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Original article

Masticatory function in patients with dentofacial deformities before and after orthognathic treatment—a prospective, longitudinal, and controlled study

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Summary

Objectives: The aim of this study was to investigate the self-estimated masticatory ability and masticatory performance in patients with dentofacial deformities before and after orthognathic treatment; in comparison to an age- and gender-matched control group.

Subjects and methods: The masticatory ability and masticatory performance were evaluated in 121 consecutive patients (treatment group), referred for orthognathic treatment. Eighteen months after treatment, 98 patients (81%) completed a follow-up examination. Masticatory ability was assessed on a visual analog scale, while the masticatory performance was evaluated by a masticatory test using round silicon tablets. Signs and symptoms of temporomandibular disorders (TMD) were registered by a clinical examination and a questionnaire. The control group comprised 56 age- and gender-matched subjects who were examined at baseline.

Results: At the baseline examination, the treatment group had a significantly lower masticatory ability and performance compared with the control group. After treatment, the masticatory ability significantly improved in the treatment group and reached the same level as in the control group. The masticatory performance index increased significantly but was still lower than in the control group. Both the masticatory ability and masticatory performance were affected by the number of occlusal contacts during maximal biting pressure and by the self-estimated overall symptoms of TMD.

Conclusions: Patients with dentofacial deformities, corrected by orthognathic treatment, have a significant positive treatment outcome in respect of masticatory ability and masticatory performance. Furthermore, the occlusion and symptoms of TMD have an impact on both masticatory ability and masticatory performance.

Introduction

Mastication is the first step, and one of the main functions in the digestion process, in which food is broken down into smaller particles to facilitate the enzymatic activity. Continuously the mastication is adapting to food, occlusion, and oral health. Mastication can be assessed by subjective and objective measurements. Self-estimated masticatory ability has been defined as an individual's own assessment of mastication. Masticatory ability has been shown to be lower in individuals having signs and symptoms of temporomandibular disorders (TMD) (1, 2). Masticatory performance, defined as a person's capacity to break down a standardized test food, has been shown to be related to maximum bite force, body size, salivary flow rates, and to the number of interocclusal contacts during maximum intercuspidation (1, 3–7). A reduced masticatory performance has been reported for patients with malocclusions (1, 8) and especially skeletal open bite has been correlated to impaired bite force (9). Individuals with an impaired masticatory performance often compensate it by a higher number of chewing cycles resulting in longer duration of masseter muscle activity before swallowing and by swallowing coarser particles than individuals with good masticatory performance (7).

Brennan *et al.* (10) concluded that the masticatory ability was correlated to the number of teeth in contact and positively associated with oral-health-related quality of life assessed by the Oral Health Impact Profile 14-item version. Still there is a discussion to what extent nutrition and general health might be affected by an impaired masticatory ability and performance (10, 11).

Impaired masticatory ability is, apart from TMD and aesthetics, one of the main reasons for orthognathic surgery in patients with dentofacial deformities (12–14). Previous controlled studies in patients with dentofacial deformities (5, 15, 16) indicate impaired masticatory ability and performance both before and after treatment compared with controls. The studies mentioned previously disclose somewhat different results considering if treatment will be beneficial for the patients regarding masticatory ability and performance. There are few studies on this topic, and in general with small sample sizes, and also, using different methodologies. Therefore, a great need exist to evaluate longitudinally and in a controlled manner the masticatory ability and masticatory performance in patients who have undergone treatment of dentofacial deformities.

The aim of this study was to investigate the self-estimated masticatory ability and masticatory performance in patients with dentofacial deformities before and after orthognathic treatment, in comparison with an age- and gender-matched control group. A further aim was to investigate factors with possible impact on masticatory ability and masticatory performance.

The hypothesis was firstly, that patients with dentofacial deformities have, compared to controls, impaired masticatory ability and masticatory performance. Secondly, the masticatory ability and masticatory performance will be improved by orthognathic treatment.

Subjects and methods

The treatment group comprised 121 consecutive patients (51 males and 70 females) with dentofacial deformities, referred to the Department of Oral Maxillofacial Surgery, Malmö University Hospital, Sweden for orthodontic treatment in conjunction with orthognathic surgery (forward described as orthognathic treatment). Twenty-three patients withdrew from the study after the baseline examination (Figure 1). Thus, 98 patients (81%) met the inclusion criteria, and the final sample comprised 38 males and 60 females, mean age 22.4 ± 7.5 years (17).

