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ORIGINAL ARTICLE

Degenerative changes in human temporomandibular joints in relation to occlusal support

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Abstract

Objective. Controversy exists concerning the etiological factors behind degenerative changes in the temporomandibular joints (TMJs). Tooth attrition, occlusal support, food consistency, ageing, gender and genetics are some possible causative factors that have been discussed in the literature. The aim of this study was to examine contemporary human skull material for possible relations between degenerative form and surface changes in the TMJs in relation to occlusal support. ***Material and methods.*** The material consisted of 259 human skulls from 170 males and 89 females, with an age range of 18–100 years. ***Results.*** Dental status was in general poor, and 22% of skulls were edentulous. Form and surface changes of both the condyles and the temporal components were more common in the present material compared to that in most previous studies. In males, irrespective of age, only weak and clinically insignificant correlations could be found between degenerative TMJ changes and occlusal support. In women, however, the correlations between these variables were in general much stronger, especially at higher ages. ***Conclusions.*** The present findings do not lend support to the hypothesis that loss of occlusal support is a causative factor for degenerative changes in the TMJs in male subjects. In women, such a correlation was obvious in the present sample, at least at higher ages. It can be speculated that hormonal factors play a role in the sex difference found.

Key Words: *Human skulls, occlusion, osteoarthrosis, temporomandibular joint*

Introduction

Remodeling and degenerative changes of the structures of the human temporomandibular joints (TMJs) are common findings. The remodeling process represents an attempt by the joint to adapt to altered functional demands. When the physiological limits of remodeling are exceeded, pathological degenerative changes will develop primarily in the articular cartilage [1]. Several terms have been used to describe degenerative joint disease, such as osteoarthrosis and osteoarthritis [2,3], but in the following we will use the term *degenerative changes.* Development of degenerative changes is mostly a slow process, but the end result can be severe damage to both soft and hard joint structures.

Today, it is acknowledged that the TMJs are load-bearing in normal function [1,4,5]. As a logical consequence of this, it can be assumed that the TMJs, as with other load-bearing joints, will undergo changes in response to increased functionally induced stresses since "once functional stresses exceed physical limits, the remodelling processes are no longer adequate and degenerative joint disease sets in" [4]. Thus it can be assumed that excessive loading of the joint structures might be the consequence of reduced occlusal support, bruxism, tough food consistency and combinations of these factors.

There is also overwhelming support in the literature for the opinion that ageing is closely related to the development of degenerative changes in the TMJs [6–14]. Such a relation was also found in the present material [15]. It has been suggested that the strong association between degenerative joint changes and age could reflect an intrinsic accumulation of tissue damage due to a gradual decline in cellular capacities for adaptation [14]. The regenerative capacity decreases with age, and when degenerative

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changes progress beyond the regenerative capacity this will result in deformation of the condyle [13].

During the last two decades, research has shown that genetic factors have a great impact on degenerative joint changes in general [16–22] and thus most likely also have a great impact on the development of such changes in the TMJs [1]. Genetic differences can probably also explain the differences found in different cultures in respect of the anatomical form of the TMJs [9] as well as in the prevalence of degenerative TMJ changes [23].

The results presented in the literature on sex differences in respect of degenerative changes in the TMJs are contradictory. Some studies have not found any sex differences [10,12,13,24], while others have found more degenerative changes in women [6,25], and at least one previous study found more such changes in men [7]. In the present material, men had on average more degenerative changes in the TMJs compared to women [15].

In agreement with many studies [9,26–30], but in disagreement with others [7,8,10,31–33], no correlation could be found in the present skull material between the extent of tooth attrition and degenerative changes in the TMJs [15].

Also, the relationship between occlusal support and degenerative TMJ changes found in the literature is contradictory. Many studies have found such a correlation [6,9,14,23,24,27,28,32,34], while a few other studies have not been able to find any such relationship [10,12,13].

The aim of the present study was to analyze a possible relationship between the degree of degenerative changes in the TMJs and impaired occlusal support, and the hypothesis was that there exists a significant correlation between these two factors.

Material and methods

A total of 259 well-preserved skulls from adults aged 18–100 years were included in the analyses. The skulls came from bodies that had been donated to the Federal University of São Paulo, São Paulo, Brazil during the time period 1933–73. The soft tissue had been removed from the skulls using an extremely gentle maceration technique that did not expose the bone tissue to any extrinsic trauma.

