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Masticatory function in patients with an extremely resorbed mandible restored with mandibular implant-retained overdentures: comparison of three types of treatment protocols

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SUMMARY **The objective of the present study was to analyse the effects of implant supported overdentures on masticatory function in patients with an extremely resorbed mandible, and to compare the masticatory function in these patients using three differing types of implant treatment protocols. The mandibular overdentures were retained by a transmandibular implant, by four endosseous implants following augmentation of the mandible, and by four short endosseous implants, respectively. Sixty patients (50 women, 10 men, mean age 59·4 years) were randomly allocated to one of the three treatment groups. Masticatory function was assessed before and after treatment using a questionnaire, a masticatory performance test, and a structured interview. The patient-based masticatory function improved significantly. Concerning these parameters there were no significant differences between the three groups before and after treatment. A significant difference existed between the three groups for the laboratory-assessed masticatory function before treatment, but after treatment this difference was no longer significant. From this study it can be concluded that patients with an extremely resorbed mandible and functional complaints of their lower denture report significant improvement in masticatory function after implant-overdenture treatment. Differences in masticatory function between the three studied modalities were not significant after treatment.**

KEYWORDS: **masticatory function, dental implant, implant-retained overdenture**

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Introduction

Masticatory function, particularly the comminution of tough foods during chewing, is impaired because of the loss of natural teeth (1–3). Chewing tough foods is frequently difficult for patients who wear complete dentures, and their chewing efficiency (in terms of particle size reduction) has been demonstrated to be restricted (4, 5). Several factors are thought to be responsible for a poor masticatory function in denture wearers. These include the limitations in the ability to exert and control bite forces in terms of magnitude and direction, pain from the mucoperiosteum of the denture-bearing areas, complete denture instability and finally a lack of control in terms of the intraoral manipulation of food particles (6). As some of these factors are more pronounced in edentulous patients with an extremely resorbed mandible it could be assumed that the masticatory function impairment is related to the degree of resorption (6–8). However, specific studies about this phenomenon are lacking.

In edentulous patients with problems wearing complete dentures, mandibular implant-overdenture therapy has been shown to substantially improve bite forces and

	I (TMI) ($n = 20$)	II (AUG) ($n = 20$)	III (SHORT) ($n = 20$)
Age (years)	59·4 (±12·0)	57·4 (±10·0)	61·4 (±11·4)
Female	17	15	16
Male	3	4	3
Edentulous period (years)	29·6 (±11·9)	28·0 (±7·1)	30·1 (±9·9)
Number of mandibular dentures	3 (1–5)	3 (1–4)	3 (1–6)
Age mandibular denture (years)	6·0 (±4·5)	8·3 (±7·0)	5·0 (±6·7)
Jaw height (mm)	9·7 (±1·4)	9·5 (±1·6)	9·8 (±1·4)

Table 1. Mean and standard deviation (±s.d.) of several characteristics of the patient population (median and range for number of mandibular dentures), after inclusion in the clinical trial (T0) according to treatment modality

TMI, Transmandibular Implant; AUG, Augmentation followed by endosseous implants; SHORT, short endosseous implants.

chewing efficiency (9, 10). The type of implant support for the overdenture might play a role in the improvement of masticatory function. Not only is the specific type of surgery important, but the degree of implant-support and design of the prosthetic devices could be important as well (9, 11, 12). Masticatory function was assessed both with patient-based variables as well as with laboratory-assessed variables. Three strategies were used to treat the extremely resorbed mandible with dental implants and an overdenture: insertion of a transmandibular implant (group I, TMI) according to Bosker (13), augmentation with an autogenous bonegraft (iliac crest), 3 months later followed by the installation of four endosseous implants in the interforaminal region (group II, AUG) (14), the placement of four short endosseous implants in the interforaminal region (group III, SHORT) (15). The aim of this study was to analyse the effects of implant supported overdentures on masticatory function in patients with an extremely resorbed mandible; and to compare masticatory function in patients with an extremely resorbed mandible using three differing types of implant treatment protocols.

Materials and methods

Patient selection

A total of sixty edentulous patients with an extremely resorbed mandible and persistent problems with their complete, conventional, mandibular dentures were included in this study. They were referred by general practitioners to the department of Oral and Maxillofacial Surgery and Maxillofacial Prosthetics of the University Hospital Groningen.