The control group was age- and gender-matched with the subjects undergoing treatment. It comprised 56 subjects, 23 males and 33 females, mean age 23.4 ± 7.4 years, with normal occlusion, or minor malocclusions for which neither orthodontic treatment nor orthognathic surgery was indicated. The controls were recruited from general dental patients at the Faculty of Odontology, Malmö University, Sweden, and at the Public Dental Health Clinic in Oxie, Sweden. The same exclusion criteria applied to the control group as to the treatment group (17).

The methods for the orthodontic treatment, orthognathic surgery, and postsurgical fixation have been described in detail in Abrahamsson *et al.* (17).

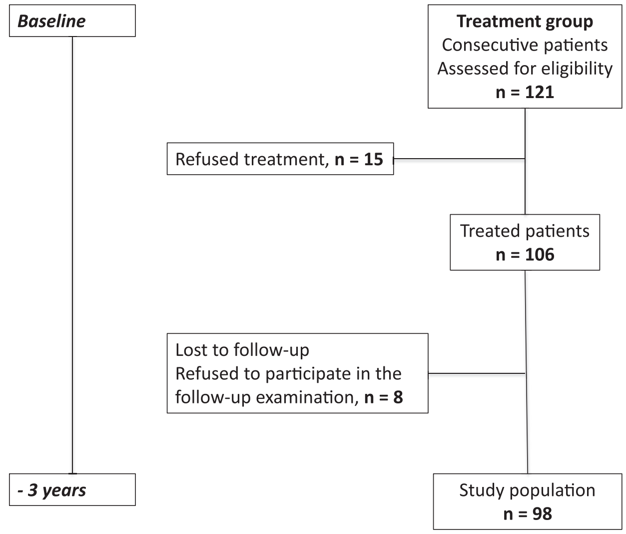

Figure 1. Flow chart: patients included in the study.

In the treatment group, the masticatory ability, masticatory performance, and signs and symptoms of TMD were assessed by means of a clinical examination, a questionnaire, and a test of masticatory performance before and 18 months post-treatment. The interval between the two examinations was approximately 3 years. The questionnaire, the test of masticatory performance, and the clinical examination were performed after treatment planning. The control group was examined at one occasion and in equal manner as the treatment group.

Clinical examination

The clinical examinations were conducted at the Department of Stomathognathic Physiology at the Faculty of Odontology, Malmö University, by two calibrated specialists in stomathognathic physiology (17). The extra oral examination preceded the intraoral examination. The methods for the clinical examination and the registration of signs and symptoms of TMD have been described in detail previously (17). TMD pain was diagnosed according to research diagnostic criteria for TMD (RDC/TMD) (18).

The number of tooth contacts was recorded in habitual intercuspal position during maximal isometric biting force. The indication of contacts was registered in the maxilla by means of a thin double-folded plastic-foil (GHM occlusion foil® 8 µm; Hanel–Ghm Dental, Langenau, Germany). The markings by the foil were registered as follows: single dot, one contact; line, two contacts; and region of several small markings, three contacts. The evaluation of the method error for measuring the number of occlusal contacts has been described earlier and was found to be low (1).

The skeletal and morphological occlusion was registered by methods described previously (17). The diagnoses in the treatment group were separated into sagittal and vertical discrepancies, according to a combination of morphological and cephalometric values (Table 1).

Questionnaire

The following variables were addressed in the baseline and follow-up questionnaires: ability to masticate different kind of food; meat (yes/no), carrots (yes/no), toffee (yes/no), French loaf (yes/no) or

Table 1. Distribution of sagittal and vertical discrepancies in the treatment group ($n = 98$).

Skeletal discrepancies	*n*
Sagittal discrepancies	
Class I	13
Class II	28
Class III	57
Total	98
Vertical discrepancies	
Open bite	40
Deep bite	9
Normal vertical relation	49
Total	98

coldcuts of ham, cheese, and cucumber (yes/no). The subjects estimated their ability to masticate food on a visual analog scale (VAS) 0–100 mm with the end points 'good' = 0 mm and 'bad' =100 mm. The individuals also estimated the severity of overall symptoms of TMD on the following scale: 0, little or none; 1, slight; 2, moderate; 3, severe; and 4, very severe.