Of the analyzed skulls, 170 came from men (66%) and 89 from women (34%). The males were statistically significantly older than the females: mean 44 years (range 20–82 years) and mean 40 years (range 18–100 years), respectively ($P < 0.01$). The material has been described in detail previously [15]. The sex and age distributions are presented in Table I.

Table I. Distribution (%) of the 170 men and 89 women according to age group.

Age group (years)	Men	Women	Total
18–30	18	38	25
31–40	31	25	29
41–50	22	19	21
51–100	29	18	25

All skulls were analyzed by two examiners (C. M., T. M.). If one examiner was uncertain how to register an individual variable, the other examiner was consulted, and a consensus was reached for the registration.

Registrations of form and surface changes of the condyles and the temporal components were made according to scales described by Wedel et al. [31], but when surface changes were estimated, a fifth step was added to the scale: compact layer broken up into areas >6 mm^2. Changes in form were registered as follows: 0 = without any of the changes described under 1, 2 or 3; 1 = slight remodeling/flattening; 2 = marked remodeling; 3 = deforming changes. Changes in surface were registered as follows: 0 = without any of the changes described under 1, 2, 3 or 4; 1 = uneven surface, unbroken compact layer; 2 = marked irregular surface and/or local perforation occupying <3 mm^2 of the compact bone layer; 3 = compact layer broken up into areas 3–6 mm^2 or largely distributed small perforations; 4 = compact layer broken up into areas >6 mm^2.

The total sum for form and surface changes of the left and right condyles and temporal component were calculated and could range from 0 to 28. From this total score, a degenerative change (DC) index was created, where a score of 0–8 was classified as no or moderate TMJ changes, 9–16 as marked changes and 17–28 as severe changes.

The number of teeth present was registered as well as the estimated number of remaining teeth at death; ante-mortem tooth loss was recorded when resorption of the socket, or bony growth within the socket, could be observed.

The estimated occlusal support was classified according to the Eichner index [35]: A1 = antagonist contact in all four supporting zones. No tooth-limited gap exists; A2 = antagonist contact in all four supporting zones. Tooth-limited gap exists only in one of the jaws; A3 = antagonist contact in all four supporting zones. Tooth-limited gaps exist in both jaws; B1 = antagonist contact present in three supporting zones; B2 = antagonist contact present in two supporting zones; B3 = antagonist contact present in one supporting zone; B4 = antagonist contact present in none of the supporting zones, tooth contact only in the frontal region; C1 = teeth in both upper and lower jaws, but no antagonist contact in either any of the supportive zones or in the front;

C2 = teeth only in one jaw; C3: no teeth in upper or lower jaws. However, when performing the statistical analyses, groups A1–A3 and groups C1–C3 were pooled.

Statistical methods

To test for statistical differences between variables and gender, the chi-square test and *t*-test were used. To test for correlations between variables, Spearman's rank correlation (r_s) was used since many of the variables are ordered categorical and have a skewed distribution (non-normal). The following *P*-levels have been used: $P \geq 0.05$ = NS, $^{*}0.01 \leq P < 0.05$, $^{**}0.001 \leq P < 0.01$, $^{***}P < 0.001$.

Results

Form and surface changes of the condyles and temporal components are presented in Tables II and III. On both sides, the form as well as the surface changes were statistically significantly more pronounced in the condyles compared to the temporal components ($P < 0.001$ for all measurements).

As previously presented [15], in both males and females there was a statistically significant high correlation between form and surface changes for the condyles and temporal components within a joint as well as between the right and left sides. Because of this correlation in respect of the degree of degenerative changes between the sides, the statistical analyses were made without separating left and right TMJs.

Table II. Distribution (%) of the material concerning change in form of the right and left condyles and of the right and left temporal components of the 170 men and 89 women.

	Right			Left		
Changes in shape of:	Men	Women	Total	Men	Women	Total
Condyle						
No changes	9	15	11	7	9	7
Slight remodeling/flattening	32	24	29	31	24	28
Marked remodeling	40	42	41	40	42	41
Deforming changes	18	20	19	23	26	24
Temporal component						
No changes	19	20	19	19	23	21
Slight remodeling/flattening	47	56	50	47	49	48
Marked remodeling	31	23	28	32	26	29
Deforming changes	3	1	2	3	2	3

Table III. Distribution (%) of the material concerning surface changes of the right and left condyles and of the right and left temporal components of the 170 men and 89 women.

