ORIGINAL ARTICLE

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Masticatory and nutritional aspects on fixed and removable partial dentures

Received: 3 March 2003 / Accepted: 16 July 2003 / Published online: 28 August 2003 © Springer-Verlag 2003

Abstract The aim of the present study was to evaluate mastication, food selection and nutritional aspects in two groups of persons restored with fixed (FPD, N=44) and removable (RPD, N=40) partial dentures respectively. The subjects were part of a cohort study of 67-68-yearold men living in Malmö, Sweden. The two groups were very similar regarding social factors and the inclusion criteria were chosen so that the groups were very equal regarding oral factors, apart from the difference in fixed and removable partial dentures. The number of natural teeth, number of replaced teeth and occlusal contacts did not differ significantly between the two groups, nor did the distribution of maxillary and mandibular dentures. A comprehensive examination of several general health factors included a home interview of dietary habits. A clinical examination included a 20-minute oral examination with registration of number of teeth, FPDs, RPDs, and occlusal contacts. It also included masticatory tests: chewing gum colour mixing, chewing gum bolus shaping, and swallowing threshold (number of strokes to the first swallow of an almond). The consumption of hard and soft foods was revealed by the dietary interview as well as the intake of energy and some nutrients. There was a significant difference between the groups regarding the capacity to mix the two-coloured chewing gum, to shape the chewing gum bolus and in the consumption of hard

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Department of Periodontology, Dental School, University of Copenhagen, Nørre Alle 20, DK 2200 Copenhagen N, Denmark foods. There was no difference in the swallowing threshold and the consumption of soft foods. The intake of energy and nutrients did not differ significantly between the groups. The differences in masticatory capacity found thus seem to have little, if any, effect on the factors of importance for general health. A reasonable explanation for the differences found is that artificial teeth that are well retained, such as FPDs, make more active chewing possible than do removable, and often somewhat loose-fitting partial dentures.

Keywords Mastication · Partial dentures · Nutrition · Cohort study

Introduction

An important problem in oral rehabilitation is to choose the method of restoration for a defective dentition from a masticatory viewpoint. The choice between fixed and removable partial dentures is one such problem.

Direct comparisons of masticatory function with fixed and removable partial dentures (FPD, RPD) are rare and old. Nagasawa and Tsuru [33] made interchangeable fixed and removable partial dentures (Nesbit type) that replaced missing first molars. No difference in masticatory performance was found. That study did not, however, focus on a problem that can be considered relevant today, as the tooth loss included only one molar.

As far as masticatory capacity is concerned, a dentition including fixed partial dentures can most probably be considered equivalent to a dentition with only natural teeth, as mentioned in some studies, though without any clinical tests [7, 10]. Studies that compare dentitions with a reduced number of natural teeth and those restored with RPDs may therefore be relevant in an analysis of FPDand RPD-restored dentitions, even if they are not actually treated with FPDs.

Wayler et al. [45] studied healthy men, aged 25– 75 years, by dividing them into different dental categories, e.g. compromised dentitions (20–26 teeth) and different removable denture groups. Their conclusions were that, although restorative therapy with RPDs can lead to concomitant improvements in masticatory function (objectively measured), low perceptual responses (subjective ability) are observed. Food textural attributes and the dental status were, however, the parameters that most influenced food selection [45].

It has been suggested that inappropriate dietary shifts occur in populations with non-replaced missing teeth as well as in persons with removable dentures, complete or partial [44].

As food selection is directly related to the intake of energy and nutrients, it is of major medical and general health importance. The fundamental aspect, whether a compromised dentition or artificially restored dentition influences chewing capacity, food selection and nutritional status, has accordingly been the subject of many studies. Conflicting results and opinions have been presented. It has been stated, for instance that "the findings of various researchers suggest that a reduction in the number and quality of functioning teeth may have deleterious consequences for the overall health of the person and especially the persons over the age of 55 years" [17]. Wayler et al. [45] concluded that "partially edentulous persons, with and without replacement of missing teeth, can self-impose certain dietary restrictions that may compromise their nutritional status", while Witter et al. [47] states that only "severe dental impairment affects food selection" and "even if the masticatory performance is poor, a connection with general health, gastric distress or dietary inadequacy cannot be substantiated".