Masticatory performance test

For assessment of masticatory performance (19), the individuals were instructed to chew round tablets of silicon impression material (Optosil®; Bayer, Leverkusen, Germany) with a standardized weight. The test implies chewing for 20 strokes of 5 separate tablets. The chewed sample was expectorated in a plastic cup. The mouth was rinsed with water until all particles were removed from the mouth. The water was also collected in the cup and then filtered. The chewed material from each of the tablets was fractionated in a system of sieves with coarse, medium, and fine meshes. Essentially, the more efficient the mastication was, the greater the quantity of material that passed through the finest sieve. The quantity of material was estimated by weight.

A masticatory performance value, by proportion of weight, was calculated for each test portion, and the mean of the best four values out of five was used as the masticatory performance index (MPI) (19). The index ranges from 0 to 100—the highest number corresponds to the highest performance value. Data of the MPI test were lost from one patient at baseline and another six patients at follow-up in the treatment group.

Statistical methods

Significance (α) was set at 0.05. The test was two-tailed, i.e. an effect in either direction was analysed.

Differences between groups

Pearson's chi-square test with Yate's correction for continuity was used when 2 × 2 cross tabulations were applicable. When the expected cell value in a 2 × 2 table was less than 5, Fisher's exact test was used. The two-sample *t*-statistic was used to compare means in numerical variables. To calculate ordinal data, Mann–Whitney test was used. The tested MPI was considered a numerical variable, while the masticatory ability on a VAS was considered ordinal data. When comparing means between subgroups of sagittal and vertical discrepancies, analysis of variances was used.

Differences within groups before and after treatment

McNemar exact test was used to compare ordinal data and the paired *t*-test for the numerical data.

For multivariate analysis, a linear regression analysis, with the enter method to adjust for age and group belonging, was used.

Results

Analysis of those who withdrew from the treatment group ($n = 23$, 19%), shown in Figure 1, did not differ from the final study group with respect to age, gender, self-estimated masticatory ability, or masticatory performance. Thus, the patients who completed the study were considered to be representative of the initial study sample.

Self-estimated masticatory ability

A large individual variation of the masticatory ability was found within the groups (Figure 2). At baseline, the patients (mean = 52.2 ± 29.5, median = 50.0) rated their masticatory ability lower than the control group (mean = 85.7 ± 17.4, median = 92.0, $P < 0.001$, Mann–Whitney test; Figure 2). They also found it more difficult to chew meat ($P < 0.001$), raw carrots ($P = 0.019$), toffee ($P = 0.002$), French loaf ($P < 0.001$) or coldcuts of ham, cheese, and cucumber ($P < 0.001$). At follow-up, the masticatory ability had significantly improved in the treatment group (mean = 83.9 ± 19.2, median = 92.0, $P < 0.001$) and reached similar level as in the control group implying no significant difference between the groups.

Factors influencing the self-estimated masticatory ability

Occlusal contacts during maximal biting pressure, severity of overall symptoms of TMD, and study group belonging explained 45 per cent of the total variation of the masticatory ability in a linear regression analysis adjusted for age (Table 2). The masticatory ability was in the regression analysis negatively affected by fewer occlusal contacts during maximal biting pressure, a higher severity of the overall symptoms of TMD and belonging to the treatment group (Table 2).