The criteria for inclusion were edentulous upper and lower jaw for at least 2 years with a symphyseal mandibular height ≤ 12 mm, measured on a standardized lateral radiograph, and severe functional problems with the mandibular dentures, i.e. poor retention and stability of the lower denture. In addition, it was required that little or no improvement could be expected from making new dentures. Patients with a history of radiotherapy in the head and neck region, a history of pre-prosthetic surgery or previous oral implantology were excluded from the study.

All patients were informed about the three possible modes of treatment, and about the extra efforts associated with the clinical trial (e.g. questionnaires, evaluation visits) before they gave their written consent to participate. The study was approved by the Medical Ethical Committee of the University Hospital Groningen.

The study sample consisted of 50 women and 10 men. The mean (±s.d.) age was 59·4 ± 11·0 years. The patients were edentulous for an average of 28·9 ± 10·0 years. In most cases the latest denture was their third denture (range 1–6), and it was functioning for 6·4 ± 5·8 years. The mean (±s.d.) jaw height measured in the symphyseal area on a standardized lateral cephalometric radiograph was 9·7 ± 1·4 mm. The pre-treatment characteristics of the three groups are summarized in Table 1.

Patient allocation and treatment procedures

Eligible patients were randomly allocated to one of the three surgical protocols.

Group I (20 patients) was treated with an overdenture supported by a Transmandibular Implant according to Bosker* consisting of a base plate, four implant posts, five cortical screws, all made of a gold alloy (13). The transmandibular implant was inserted under general anaesthesia via an extra oral approach. After 3 months an overdenture was constructed, according to a specified protocol (16). The overdenture which is mainly implant

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borne, is retained by five clips on a triple-bar construction with distal cantilevers.

In group II (20 patients), the mandible was augmented using an autologous bone graft from the iliac crest. This procedure was performed under general anaesthesia (14). After 3 months, four IMZ apical screw implants[†] were inserted in the interforaminal region under local anaesthesia. After an initial healing period of 3 months abutment connection took place. The implants were connected with an egg-shaped triple-bar construction. The implant-mucosa-borne mandibular overdenture was connected with three clips to this bar construction.

In group III (20 patients), four short (8 or 11 mm) Twin Plus IMZ implants[†] were inserted in the interforaminal region under local anaesthesia in an outpatient clinic setting. Three months later, abutment connection took place and new overdentures were inserted according to the same procedure as described for group II.

One surgeon performed all surgical procedures according to protocols that were established in close cooperation with the manufacturers of the implant systems. The prosthetic procedures were performed by two experienced prosthodontists following specific protocols for each treatment strategy.

All patients received new maxillary dentures. The dentures were all made with the same number of posterior teeth (each side with one premolar and two molars) in bilateral balanced occlusion using the lingualized occlusion concept with porcelain teeth (17).

Treatment allocation was performed using a minimization procedure, ensuring a balanced distribution of age, gender, the edentulous period of the mandible, the number of previously made mandibular dentures, the number of years having worn the present mandibular denture, and the symphyseal bone height of the mandible (18).

Data collection

Chewing Ability Questionnaire All patients were requested to fill out the Chewing Ability Questionnaire immediately after inclusion. In this questionnaire patients gave their opinion about their ability to chew nine different kinds of food on a 3-point rating scale (0 = good, 1 = moderate, 2 = bad). The items were grouped into three scales, i.e. (1) 'soft food' (boiled vegetables and potatoes, crustless bread, minced meat): inter-item correlation 0·35, reliability according to Cronbach's $\alpha = 0{\cdot}60$; (2) 'tough food' (crusty bread, steak, Gouda cheese): inter-item correlation 0·69, Cronbach's $\alpha = 0{\cdot}86$; (3) 'hard food' (apple, carrot, peanuts): inter-item correlation 0·48, Cronbach's $\alpha = 0{\cdot}73$. Each factor final score was calculated as the mean of the item score ranging from 0 to 2. This questionnaire was filled out again 3 months after placement of the implant-retained denture (T1).