	Right			Left		
Change in surface of:	Men	Women	Total	Men	Women	Total
Condyle						
No changes	17	20	18	14	16	15
Uneven surface	24	17	21	19	17	19
Local perforations	22	27	24	21	16	19
Perforations 3–6 mm^2	15	12	14	17	15	16
Perforations >6 mm^2	22	24	23	29	37	32
Temporal component						
No changes	25	35	28	24	35	28
Uneven surface	23	19	22	20	20	20
Local perforations	31	28	30	32	21	28
Perforations 3–6 mm^2	8	9	9	10	9	10
Perforations >6 mm^2	13	9	12	14	15	14

Table IV. Distribution (%) of the material according to the estimated and modified Eichner index.

Eichner index	Men (n = 170)	Women (n = 89)	Total (n = 259)
A	11.8	14.6	12.7
B1	11.2	10.1	10.8
B2	11.8	11.2	11.6
B3	10.6	3.4	8.1
B4	18.2	11.2	15.8
C	36.5	49.4	40.9

Nineteen percent of the men and 29% of the women had a DC index of 1 (no or moderate TMJ changes), 49% and 32%, respectively had an index of 2 (marked TMJ changes) and 32% and 39%, respectively had an index of 3 (severe TMJ changes). According to this index, men had statistically significantly more degenerative changes in the TMJs compared to women ($P < 0.05$).

In the skulls with remaining teeth, the median number of teeth in the upper jaw was six. The corresponding figure for the lower jaw was seven. The estimated mean number of teeth ante-mortem was nine in the upper jaw and 10 in the lower.

The distribution of the skulls according to the estimated Eichner index is presented in Table IV. There was no statistically significant difference between men and women.

For the whole sample, the correlations between occlusal support according to the Eichner index and the variables form and surface changes as well as the DC index were in general weak (r_s = 0.49, 0.38 and 0.41, respectively).

The correlations between occlusal support and degenerative joint changes within the four different age groups in men and women, respectively, are presented in Tables V and VI. In men, although there were some statistically significant correlations, the correlation coefficients found were low. In women, however, much stronger correlations were found, especially at higher ages.

Table V. Correlation coefficient (r_s) between occlusal support and degenerative joint changes in 170 male subjects.

Age group (years)	n	Form changes (r_s)	P	Surface changes (r_s)	P	DC index (r_s)	P
18–30	31	0.20	NS	–0.14	NS	–0.04	NS
31–40	52	0.45	***	0.35	*	0.34	*
41–50	37	0.12	NS	0.33	*	0.18	NS
51–100	50	0.27	NS	0.25	NS	0.21	NS
Total sample	170	0.41	***	0.34	***	0.33	***

$P \geq 0.05$ = NS; *$0.01 \leq P < 0.05$; **$0.001 \leq P < 0.01$; ***$P < 0.001$.
n = number of subjects.

Table VI. Correlation coefficient (r_s) between occlusal support and degenerative joint changes in 89 female subjects.

Age group (years)	n	Form changes (r_s)	P	Surface changes (r_s)	P	DC index (r_s)	P
18–30	34	0.44	**	0.11	NS	0.23	NS
31–40	22	0.55	**	0.50	*	0.46	*
41–50	17	0.52	*	0.62	**	0.69	**
51–100	16	0.62	*	0.69	**	0.68	**
Total sample	89	0.61	***	0.45	**	0.52	***

$P \geq 0.05$ = NS; *$0.01 \leq P < 0.05$; **$0.001 \leq P < 0.01$; ***$P < 0.001$.
n = number of subjects.

Discussion

As we have stated previously [15], when the results of the present study are interpreted, it should be kept in mind that this skull material is not representative of the average Brazilian population in the 20th century. Most of the study subjects came from a poor background. As a result, their dental status is likely to be much worse than that of the general population. In the present sample, only 13% had occlusal support in all four supporting zones, and as many as 41% had no occlusal support.

