Original Article

Association of Malocclusion and Functional Occlusion With Signs of Temporomandibular Disorders in Adults: Results of the Population-based Study of Health in Pomerania*

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Abstract: The objective of this study was to determine whether associations exist between occlusal factors and signs of temporomandibular disorders (TMD) in adults using the population-based Study of Health in Pomerania (SHIP), Germany. A representative sample of 4310 men and women aged 20 to 81 years (response 68.8%) was investigated for TMD signs, malocclusions, functional occlusion factors, and sociodemographic parameters. Multiple logistic regression analysis, adjusted for sex, age, and socioeconomic status, was used. The results were compared with other population-based studies identified by a systematic review. Few malocclusions and no factors of functional occlusion except socioeconomic parameters were associated with TMD signs, and these associations were mostly weak. Only bilateral open bite up to three mm appeared to be clinically relevant and was associated with TMD signs (odds ratio [OR] = 4.0). This malocclusion, however, was of rare occurrence, with a prevalence of 0.3% (n = 9), and this finding was not confirmed by other representative studies. Occlusal factors examined in this study explained only a small part of the differences between normal subjects and those with TMD signs. This and other population-based studies indicate that malocclusions and factors of functional occlusion surveyed should be seen as merely cofactors in the sense of one piece of the mosaic in the multifactorial problem of temporomandibular dysfunction. Single occlusal factors that showed significant effects throughout several studies could not be detected. In view of the large number of occlusal variables already investigated, other variables including nonocclusal ones probably also play a role and should be looked at more intensely. (*Angle Orthod* 2004;74:512–520.)

Key Words: Population-based study; Malocclusion; Functional occlusion; Temporomandibular disorders; Association

INTRODUCTION

Because there seemed to be no agreement in the literature as to whether or not associations exist between occlusal factors and temporomandibular disorders (TMD), we conducted a systematic review to identify all relevant population-based studies that examined the relationship between malocclusion or functional occlusion and TMD in adults.[1]

We found that the methodological approach and quality of the studies were among the reasons for the mixed picture. Differences in sampling (randomized or selected, patient or nonpatient population, response rate, sample sizes, etc) and differences in examination methods (variables ex-

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TABLE 1. TMD Signs Investigated and Prevalences in 4289 Men and Women

Signs of TMD[a]	Prevalence (%)	95% CI
TMJ tenderness on palpation/compression		
TMJ tenderness or pain on palpation, left or right	4.9	4.3–5.6
TMJ tenderness or pain on dorsocranial compression, left or right	2.0	1.6–2.4
Masticatory muscle tenderness		
Tenderness or pain, left or right m. masseter	4.5	3.9–5.1
m. temporalis	3.5	3.0–4.1
m. pterygoideus medialis	4.7	4.1–5.4
m. pterygoideus lateralis (isometric testing)	4.8	4.1–5.4
Joint sounds		
Clicking on opening or closing, left or right, initially intermediate or terminally	20.0	18.8–21.2
Crepitation on opening or closing left or right, initially intermediate or terminally	7.2	6.5–8.0
Mobility of mandible		
Limited maximum mouth opening <40 mm, with or w/o pain	9.1	8.2–9.9
Limited lateral movement of mandible <5 mm left or right, with or w/o pain	2.9	2.4–3.4
Deviation (±2 mm) on opening/closing	18.7	17.5–19.9
Deflection or terminal deflection left or right on opening or closing	9.7	8.8–10.6

[a] Abbreviations: TMD indicates temporomandibular disorders; TMJ, temporomandibular joint; and 95% CI, 95% confidence interval.

TABLE 2. Distribution of TMD Signs[a]

Number of TMD Signs	Frequency	Percentage
0	2137	49.81
1	860	20.05
2	496	11.56
3	251	5.85
4	222	5.17
5	179	4.17
6–10	139	3.25
>10	6	0.13

[a] Abbreviation: TMD indicates temporomandibular disorders.

amined, data collection methods) were contributing factors. Only four epidemiologic studies[2–5] and one unpublished study[6] on adults fulfilled the criteria of being population-based and therefore are representative of the target population under survey. However, methodological problems were encountered even in these studies (eg, lack of adjustment for possible confounders, no strength of associations given). The associations between occlusion and TMD were analyzed using multivariate statistical methods in only two of these studies, although today it is assumed that multifactorial associations exist between TMD and various known and unknown factors.[7,8] In view of the small number of population-based studies and their methodological quality, it was recommended that the results of this study should be verified by means of further valid representative studies.