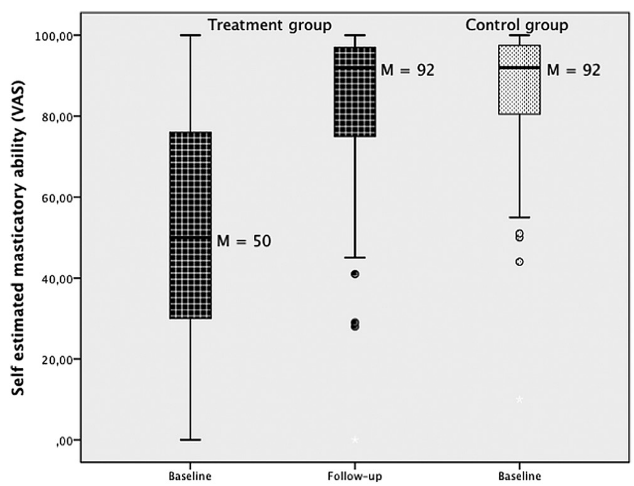

Figure 2. Before treatment, the treatment group estimated their masticatory ability, on a visual analog scale (VAS), to be poorer than what the control group did ($P < 0.001$). After treatment, there was no significant difference in the reported masticatory ability between the two groups. Fifty per cent of the individuals have values within the box. The bar across the box represents the median. The whiskers show the largest and smallest value that is not an outlier. o = outliers, values more than 1.5 box lengths from the box; star = extreme, values more than 3 box lengths from the box.

Masticatory performance

There was a large individual variation of the MPI, within the groups (Figure 3). At baseline, the treatment group had a lower MPI than the control group [mean = 10.4 ± 10.4, median = 7.1 versus mean = 37.3 ± 16.8, median = 37.1, respectively, $P < 0.001$, 95% confidence interval (95% CI) 21.3–30.9]. For the treatment group, the MPI increased at follow-up (mean = 21.0 ± 19.2, median = 12.9, $P < 0.001$) but was still lower than the control group ($P < 0.001$, 95% CI 10.2–22.4).

After stratifying the material into sagittal and vertical deformities, it was found that the MPI improved after treatment in patients with a Class III malocclusion, from 11.7 ± 10.5 to 25.3 ± 19.6 ($P < 0.001$, 95% CI 8.2–19.0), and in patients with an open bite, from 7.0 ± 6.8 to 18.1 ± 18.7 ($P < 0.001$, 95% CI 5.5–16.8). No significant alteration was found in patients with deep bite or Class II malocclusion.

Factors influencing MPI

Variables like gender, number of occlusal contacts during maximal biting pressure, self-reported severity of overall symptoms of TMD,

Table 2. Multiple linear regression analysis (enter method) of the relation between self-estimated masticatory ability and explanatory variables, adjusted for age.

Explanatory variables	B	SE B	*P*	Lower MPI
Study group	21.3	4.5	<0.001	Treatment group
Gender	7.4	3.9	NS	
Number of occulsal contacts during maximal biting pressure	1.1	0.3	<0.001	With lower number of occlusal contacts
Severity of overall symptoms of TMD (verbally)	−8.0	1.9	<0.001	With more severe symptoms

B, regression coefficient; NS, not significant; SE B, standard error of B; TMD, temporomandibular disorders. Total factor of explanation (R^2) = 45%. Distribution of residuals tested with Shapiro-Wilk normality test with plots was found to be acceptable.

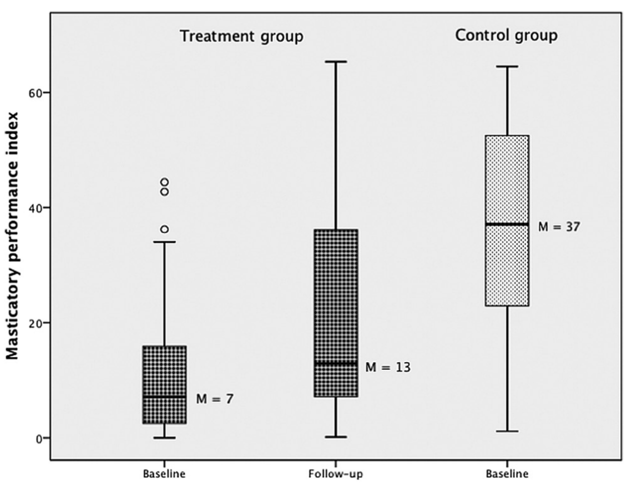

Figure 3. Individuals in the treatment group had a lower masticatory performance index compared with the control group ($P < 0.001$). Fifty per cent of the individuals have values within the box. The bar across the box represents the median. The whiskers show the largest and smallest value that is not an outlier. o = outliers, values more than 1.5 box lengths from the box.

and TMD pain diagnoses were all found to significantly have an influence on the MPI at baseline (Table 3). No association was found between age and MPI.