An unknown factor that might have influenced the result is that we have no knowledge of how many subjects had removable partial or complete dentures, but most probably only a few subjects had had such reconstructions.

Yet another weakness is that many teeth had been lost post-mortem: on average five teeth per skull with remaining teeth. In most cases, it was not a problem to decide whether teeth had been lost ante- or post-mortem, but it is not possible to know whether the lost teeth had antagonist contact or not, and this may have had an influence on the estimation of the Eichner index.

The question of when does a correlation coefficient reach the level for clinical relevance, irrespective of its statistical significance, is always a matter for discussion. Colton [36], for instance, states that correlations between 0.25 and 0.50 indicate a fair degree of relationship and those from 0.50 to 0.75 a moderate-to-good relationship. He stresses, however, that these levels are a very crude rule of thumb. Results must be judged not solely in respect of their statistical significance and a researcher has the responsibility to interpret them honestly [37].

As seen from Figure 1a, Spearman's rank correlation is 0.34 and the correlation is statistically significant from zero. The null hypothesis is that the correlation is zero, and the alternative hypothesis is that the correlation is different from zero. The fact that the null hypothesis is rejected does not provide

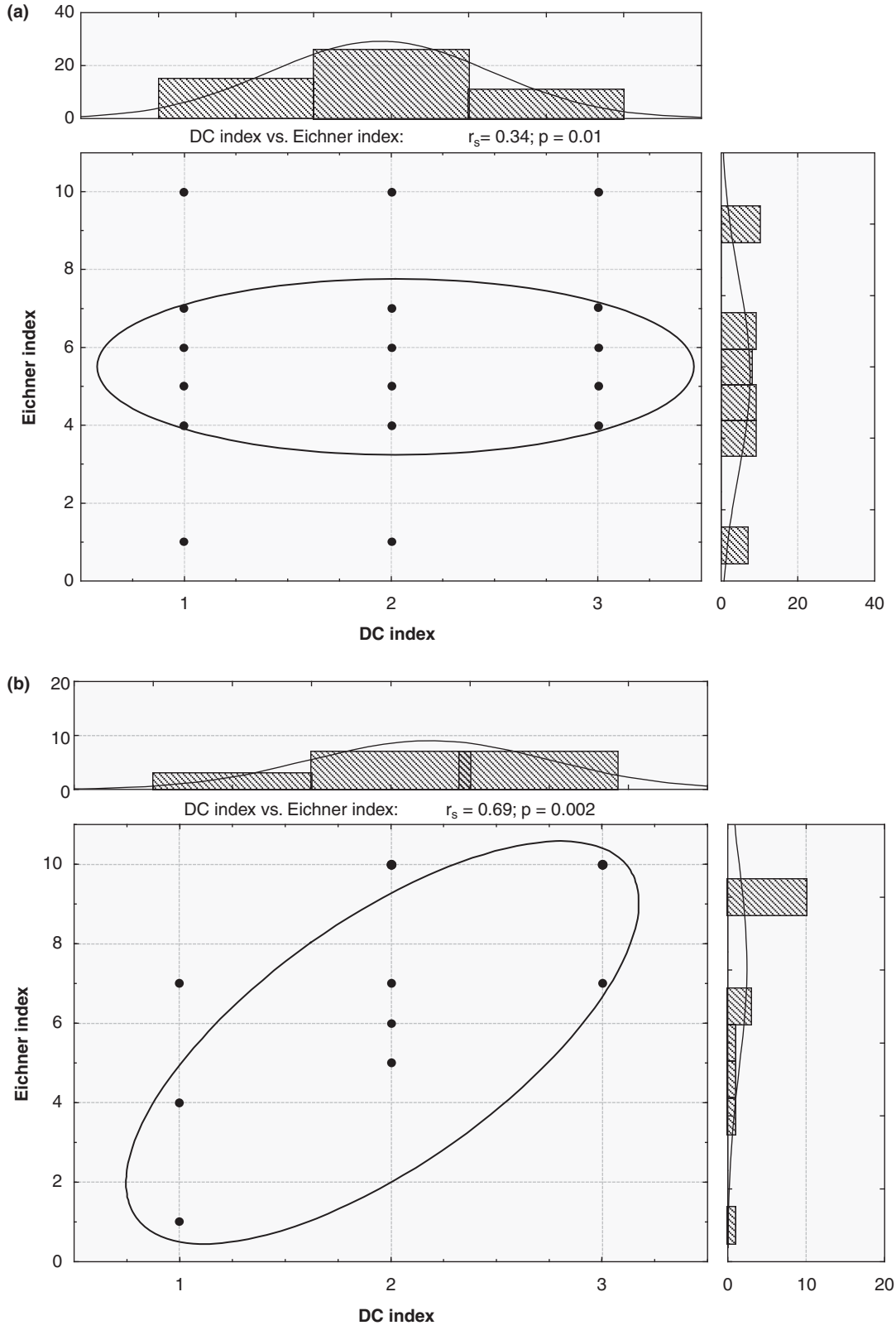

Figure 1. Plots of DC index versus Eichner index for (a) males aged 31–40 years and (b) females aged 41–50 years.

evidence that there is some agreement between the two variables. The size of the correlation matters, and in this case the correlation, although Colton considers it to be "a fair degree of relationship", gives no evidence of a fair degree of agreement between the DC index and the Eichner index. As seen from the histogram at the top of Figure 1a, data for the DC index are symmetrically distributed, and

the data for the Eichner index (right-hand histogram) are uniformly distributed. The vast majority of data points are inside the ellipse (38/52 cases), and the correlation of 0.34 is due to the fact that there are a few observations in the lower left-hand corner (six cases) and in the upper right-hand corner (four cases). The fact that the data are centered inside the ellipse gives support for our argument that there is no relationship between the DC index and Eichner index among males aged 31–40 years.

As for females aged 41–50 years, a plot of the same type as that in Figure 1a gives another picture of the data (Figure 1b). In this age group, Spearman's rank correlation is 0.69, and the correlation in this case is also significantly different from zero. In this case, more observations lie inside the ellipse (which is tilted at ≈45°). These data support the fact that there is an agreement between the DC index and Eichner index for females in the age group 41–50 years. There is a more pronounced depiction in this example that high values on the DC index have corresponding high values on the Eichner index and vice versa.