On the basis of this survey, the objective was to determine whether associations existed between different types of malocclusion or factors of functional occlusion (eg, occlusal interferences, nonworking side contacts), or both, and clinical signs of TMD in adults, taking into account age, sex, and socioeconomic status as possible confounders. This was done with multivariate analyses, and particular attention was devoted to the strength of any such associations.

MATERIALS AND METHODS

Study of Health in Pomerania (SHIP)-0 is a population-based epidemiologic study that was conducted from October 1997 to May 2001 in West-Pomerania, northeast Germany. For a full description of the design of the study see John et al[9] and for that pertaining to the dental aspect Hensel et al.[10]

SHIP-0 included a representative random sample of 7008 women and men aged 20 to 79 years, drawn stratified by age and sex from three cities and 29 communities in the surrounding region. The subjects were drawn from official resident data files, proportional to the population size of each community. From the entire regional population of 212,157 inhabitants, 7008 subjects were sampled, with 292 persons of each sex in each of the 12 five-year age strata.

Temporomandibular function/dysfunction

In the dental aspect of SHIP-0, four TMD categories were clinically examined in accordance with the TMD diagnosis guidelines of the Academy of Orofacial Pain.[8] Unilateral or bilateral findings were registered. In the case of the temporomandibular joint (TMJ) or masticatory muscle, tenderness or pain was recorded. The TMD signs investigated (12 variables) and representative prevalences are shown in Table 1 and have been published in detail elsewhere.[11] The dependent variable was defined in this field study without further clinical examination (X-ray, magnetic resonance imaging, etc). Subjects with no or one TMD sign are defined as controls and subjects with two or more clin-

TABLE 3. Results of the Univariate Logistic Regressions and Prevalences (%). Regressions of the Dependent Variable TMD Signs Associated with Occlusal Factors (Normal or Malocclusions and Factors of Functional Occlusion), Adjusted for Sex, Age, and Socioeconomic Status[a]

Independent Variable Normal/Malocclusion[b]	*P*	Levels of Statistical Significance	Prevalence
Dentoalveolar			
Crowding upper incisors	.353	NS	
No			60.9
Degree 1[c]			33.5
Degree 2			4.9
Degree 3			0.7
Crowding lower incisors	.571	NS	
No			39.9
Degree 1			48.7
Degree 2			10.5
Degree 3			0.9
Labial/lingual position of 1 canine	.422	NS	11.5
Labial/lingual position of 2 canines	.982	NS	7.1
Labial/lingual position of 3 canines	.773	NS	1.4
Labial/lingual position of all canines	.425	NS	0.8
Posterior crowding (inclusive canines)	.001	**	45.1
Spacing (except of tooth loss)	.174	NS	27.3
Sagittal			
Overjet	.756	NS	
Normal (<4 mm)			60.8
4–6 mm			29.3
>6 mm			9.9
Retroclined maxillary incisors	.289	NS	26.5
Edge-to-edge bite	.014	*	6.0
Crossbite anterior	.140	NS	3.9
Negative overjet	.008	**	1.0
Distoclusion 1/2 (1/4 to 3/4) pw	.935	NS	24.2
Distoclusion 1+ (≥3/4) pw	.040	*	9.2
Mesioclusion (>1/4 pw)	.053	x	3.8
Mixed occlusion (no specific type)	.770	NS	28.9
Vertical			
Open bite anterior	.925	NS	3.4
Open bite unilateral up to 3 mm	.247	NS	1.0
Open bite bilateral up to 3 mm	.038	*	0.3
Deep bite	.200	NS	
No			75.3
Without gingiva contact (incisor contact)			17.6
With gingiva contact			7.1
Transverse			
Buccolingually cusp-to-cusp relation unilateral	.150	NS	28.7
Buccolingually cusp-to-cusp relation bilateral	.329	NS	6.9
Crossbite posterior unilateral	.016	*	22.6
Crossbite posterior bilateral	.332	NS	5.2
Scissors-bite unilateral	.148	NS	3.7
Scissors-bite bilateral	.550	NS	0.5
Normal occlusion	.081	x	2.6
Functional Occlusion[b]			
Attrition			
Dental attrition degree 1[d]	.720	NS	29.0
Dental attrition degree 2	.252	NS	54.7
Dental attrition degree 3	.184	NS	11.2
Attrition in dental restaurations	.981	NS	72.3
Occlusal contacts			
Nonworking side interference unilateral	.183	NS	3.5
Nonworking side interference bilateral	.231	NS	0.8

