlusion. A deviation from normal occlusion was regarded as malocclusion.[7]

Functional occlusion factors

Fourteen factors of functional occlusion comprising occlusal contacts or interferences during mandibular movement and dental attrition were clinically examined (Table 3). Tooth contacts were analyzed by themselves and in combination with wear facets.[8] This was done to see whether the person concerned ''uses'' the ''interfering'' occlusion (Table 3). Whether tooth contacts occurred on one or both lateral movements of the mandible as well as whether they occurred on one or both sides on protrusion were registered. Parafunctions like sometimes or frequent grinding or clenching were obtained by the dental part of the online interview (Table 3).

Socioeconomic status

Sociodemographic parameters like age, sex, education, and professional training were determined from the general question section of the online interview. Socioeconomic items such as net income were registered by means of a self-administered questionnaire (Table 3, for definitions see Gesch et al[1]).

When subjects stated a history of ''inflammatory joint diseases'' (such as chronic polyarthritis) or ''one or more accidents involving cranial injury in the past 12 months'' in the medical questions section of the online interview, they were excluded (n = 316).

Clinical examinations were performed by eight calibrated examiners. Prebaseline orthodontic certification of the dentists was based on the examination of 30 pairs of dental casts showing complex symptoms of occlusal deviation that was repeated after several days. The findings recorded by the specialist were the gold standard. Intraexaminer and interexaminer agreement were tested by Cohen's κ.[9]

The results were within the range of ''strong agreement''

(κ 0.66–0.81). Regarding examiner agreement for the clinical examinations, the examiners were compared for corresponding prevalences of the recorded malocclusions and the results presented in biannual Data Safety and Monitoring Committee reports. In case of distinct deviation, the examiner concerned was recalibrated. The dental interview was conducted by two trained dental assistants. With the informed consent of the subjects, the data input quality was tested by means of tape recordings and comparison of the acoustic and computerized data in a 10% sample of all interviews. In 18 controlled tape recordings, only one input error per dental assistant was found in 1217 single inputs per subject. For further description of quality management procedures see Hensel et al.[4,10] All measurements and evaluations were performed blinded with respect to the identity of the study participants.

Statistical analysis

The data obtained were recorded online on a standardized data entry sheet and later statistically processed, edited, and analyzed at the Institute of Epidemiology and Social Medicine at the University of Greifswald, using the SAS System (SAS Institute Inc., Cary, NC). Statistical test results with $P < .05$ are considered statistically significant.

At stage 1, potential occlusal factors for TMD symptoms were screened with several multivariate logistic regression models (SAS PROC LOGISTIC) including age, sex, socioeconomic factors, and one of the occlusal factors in each model (thus further called ''univariate models''). Also interactions of occlusal factors with sex were tested to detect possible risk differences between sexes. Results and prevalences of occlusal factors and other factors are shown in Table 3. At stage 2, all independent variables and interactions between sex and occlusal factors were simultaneously entered into a multivariate logistic regression model. With the stepwise backward method, first all nonsignificant interactions and afterward all nonsignificant single independent variables were eliminated (SAS SLSTAY = 0.05, SLENTRY = 0.20). The results were adjusted for sociodemographic and socioeconomic variables as in the univariate models. Intervariable correlations were examined for potential multicollinearity between variables.

In this area of research it has been recommended that, for an odds ratio (OR) to be relevant, it would need to be statistically significant and, for it to be clinically noticeable, it should represent a doubling (OR > 2)[11,12] or halving (OR < 0.5) of risk, although prevalence of disease and base risk must be taken into account for a final decision of clinical relevance. An OR of less than 1 indicates that the presence of the factor is associated with reduced risk, an OR more 1 indicates increased risk.