Masticatory performance tests The comminution of food was tested with the artificial food Optocal Plus (19), a derivate of Optosil Plus®[‡] which was prepared in standardized cubes with an edge size of 5·6 mm. Portions of 17 cubic particles, i.e. approximately 3 cm^3, were offered as test food. The masticatory performance was evaluated in a series of chewing tests, described in detail by Slagter *et al.* (20). During each test, the patient was requested to chew the 17 particles normally and to spit out the fragmented remains in a special sieve. Subsequently, the patients were asked to remove their dentures. The particles sticking to the dentures were rinsed off with water, and collected in the same sieve. To collect the particles remaining in the oral cavity, patients were asked to rinse their mouth with water and to spit out the water and the remaining particles into the same sieve. The investigator checked the presence of possible remaining particles on the dentures and in the oral cavity. First, the test was carried out with 20 chewing strokes and repeated once. This procedure was then repeated with 60 chewing strokes. The two portions of fragmented food for each number of chewing strokes were pooled and dried. The particles were sieved for 20 min on stacks of up to 10 sieves, with apertures from 5·6 mm decreasing to 0·5 mm with a bottom plate (Laboratory Sieving machine VS1000)[§]. The amount of test food on each sieve and on the bottom plate was weighed. The median particle size (×50), which is the aperture of a theoretical sieve through which 50% of the test food particles by weight can pass, was determined. The chewing test was performed by all patients prior to treatment (T0) while wearing their complete mandibular and maxillary dentures. The test was repeated 3 months after placing the implant retained denture (T1), again while wearing their mandibular overdenture and maxillary denture.

[†]Friadent, Mannheim, Germany.

[‡]Bayer Dental, Leverkusen, Germany.

[§]F. Kurt Resch GmbH & Co. KG, Haan, Germany.

Structured interview

The chewing tests (both at T0 and T1) were followed by a structured interview based on five items with regard to possible problems during chewing of the artificial food, including the effort needed to comminute the test food (to be reported on a 4-point rating scale: 0 = no effort, 1 = little effort, 2 = moderate effort, 3 = severe effort), pain felt in upper and lower jaw (each reported on 10-point rating scale: 0 = no pain, 10 = unbearable pain), and loss of retention of either the maxillary or the mandibular denture (scored as either 0 = no loss of retention or 1 = loss of retention).

Data analysis

Questionnaire and structured interview The results of the questionnaire 'Chewing ability' as well as the effort needed to chew the test food were analysed with Wilcoxon Matched Pairs Signed Ranks test *within* each of the three treatment groups. Differences *between the groups* were analysed by applying Kruskal–Wallis one-way ANOVA.

The treatment effect on the pain experienced in lower and upper jaw during chewing of the test food was analysed with paired samples *t*-tests. Differences with regard to the loss of retention of the maxillary and mandibular dentures during the tests before and after treatment were analysed using the chi-square test.

Masticatory performance tests Between-group differences with regard to median particle size variables were analysed using ANOVA. In case of significance, *post hoc* multiple comparison tests (Tukey's test) were carried out. Within-group differences in median particle size (×50) before (T0) and after treatment (T1) were analysed with paired sample *t*-tests.

Relationship between masticatory performance and patient based parameters Kendall's tau coefficients of associations were determined to investigate the presence of relationships between parameters assessed during the chewing tests (median particle size ×50, 20 and 60 chewing strokes) and parameters reflecting the patients' subjective appreciation of their chewing ability and experiences obtained from the questionnaire 'Chewing ability' (scales for 'soft', 'tough', and 'hard' food) and interview (scales for 'effort', 'pain', 'loss of retention upper/lower denture'). A multiple stepwise regression analysis was carried out to construct a model that relates the patients' subjective appreciation of chewing ability to their masticatory performance.

In all statistical tests, a significance level of $\alpha = 0{\cdot}05$ was chosen. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS, version 10·0 for Windows)[¶].

Results

The pre-treatment characteristics of the three groups are summarized in Table 1. Within 3 months after placement of the new dentures one patient (group III) had died, and one patient (group II) had moved out of the region and was lost to follow-up. These two patients were excluded from the study, so that 58 patients were available for evaluation.