TABLE 3. continued

Independent Variable Normal/Malocclusion[b]	*P*	Levels of Statistical Significance	Prevalence
Unilateral interference on protrusion of mandible	.931	NS	1.4
Bilateral interference on protrusion of mandible	.360	NS	2.6
Nonworking side contact unilateral	.271	NS	24.8
Nonworking side contact bilateral	.138	NS	9.9
Unilateral contact during protrusion of mandible	.407	NS	14.7
Bilateral contact during protrusion of mandible	.918	NS	7.1
Nonworking side contact with wear facets[e]	.850	NS	20.2
Lateral contact on mandibular protrusion + wear facets[f]	.272	NS	15.5
Adjustment Variable			
Sociodemographic/-Socioeconomic			
Male			49.1
Female			50.9
Age (y)			
20 to <30			12.9
30 to <40			18.0
40 to <50			17.5
50 to <60			18.4
60 to <70			18.6
70+			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] Abbreviations: NS, indicates not significant; pw, premolar width; and 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.[13] Degree 1: facets in enamel, spots of dentine, degree 2: loss of up to one third of the crown, or degree 3: loss of more than one third 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 2251 (crowding upper incisors) to 3275 observations (dental attrition degree 2) for the occlusal variables because of tooth loss, missings due to incomplete data, and the exclusion variables.

[x] $P < 0.10$, * $P < .05$, ** $P < .01$.

TABLE 4. Gender and Age Distribution of the Sample (n = 4289)

	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	274	6.4	611	14.3
Total	2109	49.2	2180	50.8	4289	100

ical TMD signs as cases. The distribution of TMD signs is given in Table 2.

Normal occlusion/malocclusions and functional occlusion factors

An anatomically correct occlusion was considered as normal (ideal) occlusion. A deviation from normal occlusion was regarded as malocclusion (Table 3).[12] The functional occlusion factors defined were occlusal contacts and interferences during mandibular movement as well as dental attrition.[13] Thirty-three variables of malocclusion and normal occlusion and fourteen factors of functional occlusion were clinically investigated (Table 3). Where three or more teeth per group were missing from at least two groups

of the two anterior dental groups and four lateral dental groups, regardless of whether or not the gaps were filled by prosthesis, malocclusions were regarded as no longer identifiable. Affected subjects were excluded from the analysis.

Sociodemographic parameters were determined from the online interview (Table 3). Besides gender and age these were: ''Higher education''—high school diploma or university entrance qualification, ''Medium education''—junior high school qualification or intermediate high school certificate, and ''Lower education''—no secondary school qualification or secondary modern school qualification. No professional training—subject had no training qualification or current training. Professional training—technical or advanced technical college qualification, semiskilled worker, subject who had completed apprenticeship, or university graduate. The socioeconomic parameter net income—the income of the entire household—was recorded by means of a self-administered questionnaire (Table 3).

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

Clinical examinations were performed by eight calibrated examiners. Interexaminer variability when diagnosing signs of TMD was assessed in five calibration sessions using a total of 22 volunteers. Based on the examiner calibrations carried out before and during the examinations, Cohen kappa[14] values ranging from 0.53 to 0.63 were determined in the final calibration session for detecting tenderness of the masticatory muscles and the TMJ during palpation, comparing the values obtained by all examiners with those obtained by the one who was defined as the reference. For the measurement of the vertical jaw movements, an intraclass correlation coefficient of 0.95 for all examiners was found. In detecting joint sounds, kappa values ranging from 0.71 to 1.0 were established. Prebaseline orthodontic certification of the dentists participating in the survey was based on the examination of 30 pairs of dental casts showing complex symptoms of malocclusion repeated after several days.