RESULTS

Random sample

Of the 7008 subjects initially sampled, 741 dropped out, either because they moved away (n = 615) or because of death (n = 126), reducing the sample size to 6267. A response rate of 68.2% for men and 69.4% for women, resulted in a sample of 4310 subjects. The overall response rate was 68.8% for the ages of 20 to 81 years and 71.3% for the age groups 20 to 74 years. An analysis of nonresponders found that the main reasons for nonparticipation were disinterest (39.7%), health problems (23%), adequate available medical care (11.6%), lack of time (16.7%), fear of examination results (3%), and others (6%).[4] Twenty subjects were unable to undergo the oral examination. Finally, 4290 adults could get investigated anamnestically for symptoms of temporomandibular dysfunction and clinically for different types of malocclusions as well as for factors of functional occlusion. Sex and age distribution of the sample are given in Table 4.

Results of the univariate logistic regression analysis

The univariate analysis revealed that the dependent variable TMD symptoms were associated with one factor of morphologic occlusion (spacing) and parafunctions (clenching, grinding) but none of the factors of functional occlusion. It was not possible to calculate any ORs for unilateral or bilateral open bite above three mm because of the small number of observations (Table 3).

Interactions between sex and a single occlusal factor were not significant throughout, apart from unilateral non–working side interference and unilateral scissors-bite (total buccal crossbite), but in these cases the occlusal factor was not significant itself. An exception was the variable spacing (meaning primary spacing, not because of tooth loss).

Results of the multivariate regression analysis

Although grinding was significantly associated with TMD symptoms in the univariate logistic regressions ($P < .001$), it proved nonsignificant when considered simultaneously with the other variables of the multivariate logistic regression (Table 5). On the other hand, wear facets in dental restorations were not significant in the univariate, but in the multivariate logistic regression (OR = 0.7, Table 5; for a detailed description of the prevalences of wear facets see Bernhardt et al[13]). As in the univariate logistic regressions, the dependent variable TMD symptoms were significantly associated with spacing with an OR of 0.6 (prevalence 27.3%), with frequent clenching (OR = 3.4, 5.2%), and with the sex by spacing interaction. Only subjects who were aware of frequent clenching, more frequently stated one or more subjective TMD symptoms compared with those without this parafunction.

On the other hand, the occlusal factors spacing and wear facets in dental restorations were connected with less frequently perceived TMD symptoms. Normal occlusion was not significantly associated with TMD symptoms. The same

TABLE 3. Results of the Univariate Logistic Regressions and Prevalences (%) of Independent Variables. Regressions of the Dependent Variable TMD Symptoms in Dependence on Occlusal Factors (Normal or Malocclusions and Factors of Functional Occlusion) as well as on Parafunctions, Adjusted for Sex, Age, and Socioeconomic Status[a]