So, in conclusion, when analyzing correlations one must consider their size and also the plot data. It is not satisfactory just to look at the statistical significance. If one does so, there is a great risk of misinterpreting the results.

We analyzed each single scatter plot for linearity and came to the conclusion that the correlation coefficient between the Eichner index and DC index must be at least 0.50 to be of any clinical relevance.

There are many possible explanations of the conflicting findings found in previous studies on the correlation between severity of degenerative joint changes and impaired occlusal support, where many have reported such a correlation [6,9,14,23,24,27,28,32,34] and others did not [10,12,13]. One possible explanation for these divergent results is that a number of previous studies have been conducted on archeological materials [9,23,27,28,32] and, as has been stressed by Wedel et al. [29], there is a great risk that, post-mortem, hard tissue artifacts are misinterpreted as degenerative changes. The present material is not flawed in this respect since the skulls have never been exposed to soil.

Another possible explanation is that some of the previous studies have examined soft tissue changes using arthroscopy [34] or in autopsy specimens [6,14,24]. Such soft tissue changes can be subjected to healing and do not necessarily result in degenerative hard tissue changes. Several of the studies did not correct for age and many used coarse measures for both occlusal state and degenerative joint changes, such as comparing edentulous subjects and subjects "with remaining teeth" [24] and comparing 17 subjects with "clearly visible (hard tissue) changes" and 105 subjects "without visible changes" [28].

To our knowledge, no previous study has considered the possibility that a correlation between occlusal support and degenerative TMJ changes might be different in men and women. In the present study, we found no correlation of clinical relevance between these variables in men, while a fairly strong correlation was found in women, especially at higher ages. It can be speculated that hormonal factors play a role in the sex difference found. This hypothesis needs to be addressed in future research.

Today, it is widely accepted that both increasing age and genetic factors are important to the development of degenerative joint changes. The present results indicate that impaired occlusal support is of importance in women but not men. The hypothesis presented is thus partly accepted and partly rejected.

Conclusions

Severe form and surface changes in both the condyles and in the temporal component were common findings in the present sample. Dental status was on average poor and many of the dentate subjects had pronounced tooth wear. It seems that the importance of impaired occlusal support to the development of degenerative joint changes is sex-related.

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