The findings recorded by the specialist were the gold standard. Intra- and interexaminer agreement were again tested by Cohen kappa. The results were within the range of ''strong agreement'' (Cohen kappa 0.66–0.81). The dental interview was conducted by two trained dental assistants. With the informed consent of the subjects, the quality of the input data was tested by means of tape recordings and comparison of the acoustic and computerized data. 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[10,15] All measurements and evaluations were performed blinded to the identity of the study participants.

Statistical analysis

The SAS System (SAS Institute Inc) was used for all analyses. As a first step, potential occlusal factors for TMD signs 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''). A level of $P < .10$ in the Type III Analysis of Effects table was used (see Table 3 for results and prevalences of occlusal factors and other factors).

As the second step, the significant variables were simultaneously entered in a multivariate logistic regression model. The results were adjusted for sociodemographic and socioeconomic variables as in the univariate models. Interactions of occlusal factors with sex were tested in the univariate and multivariate models because sex exhibited a strong influence on the prevalence of TMD.[11] Intervariable correlations were examined for potential multicollinearity between variables. For an odds ratio (OR) to be clinically relevant, it has to be statistically significant and clinically noticeable; it is assumed that it should represent a doubling ($OR > 2$)[16,17] or halving ($OR < 0.5$) of risk. An $OR < 1$ indicates that the presence of the factor is associated with reduced risk, an $OR > 1$ indicates increased risk.

A sample size calculation (power analysis) for planning further studies was done with the publicly available SAS-macro UnifyPow[18] using our data as the exemplary comparison data.

RESULTS

Random sample

Of the 7008 subjects initially sampled, it was possible to contact 6267, whereas 615 had moved away, and 126 had died. A total of 4310 subjects took part in the study (68.8% of 6267). Twenty subjects were unable to undergo the oral examination. In the case of one subject, it was not possible to obtain data on the TMJ. Finally, 4289 adults between the ages of 20 and 81 years (at the time of examination) were investigated clinically for signs of temporomandibular dysfunction, for different types of malocclusions, and for factors of functional occlusion. The sample consisted of 2109 men (49.2%) and 2180 women (50.8%, Table 4). For a further description of the response rates see Hensel et al.[10]

Results of the univariate logistic regression analysis

The results of the univariate logistic regression analysis and prevalences of occlusal and other factors are shown in Table 3. The univariate analysis revealed that the dependent variable (TMD signs) was associated with seven malocclusions, normal occlusion and none of the functional occlusion factors (at $P < .10$). It was not possible to calculate

TABLE 5. Results of the Multivariate Logistic Regression. OR and 95% CI for the Dependent Variable TMD Signs Associated with Occlusal Factors (Normal or Malocclusions and Factors of Functional Occlusion), Adjusted for Sex, Age, and Socioeconomic Status[a]

Independent Variable Normal/Malocclusion[b]	OR	95% CI Lower	95% CI Upper	*P*	Levels of Statistical Significance
Posterior crowding (inclusive canines): yes vs no	1.3	1.1	1.6	.004	**
Edge-to-edge bite: yes vs no	1.5	1.0	2.2	.046	*
Negative overjet: yes vs no	2.4	1.0	6.1	.063	NS
Distoclusion 1+ (≥3/4) pw: yes vs no	1.4	1.0	1.9	.047	*
Mesioclusion (>1/4 pw): yes vs no	1.2	0.7	1.9	.559	NS
Open bite bilateral up to 3 mm: yes vs no	4.0	1.0	15.5	.044	*
Crossbite posterior unilateral: yes vs no	1.2	0.9	1.5	.166	NS
Normal occlusion: yes vs no	0.8	0.4	1.5	.476	NS
Functional Occlusion[b]	-	-	-	-	-
Sociodemographic/socioeconomic					
Gender: female vs male	2.3	1.9	2.8	<.0001	***
Age (y)					
30 to <40 vs 20 to <30	1.6	1.2	2.1	.001	**
40 to <50 vs 20 to <30	1.4	1.0	2.0	.024	*
50 to <60 vs 20 to <30	1.2	0.9	1.7	.249	NS
60 to <70 vs 20 to <30	1.5	0.9	2.3	.098	NS
70+ vs 20 to <30	1.8	0.9	3.6	.108	NS
Education					
Higher vs lower	1.4	1.0	2.0	.035	*
Medium vs lower	1.0	0.8	1.4	.764	NS
Net income					
Medium ($875–2000) vs higher (>$2000)	1.1	0.8	1.4	.659	NS
Lower (<$875) vs higher (>$2000)	1.2	0.9	1.7	.150	NS
Professional training: yes vs no	0.9	0.6	1.4	.588	NS