Witter et al. [47] studied chewing ability (subjective evaluation) of persons with either untreated shortened dental arches (SDA) or restored with RPDs. Their conclusion was that free-end RPDs in the mandible did not contribute to oral comfort, including mastication. Their discussion draws attention to the question whether mastication should be judged by masticatory tests (masticatory performance), or by the subjective evaluation (masticatory ability) of chewing function and food selection.

Liedberg et al. [27] made an intra-individual comparison of chewing with or without RPDs in 22 subjects with a total of 27 RPDs. Chewing gum colour mixture and bolus shaping and comminution of silicone tablets did not reveal any significant difference, while the number of chewing strokes needed to the first swallow of an almond was significantly higher when the RPDs were not in place. This indicates that different methods for measuring masticatory function may give different results, and highlights the problem of finding a reliable parameter to measure masticatory capacity objectively.

There are, accordingly, several studies and opinions in the literature that support the statement by Carlsson [5], who in a review article concluded that "the correlation between the self-assessed chewing ability and chewing efficiency (capacity to triturate a test food) is not very clear".

The restoration of a partially edentulous arch with an FPD treatment very often results in fewer teeth than in a

complete dentition, while an RPD treatment will generally result in a dentition of 28 teeth, natural and artificial together. Which one of those treatment options favours mastication best has not been studied in a comprehensive way.

The aim of this study was to evaluate mastication and food selection in well-defined groups of elderly men, as similar as possible, with dentitions with either fixed or removable partial dentures.

Materials and methods

The study population

The participants in this study were all men born in even months in 1914, aged 67–68 years, and living in Malmö, Sweden. They were drawn from the material of 483 men from the cohort study "Men born in 1914", which was a comprehensive health examination. The study was restricted to men, as the cohort was defined in the same way as in an earlier study about cardiovascular and respiratory diseases. The background of the study and details of the material as well as the overall medical aspects have been presented earlier [18, 19].

The study group of the cohort study as a whole was defined every fourth month during the study to reduce the risk of inviting someone that had died or left town after the population had been originally defined. The total cohort included 621 men. Of these, 483 participated in the dental and clinical examinations. For details see [13].

A 20-minute dental clinical survey, including chewing tests, was part of a half-day clinical examination of mainly cardiovascular parameters. A nutritionist paid a home visit to each participant and assessed dietary habits and put questions independently of the clinical examination [14, 34]. The inclusion criteria were:

- 1. FPD group: No removable denture. Three or more teeth replaced by an FPD (FPDs).
- RPD group: No complete denture. The RPD should replace seven teeth or fewer. If RPDs were present in both jaws, neither should replace more than seven teeth.

These inclusion criteria limited the groups to 44 men in the FPD group with a total of 50 FPDs and 40 men in the RPD group with 48 RPDs.

Details of the dental situation and social factors in the two groups are presented in Table 1. There are no statistical differences in any of the variables.

The 48 RPDs included 18 with only tooth-bound saddles and 30 with distal extension saddles. In 12 there was a unilateral distal extension saddle and in 18 there were bilateral distal extension saddles. The 50 FPDs included 28 with abutments at both ends and 22 with cantilever pontics, 3 FPDs with single cantilever pontics mesially and 19 with distal extension cantilevers (11 unilateral single, 2 unilateral double, 1 unilateral triple, 4 bilateral single and 1 bilateral double).

Social factors

From a self-completion questionnaire, the following social factors were extracted: social class, educational level, and marital status. Social classification was determined in accordance with the Swedish official system for the economically active population [41]. The classification of economically inactive populations, based on previous occupation, is in accordance with this system.