Variables			
Normal/Malocclusion[b]	*P*	Sign.	Prevalence %
Dentoalveolar			
Crowding upper incisors	.638	NS	
No			60.9
Degree 1[c]			33.5
Degree 2			4.9
Degree 3			0.7
Crowding lower incisors	.721	NS	
No			39.9
Degree 1			48.7
Degree 2			10.5
Degree 3			0.9
Labial/lingual position of 1 canine	.376	NS	11.5
Labial/lingual position of 2 canines	.287	NS	7.1
Labial/lingual position of 3 canines	.910	NS	1.4
Labial/lingual position of all canines	.700	NS	0.8
Posterior crowding (inclusive canines)	.463	NS	45.1
Spacing (not because of tooth loss)	.005	**	27.3
Sagittal			
Overjet	.564	NS	
Normal (<4 mm)			60.8
4–6 mm			29.3
>6 mm			9.9
Retroclined maxillary incisors	.808	NS	26.5
Edge-to-edge bite	.634	NS	6.0
Crossbite anterior	.597	NS	3.9
Negative overjet	.436	NS	1.0
Distoclusion 1/2 (1/4 to 3/4) premolar width	.909	NS	24.2
Distoclusion 1 + (≥ 3/4) premolar width	.927	NS	9.2
Mesioclusion (>1/4) premolar width	.801	NS	3.8
Mixed occlusion (no specific type)	.912	NS	28.9
Vertical			
Open-bite anterior	.331	NS	3.4
Open-bite unilateral up to 3 mm	.926	NS	1.0
Open-bite bilateral up to 3 mm	.330	NS	0.3
Deep bite	.821	NS	
No			75.3
Without gingiva contact (incisor contact)			17.6
With gingiva contact			7.1
Transverse			
Buccolingually cusp-to-cusp relation unilateral	.349	NS	28.7
Buccolingually cusp-to-cusp relation bilateral	.850	NS	6.9
Crossbite posterior unilateral	.771	NS	22.6
Crossbite posterior bilateral	.608	NS	5.2
Scissors-bite unilateral	.761	NS	3.7
Scissors-bite bilateral	.761	NS	0.5
Normal occlusion	.656	NS	2.6
Functional occlusion[b]			
Attrition			
Dental attrition degree 1[d]	.366	NS	29.0
Dental attrition degree 2	.352	NS	54.7
Dental attrition degree 3	.636	NS	11.2
Attrition in dental restorations	.921	NS	72.3
Occlusal contacts			
Non–working side interference unilateral	.738	NS	3.5
Non–working side interference bilateral	.517	NS	0.8
Unilateral interference on protrusion of mandible	.375	NS	1.4

TABLE 3. Continued

Variables			
Normal/Malocclusion[b]	*P*	Sign.	Prevalence %
Bilateral interference on protrusion of mandible	.459	NS	2.6
Non–working side contact unilateral	.479	NS	24.8
Non–working side contact bilateral	.128	NS	9.9
Unilateral contact during protrusion of mandible	.657	NS	14.7
Bilateral contact during protrusion of mandible	.443	NS	7.1
Non–working side contact with wear facets[e]	.281	NS	20.2
Lateral contact on mand. protrusion + wear facets[f]	.675	NS	15.5
Parafunctions			
Grinding	.001	***	
No			88.6
Sometimes			8.0
Frequent			3.4
Clenching	<.0001	***	
No			77.4
Sometimes			17.3
Frequent			5.2
Adjustment variable: sociodemographic/socioeconomic			
Male			49.1
Female			50.9
Age:			
20 to <30 y			12.9
30 to <40 y			18.0
40 to <50 y			17.5
50 to <60 y			18.4
60 to <70 y			18.6
70+ y			14.7
Education:			
Lower			39.8
Medium			43.8
Higher			16.4
Net income:			
Lower (<875$)			21.9
Medium (875$–2000$)			57.2
Higher (>2000$)			20.9
Without professional training			7.3
With professional training			92.7

[a] Sign. indicates levels of statistical significance: ** $P < .01$; *** $P < .001$; NS, not significant; TMD, temporomandibular disorders.

[b] One or more teeth of the respective variable.

[c] Degree 1, ≤1/2 width of lateral incisor; degree 2, >1/2≤1 width of lateral incisor; degree 3, >1 width of lateral incisor.

[d] According to Hugoson et al[8] degree 1, facets in enamel, spots of dentine; degree 2, loss of up to 1/3 of the crown; or degree 3, loss of more than 1/3 of the crown.

[e] The wear facets had to be at the guiding upper canine on the working side.

[f] The wear facets had to be at the guiding incisors or canines.

Univariate logistic regressions were based on 2257 observations (crowding upper incisors) to 3295 observations (dental attrition) for the occlusal variables because of tooth loss, missings due to incomplete data, and the exclusion variables (a maximum of 3670 observations for parafunction clenching).

was true for the sociodemographic and socioeconomic parameters. The ORs of none of the significant variables of the multivariate logistic regression analysis were between one and two. They were either below or, solely in the case of the nonocclusal variable frequent clenching, higher than two.