[a] Abbreviations: NS, indicates not significant; pw, premolar width; OR, odds ratio; CI, confidence interval; and TMD, temporomandibular disorders.

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

The first group of each variable was considered the reference group with an OR = 1.0. Multivariate logistic regressions were based on 2229 observations because of tooth loss, missings due to incomplete data, and the exclusion variables.

* $P < .05$, ** $P < .01$., *** $P < .001$.

ORs for unilateral or bilateral open bite greater than three mm because of the small number of observations.

Interactions between sex and a single occlusal factor were not significant throughout, except for a borderline significance ($P = .047$) for unilateral interference on the protrusion of the mandible, but in this case, the occlusal factor was not significant itself ($P = .97$). Because of this result, interactions were not taken into account for selecting occlusal factors for entering the multivariate model.

Results of the multivariate regression analysis

In the multivariate model, interactions of occlusal factors with sex were all nonsignificant; thus, a model without interactions was calculated. All intervariable correlations between the occlusal variables of the final multivariate logistic models were <0.25 (Pearson) showing no potential redundancies.

Although negative overjet, mesiocclusion, unilateral posterior crossbite, and normal occlusion were significantly associated with TMD signs in the univariate logistic regressions ($P < .1$), they proved nonsignificant when considered simultaneously with the other variables of the multivariate logistic regression (Table 5, $P < .05$). The dependent variable (TMD signs) was significantly associated with the following malocclusions: bilateral open bite up to three mm with an odds ratio of 4.0 (prevalence 0.3%); edge-to-edge bite (OR = 1.5, prevalence 6.0%) as well as distocclusion of one or more premolar width (OR = 1.4, prevalence 9.2%); and posterior crowding (OR = 1.3, prevalence 45.1%) but not with any factors of functional occlusion (Table 5). Subjects with these malocclusions more frequently displayed more than one clinical sign of TMD than did those without these malocclusions. Of the sociodemographic-socioeconomic parameters, this was also true for sex, age, and education, in other words for women (OR = 2.3) compared with men, or for subjects aged 30 to 40 years (OR = 1.6) as well as 40 to 50 years (OR = 1.4), compared with the age group of 20 to 30 years. Compared with lower education, higher education (OR = 1.4) was associated with more TMD signs. Normal occlusion was not signifi-

cantly associated with TMD signs. As can be seen, the ORs of all significant variables of the multivariate logistic regression analysis were in the 1 to 2:1 range. Of the occlusal variables, only bilateral open bite up to three mm was above the 2:1 threshold. However, only nine subjects showed this type of malocclusion.

For future studies to replicate the effects of the occlusal factors that were found in our model, the following sample sizes (rounded to the nearest 100) are needed:

- about 2000 subjects for testing a model of only sociodemographic and socioeconomic factors against a full model with sociodemographic and socioeconomic and the five occlusal factors (posterior crowding, edge-to-edge bite, negative overjet, distocclusion 1+ premolar width, bilateral open bite) in our final model (Table 5) with $P < .1$;
- about 5500 subjects for testing a full model against a full model without one of the occlusal factors;
- about 6800 subjects for testing a univariate OR of 1.3 for edge-to-edge bite;
- about 2300 subjects for testing a univariate OR of 2.9 for negative overjet.

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 in the small and medium cities in a rural setting. It is thus also representative of the functional status of the population's stomatognathic system as well as the malocclusions and factors of functional occlusion.