- Social class I: non-manual employees and self-employed professionals and farmers
- Social class II: "white-collar workers" on a low or medium level
- Social class III: "blue-collar workers"

Table 1	Dental	and sc	cial data	a for the	FPD and	RPD	groups.	No
significa	nt diffe	rence i	n any of	the para	ameters			

	FPD (n=44)	RPD (n=40)			
Dental data					
Partial dentures Maxillary Mandibular	50 39 11	48 32 16			
Natural teeth (incl po	ontics) in actual jaw				
Mean Range Teeth replaced	7.8 4–8	7.5 [#] 5–11			
Mean	4.2 3_8	5.4 3_7			
Occlusal tooth contacts* totally (including artificial teeth)					
Mean Range	15.1 2–24	13.7 4–22			
Total number of teet	h (natural and artificial	l)			
Mean Range	23.2 16–30	24.2 17–28			
Social data					
Social class I Social class II Social class III	13 26 10	5 18 17			
Marital status					
Cohabiting Living alone	10 33	6 34			
Educational level					
\geq 14 years 7–13 years \leq 6 years	2 35 6	4 35 1			

[#]Nine arches restored with RPDs included FPDs in the dentitions *According to Liedberg et al. [27] and Pancherz and Anehus [36]

Marital status was classified as married (including people living together) and single (including divorcees and widowers). The educational levels were: \geq 14 years of education, corresponding to university-college or university degree, 7–13 years, \leq 6 years. A comparison of the FPD and RPD groups regarding the distribution of the social factors did not reveal any significant differences.

Chewing tests

Chewing gums were used for two simultaneous masticatory tests: chewing gum colour mixing and bolus-shaping. The tests have been described earlier [28].

Red and blue chewing gums were put together in a cube $10 \times 10 \times 10$ mm. The participant chewed three such cubes habitually for ten chewing strokes each, opened his mouth and the examiner took the bolus out. Colour mixing, kneading of a bolus, was evaluated according to a five-grade reference scale for both sides separately. The mean of six indexations, both sides of each gum, was used to characterize the colour mixing. Bolus-shaping, forming a coherent bolus, before swallowing was also evaluated according to a reference scale including five different shapes. The mean of three indexations, one for each gum, was used to characterize the bolus-shaping capacity.

Three blanched almonds, standardized in size, were used to record the number of chewing strokes before swallowing. The participants were asked to chew each almond separately and naturally and were told that the number of stokes to the first swallow was to be counted individually by two observers. No other instruction or information was given. Where different numbers of strokes were recorded, the mean was used. This test is in accordance with earlier published tests, named "swallowing threshold tests" [6, 16].

The mean difference between the two observers in number of chewing strokes to the first swallow was insignificant (p>0.68) and maximally 0.2 (SD 3.8). The intra-individual range of variation (mean of the two observers recordings) in number of chewing strokes for the three almonds was for the FPD group 1.5–44.5, with 69% below ten and for the RPD group 0.5–27.5, with 64% below ten.

Choice of food

The participants were interviewed for 45–60 min on dietary habits, using the dietary history method modified for elderly people [40]. From the interview results, some hard and soft foods were selected. They had been recorded in times per month and grams per portion (for instance, for meat and fish), slices per day (for example, for bread) and pieces per day (for instance, for fruit). Cod fish, herring, minced meat, boiled vegetables, sausages and bananas were classified as soft food, and pork (whole pieces), beef (whole pieces), raw vegetables, apples/pears (untreated), crisp bread and wholemeal bread were considered as hard food.

To obtain a sum of the total amount of different soft and hard food items consumed, the following index was constructed. For the whole material of this study, the participant who had eaten the most of each of the selected foods was given the index value 100. The intake for each of the other participants was calculated in percent of this top value. The total consumption of soft and hard foods, respectively, was then calculated for each participant as the sum of these values, whatever type of measure that had been used in the diet interview recording.