A linear regression analysis, adjusted for age and group belonging, explained 37 per cent of the total variation of MPI (Table 4). Number of occlusal contacts during maximal biting pressure was the factor that had the highest influence on MPI and indicated that MPI increased with a higher number of contacts during maximum biting pressure. Open bite was the only kind of dentofacial deformity having a significant influence on MPI, i.e. open bite had negative effect on MPI.

Occlusal contacts

Before treatment, there were no significant differences in number of teeth between the treatment (mean = 28 ± 1.9) and the control group (mean = 29 ± 2.0). The treatment group had significantly fewer intercuspal contacts during maximum biting pressure than the control group (mean = 13 ± 6.4 versus 18 ± 5.5, $P < 0.001$, 95% CI 3.5 – 7.5). At follow-up, the number of occlusal contacts increased in the treatment group (mean= 16 ± 6.1, $P < 0.001$, 95% CI 2.1–5.2) and did not significantly differ from the control group. When subgroups of sagittal and vertical discrepancies were assessed before treatment, the 40 patients with open bite had significantly fewer intercuspal contacts during maximum biting pressure compared with the nine patients with deep bite (mean = 10 ± 5.0 versus 19 ± 9.5, $P < 0.001$) and those 49 patients with normal vertical relation (mean = 14 ± 5.8, $P = 0.014$). No significant differences between sagittal discrepancies were found before treatment. After treatment, there were no differences between neither of the subgroups.

Discussion

The main findings in this study were that patients with dentofacial deformities had impaired masticatory ability and performance in comparison with the control group before treatment. Furthermore, the masticatory ability and masticatory performance improved after orthognathic treatment why the hypotheses cannot be rejected. The number of occlusal contacts during maximal biting pressure and the severity of overall symptoms of TMD were found to have an influence on both masticatory ability and masticatory performance.

In this study, both the masticatory ability and masticatory performance improved significantly after treatment. The masticatory ability was at the follow-up estimated equal in the patient and control group. However, the MPI did not reach the same level as in the control group, which may be explained by the limited follow-up period. It has been discussed that a follow-up period of 5 years after treatment, to be compared with 18 months in this study, would be more appropriate and beneficial for the masticatory performance. An explanation can be that the musculature may need time to readapt after surgery before regaining full strength (20, 21). Van den Braber *et al.* (20) showed an improvement in masticatory performance in retrognathic individuals 5 years after treatment, which was not found in previous studies with shorter follow-up performed by the same research group (16, 22). Neither did Zarrinkelk *et al.* (15) find any difference in masticatory performance 2–3 years after orthognathic treatment of individuals with dentofacial deformities. Anyhow, an interesting finding in this study was that the individuals with a Class II bite did not show an improvement, which was in line with van den Braber *et al.* (20).

Unfortunately, after subgrouping the patient group into different kinds of dentofacial deformities, the sample sizes were small,

Table 3. Statistically significant differences of the mean MPI by levels of occlusal factors and TMD in the whole study group (both treatment and control group), $n = 153$.

Influencing binary parameters	*n*	MPI	SD	*P*	95% Confidence interval of the difference
Female	93	17.0	16.9	0.008	2.2–14.4
Male	60	25.3	19.6		
Number of occlusal contacts during maximal biting pressure					
<10	37	7	9.5	<0.001	12.6–21.9
≥10	116	24	18.7		
One diagnosis of TMD pain					
No	115	23.8	18.8	<0.001	9.6–18.7
Yes	38	9.6	12.2		
Severity of overall symptoms of TMD					
Insignificant-light	106	24.5	19.3	<0.001	8.9–18.9
Moderate-very severe	47	10.6	11.8		

MPI, masticatory performance index; SD, standard deviation; TMD, temporomandibular disorders.

Table 4. Multiple linear regression analysis (enter method) of the relation between tested MPI and explanatory variables, adjusted for age and group belonging (treatment group or control group).