In the univariate logistic regressions, four occlusal variables (negative overjet, mesioclusion, unilateral posterior crossbite, and normal occlusion) were significantly associated with TMD signs. This was no longer the case in the multivariate logistic regressions, however. This shows that in a multivariate analysis, as opposed to a bivariate analysis, certain factors no longer display a significant association with TMD signs when they are considered simultaneously with other factors. This illustrates the limitations of univariate analyses for assessing a multifactorial problem like TMD and argues in favor of multivariate analyses of TMD in future studies and multivariate reanalyses of existing data.

Consequently, multivariate logistic regression methods were used to find out whether associations exist between malocclusions and functional occlusion factors and signs of TMD and the strength of these associations. Multivariate logistic models, identifying subjects with more than one sign of TMD, were generated incorporating just four statistically significant malocclusions and no functional occlusion factor (Table 5) when assessed simultaneously with the significant variables of the univariate regression analysis. The population-based studies of the systematic review[1] also showed only few significant occlusal factors. Subjects with the malocclusions Angle Class II/2 and deep bite[4] or anterior crossbite[5] showed fewer signs of TMD. No associations between malocclusions and TMD were found by Mohlin[2] for clinical signs of TMD in women (men were not included in the study) and by De Kanter.[6] Unfortunately, the strength was not given in the case of an association or correlation. Only significance and/or *P* values were mentioned. Except for the study of Dworkin et al,[5] the clinical dysfunction index according to Helkimo was used.[19]

In this study, it was found that only bilateral open bite up to three mm with an OR of 4.0 was above the value of 2 that was used as clinically relevant (Table 5).[16,17] However, it occurred in just nine of 2590 (0.3%) subjects. Besides, this was not confirmed by other studies.[2,4,5] All other significant occlusal variables were below this threshold. Edge-to-edge bite (OR 1.5) of our sample was not confirmed by the study of Szentpetery et al,[4] in which only bivariate correlations were investigated. Dworkin et al[5] did not prove this malocclusion. They found a more frequent occurrence of anterior crossbite not in TMD cases but in ''community controls.'' Analogously, Szentpetery et al[4] described a negative correlation between Angle Class II/2 malocclusion and the clinical dysfunction index according to Helkimo,[19] unlike a positive association of distocclusion of one or more premolar width with TMD signs in our sample (OR = 1.4). Szentpetery et al[4] did not provide any further details regarding the extent of the Angle Class II/2 and the strength of the negative correlation in their study. The extent was also not expressed in other representative studies,[2,5] except for the study by De Kanter.[6] All these studies did not present associations between Angle classification and TMD signs. Posterior crowding, although hardly of clinical relevance, proved to be significantly associated with TMD signs (OR = 1.3) in this study.

Even though not directly comparable, there might be a relationship with ''number of rotated lateral teeth'' in the study by Mohlin.[2] However, it did not present an association with TMD signs.

Normal occlusion was not significantly associated with TMD signs when compared with subjects with malocclusions. Normal occlusion thus occurred in subjects with and without clinically relevant TMD signs. A total of 2.6% of the subjects exhibited this form of morphologic occlusion (Table 3). The other population-based studies do not say anything about a possible association between normal occlusion and TMD. A ''protective'' association of the kind frequently assumed in orthodontics was likewise not investigated or described and was not confirmed in our sample.

For functional occlusion and signs of TMD, no significant associations were found in any of the population-based studies reviewed[2–4,6] except for one positive correlation between excessive tooth wear and clinical TMD signs.[4] The latter case, however, merely checked correlations and did not perform a multivariate analysis. In the univariate anal-

ysis of our sample and in the multivariate analysis, we did not find any significant associations for functional occlusion factors either (Tables 3 and 5).

Associations between age or sex and temporomandibular dysfunction were described.[6] These were also found in our sample.[11] Nearly all prevalence figures for signs of TMD were higher, often up to twice as frequent, in the case of women than men in all age groups. In many of the cases, this was significant in some or all age groups (20–80 years). Age differences within the sex groups were less pronounced but existed for some variables. Therefore, it was necessary to adjust for sex and for age in a multivariate analysis. In the multiple logistic regression model, sex and age were associated with TMD signs. With an OR of 2.3, the female sex was a clinically relevant sociodemographic risk marker regarding TMD signs, meaning that the chances of showing signs of TMD were over twice as high in women compared with men. Across the entire age range from 20 to 81 years, subjects aged 30 to 50 years (OR = 1.6/1.4) displayed relatively more frequent TMD signs compared with the youngest age group aged 20 to 30 years (Table 5). However, these associations did not reach the given clinically relevant threshold of an OR of 2. Apart from sex and age, the only factor of the sociodemographic-socioeconomic parameters investigated in this study that showed a significant association with TMD signs was higher education compared with lower education, with a rather low OR of 1.4 (Table 5). Except for age and sex, the population-based studies mentioned either did not investigate or did not mention any association with TMD for any other sociodemographic-socioeconomic factors.