Energy and nutrients

Results were obtained from the medical health examination. Body mass index (BMI) was calculated as the body weight in kilograms divided by the squared height (m²) [34]. The daily intake of energy and nutrients was calculated using the Swedish food table data [37, 42, 43].

Statistical methods

All calculations and data processing were done in the personal computer version (8.02) in the SAS system [39]. To compare differences in distribution, e.g. social variables between the two groups, chi-square test was used. Wilcoxon non-parametric test was applied when analysing differences in mean numbers, e.g. of replaced teeth and occlusal contacts, and when the different mean index values, e.g. bolus shape and total hard or soft food indices, were analysed. The level of significance was 0.05.

Results

The results are presented in Tables 2 and 3. A few subjects did not participate in all the tests due to allergies and/or

 Table 2 Results of chewing tests and subjective choice of hard and soft food items for men with either FPDs or RPDs. Mean/standard deviation

	FPD	RPD
Chewing gum color mixing	3.4/0.9 (n=44)	4.1/0.7 (n=40)
Chewing gum bolus shape	2.5/1.5 (n=44)	3.6/1.3 (n=40)
Number of stokes, almond	41.3/16.6 (n=40)	39.9/15.9 (n=38)
Hard food consumption	151.6/53.8 (n=43)	121.0/45.5 (n=40)
Soft food consumption	156.2/52.2 (n=43)	156.3/44.4 (n=40)

Table 3 Body mass index (BMI), intake of energy and nutrients fr patients with fixed partial dentures (FPD) and removable partial dentures (RPD). Mean/standard deviation and recommended values

	FPD (n= 43^)	RPD (n=40)	Rec. value
Body mass index (kg/m ²)	25.1/2.6	24.4/3.4	20-25*
Energy (MJ)	10.61/2.1	9.97/1.63	8.8-10.5*
Protein (% of energy intake)	12.6/1.9	12.5/1.7	10-15
Fat (% of energy intake)	36.5/4.6	36.7/4.4	30-35
Carbohydrates (% of energy intake)	44.0/5.9	45.5/5.0	55-60
Calcium (mg)	956/472	865/389	600-800

^ One subject did not participate in the dietary interview

* According to Svenska näringsrekommendationer [43]

[#] According to Laurell et al. [25]

lack of participation in the dietary interview. The numbers of participants are given in the tables for each test.

The capacity to mix ($p\approx 0.0001$) and shape (p< 0.0005) a chewing gum bolus differed significantly between the two groups, as did the intake of hard foodstuffs (p< 0.02). (See Table 2).

The number of chewing stokes until the first swallow of an almond (ns) and the intake of soft foodstuffs (ns) did not differ between those treated with FPDs and RPDs. (See Table 2).

The proportion of fat and calcium of the energy intake in the FPD and RPD groups was slightly above the recommended values, whereas the intake of carbohydrates was somewhat lower. No statistically significant differences were found between the FPD and RPD groups in the intake of energy and nutrients or in body mass index (BMI) (see Table 3).

Discussion

Since implant treatment for the replacement of missing teeth in partially dentate jaws is still very little used, the conventional treatment options with FPDs and RPDs need to be considered as realistic alternatives for most people. The analysis of as many aspects as possible of their advantages and disadvantages are therefore of great importance. Even though mastication sometimes has been questioned as the real goal for restoration [2], it remains one of the main indications for treatment, based on the conviction that teeth are needed for chewing, mostly without any detailed considerations of the number and type of teeth needed, nor with clear knowledge of the biological requirements for food preparation before swallowing.

In prosthodontic treatment planning, it is now widely accepted that there is no evidence that tooth loss of posterior teeth inevitably leads to disturbances in the masticatory system. Rather, the subjective chewing comfort is the relevant factor [24]. A clear correlation between the burden of illness, here the defective dentition, and the real need for prosthetic treatment has not been established. Basic studies of the shortened dental arch concept have, however, inspired new approaches in functional research [22, 47].