The only significant sex by spacing interaction showed a differential association between spacing and TMD symptoms for men and women. Women with this morphologic occlusion showed less frequent symptoms of TMD compared with those without spacing. All intervariable correlations between the occlusal variables of the final multivariate logistic models were <0.25 (Pearson), showing no potential redundancies.

TABLE 4. Sex and Age Distribution of the Sample (n = 4290)

	Sex					
	Male		Female		Total Sample	
Age (y)	n	%	n	%	n	%
20–29	274	6.4	318	7.4	592	13.8
30–39	356	8.3	404	9.4	760	17.7
40–49	352	8.2	396	9.2	748	17.4
50–59	369	8.6	420	9.8	789	18.4
60–69	421	9.8	368	8.6	789	18.4
70+	337	7.9	275	6.4	612	14.3
Total	2109	49.2	2181	50.8	4290	100

DISCUSSION

In view of the random selection method and the response rate of 68.8%, this study can be considered representative of the adult population aged 20 to 81 years in the region under survey and of small and medium cities in a rural setting. It is thus also representative of the subjective functional status of the population's stomatognathic system as well as the malocclusions, factors of functional occlusion, parafunctions, and socioeconomic parameters. For limitations of the study see Gesch et al.[1]

Besides univariate logistic regressions, multivariate logistic regression methods were used to find out whether associations exist between malocclusions and functional occlusion factors and symptoms of TMD and how strong these are. Multivariate logistic models identifying subjects with one or more symptoms of TMD were generated incorporating just one statistically significant morphologic occlusion and one functional occlusion factor as well as one parafunction for the entire study population (Table 5). Containing all significant variables simultaneously in the multivariate model after backward selection, none of the occlusal factors (malocclusions, functional occlusion) under survey was—in sense of a risk marker—significantly associated with subjective TMD symptoms (Table 5). In fact, the only two significant occlusal factors, primary spacing (not caused by tooth loss) and facets in dental restorations, were even connected with few TMD symptoms. Only the parafunction frequent clenching was significantly and clinically relevant (more often) associated with TMD symptoms.

In a systematic review[2] of exclusively population-based representative studies on associations between morphologic and functional occlusion and signs or symptoms of TMD in adults, we also found only few significant occlusal factors, although limitations of the reviewed studies should be considered.[2]

Concerning malocclusions, similar tendencies emerged from the review. Mohlin[14] stated no associations between malocclusions and subjective TMD symptoms, except for a positive relation with the number of rotated posterior teeth. Szentpetery et al[15] found no significant correlation between morphologic occlusion and the anamnestic dysfunction index.[16] However, only bivariate correlations were calculated. Dworkin et al[17] determined no statistically significant difference among TMD cases and controls with regard to the malocclusions under survey, except for anterior crossbite that, however, occurred more frequently in community controls. De Kanter[18] stated that malocclusions (eg, overbite, overjet, Angle classification, crowding) were not directly statistically relevant related to TMD symptoms. Unfortunately, in all studies the strength was not given in form of an association (OR) or correlation. Only significance or *P* values were mentioned.

Normal occlusion was not significantly associated with

TABLE 5. Results of the Multivariate Logistic Regression. OR and 95% CI for the Dependent Variable TMD Symptoms in Dependence on Occlusal Factors (Normal or Malocclusions and Factors of Functional Occlusion) as well as on Parafunctions, Adjusted for Sex, Age, and Socioeconomic Status[a]

		95% CI			
Independent Variable	OR	Lower	Upper	*P*	Sign.
Normal/malocclusion[b]					
Spacing (not because of tooth loss)	0.6	0.4	0.9	.004	**
Interaction sex by spacing				.031	*
Functional occlusion[b]					
Attrition (wear facets) in dental restorations	0.7	0.5	1.0	.044	*
Parafunctions					
Clenching, frequent	3.4	2.1	5.6	.000	***
Clenching, sometimes	1.7	1.3	2.4	.726	NS
Sociodemographic/socioeconomic					

[a] Sign. indicates levels of statistical significance: * $P < .05$; ** $P < .01$; *** $P < .001$; NS, not significant; TMD, temporomandibular disorders; OR, odds ratio; and CI, confidence intervals.