The relevance of occlusal factors for TMD can be described by two parameters ie, the strength of the associations between occlusal factors and TMD signs (ORs) and the prevalences of the occlusal factors. The few factors that displayed rather stronger associations were of relatively infrequent occurrence, whereas those with weaker associations were more frequent. For example, bilateral open bite up to three mm had the highest OR of 4.0 but occurred in only 0.3% of the subjects. In other words, only nine of 2590 subjects displayed this malocclusion. And of these, five showed TMD signs as opposed to four without clinically relevant TMD signs. The proportion of these (low) numbers explains the relatively high OR of 4.0.

In contrast, posterior crowding occurred in nearly half the subjects (45.1%), but, with the lowest OR of just over 1, displayed quite a weak association (Table 5). Of the 1169 subjects with this malocclusion (of a total of 2590 subjects), 381 (32.6%) showed TMD signs compared with 788 normals. A total of 1169 subjects with posterior crowding displayed TMD signs, which was significantly more frequent than 1421 subjects without this malocclusion.

Occlusal factors examined in this study only explain a small part of the differences between the controls and the cases.

Other parameters may also play a role. Considering the large number of occlusal variables investigated in this study, these other parameters may be further occlusal traits but they may also be nonocclusal factors. This is indicated by the considerably higher prevalence of TMD signs among women than among men,[11] apparently widely independent of occlusal factors. Therefore general medical issues should also be addressed.

Study limitations

The cross-sectional observational study design of SHIP-0 makes it possible to assess representative associations and prevalences but cannot prove etiologic relationships. That will require prospective studies with a longitudinal design in general population samples. SHIP-1, a first follow-up to the SHIP baseline, was started in October 2002. All participants of SHIP-0 are invited again five years after their baseline examination.

Whether the increasing number of missing teeth with increasing age (especially in subjects aged >50) causes any differential effects in associations cannot be fully answered with this analysis and should be examined further.

CONCLUSIONS

Within the limits of this representative study and for the malocclusions and factors of functional occlusion examined here, the following conclusions are drawn.

- In view of the statistically significant associations found between the examined occlusal factors, there was a relationship between occlusion and TMD signs. However, these associations were few and mostly not very strong.
- The relatively large number of occlusal factors investigated here only explained a small part of the differences between cases and controls, which means another part must be due to other, assumedly nonocclusal, variables.
- Female sex proves to be a relevant risk factor in all analyses. Interactions of other potential risk factors with sex were not significant. From the viewpoint of occlusion, the question why women show higher prevalences of TMD signs is still open for discussion. Possibly, differences in health perception or consciousness also might have an influence.

Sample size calculations show that, due to very low prevalences of relevant occlusal factors in population-based studies, large numbers of subjects are needed for replication of our results.

Together with the population-based studies of the systematic review,[1] the study limitations, and the set of variables studied there, the following picture emerges.

- Few associations were found or reported between malocclusion as well as parameters of functional occlusion and signs of TMD. These associations were not consistent

across studies. No particular morphological or functional occlusal factors stood out. General weak associations might be a reason, but methodological differences and deficiencies existed.
- Multifactorial TMD should be analyzed with multivariate adjustment for the confounders of sex, age, and socioeconomic status. The focus should be on the strength of the association and related confidence limits rather than the significance value.

The apparently minor role of occlusion in association with TMD signs in population-based studies should be taken into account by the clinicians. They should exercise caution when diagnosing and treating TMD signs where these are or are not attributed to the existing occlusion (malocclusions, functional occlusion). They should exercise caution when it is a matter of altering the existing occlusion to prevent or to treat temporomandibular dysfunction.

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