In the transmandibular group (group I), one implant post failed to integrate in the healing phase, and was replaced. In group II, four patients lost one implant during the healing phase and it was decided to use the remaining three implants for construction of the superstructure. One patient lost all four implants during the healing phase, and she was retreated with four implants. No loss of implants occurred in the short implants group (group III).

Questionnaire 'Chewing Ability'

Before treatment, there were no significant differences between the three groups in reporting their ability to chew soft, tough and hard food (Kruskal–Wallis one-way ANOVA, $P > 0{\cdot}05$). After treatment, there was a significant improvement in all three groups in their ability to chew soft, tough and hard food (Wilcoxon Matched Pairs Signed Ranks test, $P < 0{\cdot}05$). The differences between the groups after treatment were not significant (Kruskal–Wallis one-way ANOVA, $P > 0{\cdot}05$). The results are presented in Table 2.

Masticatory performance test

The results of the masticatory performance test are given in Table 3. Before treatment (T0) the patients allocated to group III performed significantly better (multiple comparison Tukey's test, $P < 0{\cdot}05$) than those allocated to group II, both after the 20 chewing strokes

[¶]SPSS Inc., Chicago, IL, USA.

Table 2. Results obtained by using the Chewing Ability Questionnaire before (T0) and after treatment (T1) in the three groups

	Group I (TMI)		Group II (AUG)		Group III (SHORT)	
	T0 ($n = 20$)	T1 ($n = 20$)	T0 ($n = 19$)	T1 ($n = 19$)	T0 ($n = 19$)	T1 ($n = 19$)
Soft food	0·33	0·03	0·36	0·00	0·20	0·05
Tough food	0·91	0·03	1·25	0·18	0·78	0·10
Hard food	1·60	0·31	1·73	0·64	1·63	0·26

Range 0–2: Scale 0 = good, 1 = moderate, 2 = bad.

Table 3. Median ×50 values (mm) after (A) 20 (×50-20) and (B) 60 (×50-60) chewing strokes before (T0) and after treatment (T1) in the three groups

	Group I (TMI)	Group II (AUG)	Group III (SHORT)	Comparative analysis*
(A)				
T0	4·85	5·13	4·65	S
T1	4·04	4·16	3·79	NS
T0-T1	0·81	0·97	0·86	NS
Difference scores analysis†	S	S	S	
(B)				
T0	2·88	3·33	2·57	S
T1	2·42	2·40	2·17	NS
T0-T1	0·46	0·93	0·40	S
Difference score analysis†	S	S	NS	

*ANOVA, S = significant, $P < 0·05$; NS = non-significant, $P > 0·05$.
†Students *t*-test for paired samples, S = significant, $P < 0·05$; NS = non-significant, $P > 0·05$.

test (×50 T0 20) and after the 60 chewing strokes test (×50 T0 60). Neither for the 20 chewing strokes (×50 T1 20), nor for the 60 chewing strokes tests (×50 T1 60) significant differences were found between the groups after treatment (T1) (ANOVA, $P > 0·05$).

All three groups performed significantly better (paired *t*-test, $P < 0·05$) after treatment compared with pre-treatment for the 20 chewing strokes test (×50 T1 20). For the 60 chewing strokes test the reduction of the median particle size (×50 T1 60) was significant (paired *t*-test, $P < 0·05$) in group I and II.

Between groups, differences (Table 3A) in the masticatory performance after 20 chewing strokes (×50 20) were not significant (ANOVA, $P > 0·05$). For the 60 chewing strokes test, the improvement of masticatory function (×50 60) in group II was significantly more (Tukey's test, $P < 0·05$) compared with that observed in group I and III (Table 3B).

Interviews

Table 4 presents the results of the interviews following the masticatory performance test. Before treatment (T0), most patients reported that they needed considerable effort to chew the test food, and that pain was experienced during chewing, especially in the lower jaw. The loss of retention of dentures was especially noted for the lower denture (92%), although 25% of the patients reported loss of retention of the upper denture as well. After treatment (T1), most of the patients reported that the effort needed to chew the test food had decreased, although in group II (Augmentation) this change was not significant (Wilcoxon matched pairs signed ranks test, $P > 0·05$). There was a significant reduction in pain from the lower jaw during chewing of the test food in all three treatment groups (paired *t*-test, $P < 0·05$). Pain felt in the upper jaw before treatment had vanished after treatment. After treatment (T1), few patients reported loss of retention of their implant retained lower denture. This reduction was significant in all three groups (chi-square test, $P < 0·05$).