[b] One or more teeth of the respective variable. The first group of each variable was considered the reference group with an OR equal to 1.0. Multivariate logistic regression analysis was based on 2116 observations because of tooth loss, missings due to incomplete data, and the exclusion variables of the 216 subjects, 262 showed TMD symptoms, 1854 not.

symptoms of TMD compared with subjects with malocclusions. Normal occlusion thus occurred with similar frequency in subjects with and without TMD symptoms. A total of 2.6% of the study population exhibited this form of morphologic occlusion. The other population-based studies did not mention anything about a possible association between normal occlusion and TMD symptoms. A ''protective'' association of the kind frequently assumed in orthodontics was likewise not investigated or described and was equally not confirmed in our sample.

The nonexistence of associations between the variables of functional occlusion and subjective TMD symptoms in this study was also confirmed by other representative studies. In none of the studies of the systematic review[2] were such associations described.[14,15,18,19] Mohlin[14] found no associations between functional occlusion and subjective TMD in 20- to 45-year-old women (men were not examined). Jenni et al[19] showed no significant difference in the prevalence of occlusal interferences between amnestical dysfunction groups and subjectively symptom-free persons.[16] De Kanter[18] observed in his multivariate analysis that functional occlusion factors were not related to subjective temporomandibular dysfunctions.

In this study the (nonocclusal variable), frequent clenching was the only significant variable of all independent variables under survey (malocclusions, factors of functional occlusion, parafunctions, SES, Table 3) with an OR above one (OR = 3.4), thus showing that subjects with this factor significantly more frequently complained about symptoms of TMD than persons without this parafunction. In addition, it was the only variable that was associated with subjective TMD symptoms if one considers an OR of ≥ 2 being the threshold for clinical relevance as recommended.[11,12] At 5.2% in this study, 222 subjects showed this kind of parafunction. Also, the representative studies of the review[2] have examined parafunctions; however, only Szentpetery et al[15] described correlations with the anamnestic dysfunction index according to that of Helkimo.[16]

Because associations between age as well as sex and TMD were described in other population-based studies,[18] we adjusted the univariate and multivariate analyses for age and sex (as well as socioeconomic parameters). Also, in our sample[6] nearly all prevalence figures for symptoms of TMD were higher for women than for men in all age groups, although not all significantly higher. Significant age differences existed for subjectively perceived joint sounds and pain in the facial muscles but not for subjective joint pain.[6] Regarding sex and TMD symptoms, only the significant interaction between sex and spacing pointed to a different risk for men and women. Men did not show a significant association between spacing and TMD symptoms, but in women a protective association occurred. No sociodemographic or socioeconomic factor was significantly associated with temporomandibular dysfunction symptoms. Except for age and sex, the population-based studies mentioned, either did not investigate or did not mention any other sociodemographic or socioeconomic parameters.

CONCLUSIONS

For the variables under research here and in other population-based studies the following conclusions are drawn:

- None of the occlusal factors under research, ie, none of the malocclusions and none of the functional occlusion factors, were significantly associated with the indication of more frequent subjective TMD symptoms.
- The parafunction ''frequent clenching'' was significantly and clinically relevant connected with subjective TMD symptoms.
- Only a small part of the variance of subjective symptoms of TMD could be explained by the numerous occlusal and nonocclusal variables investigated here. Additional occlusal and especially nonocclusal factors must play a role.
- As compared with other representative population-based studies of the systematic review, only few and (across studies) inconsistent associations between malocclusions and subjective TMD symptoms could be ascertained. No significant associations of factors of functional occlusion with TMD symptoms were identifiable.

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