Explanatory variables	B	SE B	*P*	Lower MPI
Gender	–6.5	1.9	0.001	Women
Number of occulsal contacts during maximal biting pressure	0.6	0.1	<0.001	With lower number of occlusal contacts
Open bite	–4.3	2.0	0.031	With open bite
Severity of overall symptoms of TMD (verbally)	–2.5	1.1	0.028	With more severe symptoms
Pain in the masticatory muscles/TMJs	4.7	2.6	NS	

B, regression coefficient; MPI, masticatory performance index; NS, not significant; SE B, standard error of B. Total factor of explanation (R^2) = 37%. Distribution of residuals tested with Shapiro-Wilk normality test with plots was found to be acceptable.

especially for a deep bite and Class II malocclusion. This fact may have contributed to the lack of significance in alterations of masticatory ability and performance in these groups.

The difference in masticatory performance between the treatment group and the control group before treatment is in accordance with other studies using similar testing methods (1, 8). English *et al.* (8) found that individuals with malocclusions had impaired masticatory performance compared with individuals with normal occlusion. They also found that individuals with a Class III malocclusion had the lowest masticatory performance compared with other malocclusion groups, vertical discrepancies not considered. Their result was not confirmed in this study, in which an open bite was the only discrepancy that was found to have an impact on the MPI.

The linear regression analysis only explained 45 per cent of the total variation of the masticatory ability and 37 per cent of the total variation of MPI. Salivary flow rates, body builds, and muscle strength are variables not assessed in this study but are probably influential factors when evaluating mastication. It has been discussed that maximum bite force is related to body size (9) and it has been shown that females have less muscular bite force than males (23, 24). Which could be a possible explanation why women were shown to have a lower masticatory performance compared with men in this study.

Moreover, the positive treatment outcome implying increased amount of occlusal contacts may be one explanation of improvement in masticatory performance. The number of occlusal contacts has been suggested to be of major importance for the masticatory performance (5, 15). This is in line with this study because it was found that before treatment, the number of occlusal contacts during maximal biting pressure was the greatest explanatory factor of the variance of the MPI. It is further confirmed by the fact that open bite, the malocclusion with the lowest number of occlusal contacts, was another explanatory factor in the regression model.

A shortcoming of this study was the limited part in the questionnaire assessing masticatory ability. After this study was initiated, in 1992, a Jaw Function Limitation Scale (JFLS) has been developed (25). The JFLS has been shown to exhibit good reliability and validity assessing limitations in mastication, jaw mobility, and verbal and emotional expressions (25). The questionnaire in this study focused solely on mastication, and it would have been interesting to extend it according to the JFLS to come to an understanding if patients with dentofacial deformities are limited in their daily life when talking, swallowing, in facial expressions, and so on.

A silicon material (Optosil®; Bayer) was chosen for testing masticatory performance (19). Silicon material and the sieving method have been used in other studies (1, 8, 22, 26), but in the study by van den Braber *et al.* (22), the Optosil tablets were modified by heat to gain a softer consistency. It is known that the newer type of Optosil has higher tear strength than the one used in the study by Edlund and Lamm (19). The main requirement of an ideal test material for studying masticatory efficiency with fractional sieving is that the material is pulverized by chewing in such a manner that the degree of pulverization can be clearly established and that the material is unaffected by water and saliva. If this requirement is met, both the fractionating and the laboratory procedure can be simplified. Optosil® (Bayer) fulfilled the above-mentioned criteria (19), and another advantage of using artificial food is that it can be standardized and easily reproduced in both form and consistency. Moreover, it has been reported that the use of artificial food gives a lower test–retest consistency variation compared with, for example, peanuts (27).

An interesting finding in this study was that the self-estimated masticatory ability was significantly affected by group belonging but not by gender. In contrast to masticatory performance that was significantly affected by gender but not by group belonging. Could it be that patients, with dentofacial deformities, men and women equally, are more prone to report impaired masticatory ability because they feel it is a more acceptable reason for having orthognathic treatment compared with for example esthetics? And therefore the gender gap, found in masticatory performance disappears. Moreover, with these results in mind, it would be of interest to assess the impact of oral health-related quality of life on masticatory ability in patients with dentofacial deformities. However, this was not in the scope of this study.

Conclusions

- Masticatory ability and performance increased after orthognathic treatment.
- The number of occlusal contacts and severity of overall symptoms of TMD influenced both the masticatory ability and performance.
- Open bite had a negative effect on masticatory performance.

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Swedish Dental Society and Faculty of Odontology, Malmö University, Sweden.

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