It has been shown that "a loss of up to seven teeth did not seem to entail an assessment of impairment" of subjectively assessed chewing ability [1]. It has also been clearly demonstrated that RPD treatment may have negative influences on oral comfort and patient satisfaction. The alternative with FPD treatment, often resulting in a total of fewer teeth than RPD treatment, may thus be warranted [3, 8, 20]. In many cases, the subjective need for prosthetic treatment is not related to a masticatory deficiency but to other parameters such as aesthetics. It such cases it is, however, also valuable to be able to include the influences on the mastication of different treatment strategies as one of the aspects that should be considered before the final choice of treatment.

For studies of masticatory capacity with different types of prosthodontic restoration, it is important to eliminate confounding factors as much as possible. Intra-individual studies, where the technical restorative alternatives are interchangeable, may seem to be the most reliable. However, there are drawbacks regarding the possibility of large homogenous materials, qualifications and preferences of the provider, subjective influences on the testpersons of other aspects than the one studied and the need for long term adaptation before a restoration can be finally evaluated.

The possibility to analyse a large group, the Malmö cohort study, of men only, of the same age and living under similar conditions and being analysed in several aspects by medically and nutritionally qualified staff, was available. The clinical study was performed 1985–1987 but there is no reason to believe that any of the results regarding mastication and nutrition, as analysed here, can be in any way time dependent. With the data from the Malmö cohort study there were so many aspects related to mastication and nutrition that could be explored, that the time elapsed from clinical study to analysis could be justified from both time- and cost-related aspects. From this material, it was possible to select subjects with FPDs and RPDs in groups large enough for comparisons. Also, social and economical parameters could be evaluated. The dentally related inclusion criteria were constructed so that the FPD and RPD groups should match each other as closely as possible in all respects but the rehabilitation with fixed or removable partial dentures. That this intention was closely achieved is demonstrated in Table 1.

The patients selected did not include any with complete dentures, which needs to be kept in mind. The background for this was the knowledge that "Individuals with a denture (partial or complete) in only one jaw and natural teeth in the other consider their chewing ability reduced to the same extent as complete denture wearers (in both jaws) did" [1].

There are several masticatory tests available. As none of them appears to be more valid than any of the others, the choice is difficult. Some tests are relatively time-consuming, e.g. the sieve-system tests that have been used frequently. For removable dentures it has been recommended that more than one test should be used [12, 28].

The correlation of masticatory tests to swallowing capacity has been very little analysed. This seems, however, to be a very relevant factor in judging masticatory function and warrants the use of the chewing gum tests that have been used in that connection [26].

The material in this study is part of a cohort study. Only 20 min of clinical time was available for oral registrations, including the masticatory tests. It was therefore necessary to use quick tests that did not require immediate analysis. The chewing gum tests had been used earlier and found to be very suitable in this respect. It was also necessary to use masticatory tests that were relevant for the whole cohort study. As several participants were complete denture wearers, a comminution test with, for instance, Optosil would not have been appropriate, even though Optosil could have been used for RPD wearers, as in an earlier study [27]. In that study, it was shown that the chewing gum tests of mixing and shaping and the Optosil particle size reduction test gave basically the same results, namely no significant differences between chewing with or without the RPDs. [27].

The intake of hard and soft foods has been used in several studies as a measure of masticatory function. There are minor differences in the choice of foodstuffs, which are probably influenced by what foods are natural ones in the regions where the studies have been performed [11, 21, 38, 45, 46].

The results of this study were that the chewing gum tests and consumption of hard foods differed significantly between FPD and RPD wearers. The three functions of mixing and kneading a gum bolus, shaping it to be suitable for swallowing, and chewing hard food items may be enhanced by a dentition that is stable and can tolerate high occlusal forces. This, for instance, is in accordance with results from studies of patients who have teeth retained by osseo-integrated implants [29]. Bite force measurements have also been used in connection with studies of masticatory capacity, and the bite force seems to influence mastication, especially of tough foods [30, 31]. This is in agreement with our results that soft food consumption did not reveal any difference between the two groups.

The swallowing threshold, in our study the number of stokes to the first swallow of an almond, did not differ between the FPD and RPD groups. In other studies it has been demonstrated that the swallowing threshold is correlated to the number of natural teeth [16], restoration with complete maxillary dentures and extensive fixed prostheses in the mandible, and adaptation [4]. In the intra-individual study of mastication with and without RPDs, significantly fewer chewing strokes were needed to the first swallow of an almond when the RPD was in the oral cavity. The number of strokes was found to relate significantly to the retention of the RPD when chewing with the dentures in place and to the number of natural teeth when chewing without the RPDs [27]. The difference between the FPD and the RPD groups could thus be a matter of retention of the artificial teeth during the masticatory act. That the soft food intake and the number of strokes for chewing an almond to the first swallow did not differ significantly can most probably be explained by the fact that relatively low occlusal forces are needed for these activities [30].

It is clear from the measurements of intake of energy and nutrients that there are no differences of practical relevance. Both groups have a fat intake that is somewhat higher and a carbohydrate intake that is somewhat lower than the recommended value. The calcium intake is well above the recommended minimum. The figures are, however, in close agreement with those of the whole material of the cohort study [14]. They concluded that on average the intake of energy and nutrients was satisfactory and well above the recommended dietary allowances, but that the variation was wide and risk groups could be identified. This means that from a general nutritional viewpoint the type of restoration, fixed or removable, is unimportant. In a broader sense it also means that the differences in chewing capacity recorded here are not important for the food intake. The lower intake of hard foods among RPD wearers did not result in any significant difference in energy or nutrients. In a study of women in Malmö who were at the time of occupational retirement, it was found that those with removable dentures did not differ from dentate subjects regarding intake of food items, energy and nutrients [35]. The women, however, had a fat intake that was slightly above the recommended values. That the dental status, as demonstrated here, has an influence on the food choice has, however, been shown several times [32] and will probably be related more to comfort and well-being in connection with chewing than to health and nutritional aspects.

Garret et al. [9] compared the dietary intake of two large groups, 111 and 107, respectively, of men with a mean age of about 50 restored with either RPDs of FPDs (endosteal blade vents). They did not find any significant differences between the two groups for any of the 30 dietary variables studied. This is in agreement with our results. However, they also found that in subgroups of those with low caloric intake and high caloric intake there was an increase and a decrease in the intake of calories and nutrients, respectively. In the high-caloric-intake group, the reduction of nutrients was significantly greater in the FPD group than in the RPD group. Even if the authors emphasize that "it would be prudent for clinicians to recognize that the placement of an RPD or FPD may or may not resolve the problem of malnourished patients with chewing deficiencies", it indicates the complexity of masticatory as well as food choice measurements, and that a definitive understanding of mastication needs to be based on several aspects and several parameters of analysis.

Conclusion

The total number of teeth and the total number of occlusal contacts, including natural and replaced teeth, were almost the same for the groups treated with fixed and removable partial dentures. The number of chewing strokes to the first swallow of an almond did not differ significantly between the two groups. This is probably because the number of chewing strokes to the first swallow, even though there are great individual variations, can be explained by the swallowing of courser particles. It is, however, still a measure of masticatory function. The chewing-gum chewing is comparable to chewing of a medium to hard, not crushable coherent bolus, and the group treated with fixed partial dentures demonstrated a significantly better capacity than the group treated with removable partial dentures. The subjectively regulated consumption of hard and soft foods demonstrates no difference in intake of soft food items chosen in this study to represent such foods but there was a significantly lower consumption of hard foods among the removable partial denture wearers, which demonstrates a handicap in the food selection. This does, however, not give any influence on energy and nutrient intake. It can thus be concluded that the removable partial denture wearers are less capable than the fixed partial denture wearers to prepare coherent relatively hard boli for swallowing in experimental situations and that this is mirrored in a lower consumption of hard foods.

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