Correlations and regression

Before treatment, only weak correlations were observed between the items 'Tough Food' and 'Loss of

Table 4. Results of the interviews following the masticatory performance test before (T0) and after treatment (T1) in the three groups

	TMI ($n = 20$)	AUG ($n = 19$)	SHORT ($n = 19$)
Effort*			
T0	2·40 (±1·10)	2·05 (±1·29)	2·43 (±0·76)
T1	0·65 (±1·04)	1·61 (±1·09)	1·42 (±1·15)
Pain upper jaw†			
T0	0·30 (±1·13)	0·42 (±1·50)	0·68 (±2·06)
T1	0	0·17 (±0·71)	0
Pain lower jaw†			
T0	3·10 (±3·110	3·89 (±3·19)	3·16 (±3·19)
T1	0·15 (±0·67)	0	0·21 (±0·89)
Loss of retention upper denture‡			
T0	10%	36·8%	26·3%
T1	5%	15·8%	5·3%
Loss of retention of the lower denture‡			
T0	85%	94·7%	94·7%
T1	5%	5·3%	5·3%

*Scale 0–3; 0 = no effort, 1 = little effort, 2 = moderate effort, 3 = severe effort, mean and s.d. (±) are presented.
†Scale 0–10; 0 = no pain, 10 = unbearable pain, mean and s.d. (±) are presented.
‡Percentage of positive loss of retention is presented.

retention' of the subjective assessment and the parameter ×50 (median particle size) from the chewing test. A multiple regression analysis did not yield a model relating subjectively assessed parameters of masticatory function with the capacity to comminute test food (masticatory performance test, T0 20 ×50 and T0 60 ×50) before treatment.

Discussion and conclusions

Masticatory function is perceived as being considerably impaired by patients with a severely resorbed mandible and conventional dentures. As assessed with the Chewing Ability Questionnaire and the structured interview following a chewing test, masticatory function in these patients appears to improve following treatment with an implant-supported mandibular overdenture. Not only the ability to chew all kinds of food significantly improved, but the reduction of pain during chewing and the reported increased retention of the lower denture was substantial as well. This was consistently observed in the three treatment groups, which is in accordance with other studies (21–23).

The results from the objective assessments with the masticatory performance test yielded a more obscure picture. The pre-treatment results mark the position of edentulous patients with an extremely resorbed mandible within the field of patients with various states of dentition. Based on their anatomic situation, the ability of these patients to reduce test food particles was expected to be poor (6, 23). The pre-treatment results on the chewing test in our study (i.e. in patients with considerable problems with retention and stability) were comparable with those from of Fontijn-Tekamp *et al.* (23) in which patients were studied with a mandibular bone height between 14 and 23 mm without such complaints. An explanation could be that the lower denture rests on flat bony structures in patients with an extremely resorbed mandible, whereas patients with less resorption often present with a remaining knife edged shaped alveolar ridge, causing more pain during the chewing of (test) food because of pressure on the thin mucoperiosteum on top of the residual ridge. Moreover, the patients in our trial had been edentulous for a very long time (mean edentulous period 30 years), making them 'experienced' denture wearers (24). This could be a contributing factor to their relatively good masticatory performance.

In the present study, masticatory function was assessed before and after treatment, while many previous studies report only post-treatment results (21, 23). This latter design only permits cross-sectional analysis of treatment strategies, which introduces a risk of drawing erroneous conclusions. This is illustrated by the finding of significant differences between the treatment groups in masticatory performance (median particle size ×50) before treatment, which was a coincidence because masticatory variables were not

included in the balancing criteria during the allocation procedure. The improvement to comminute (test) food following the treatment was apparent in the 20 chewing strokes test. When analysing the difference score (i.e. T0 versus T1) there was a significant difference between the three groups with respect to the 60 chewing strokes test. It is likely that the significant differences between the groups at baseline (T0) explain this finding. Probably because of their relatively good performance at baseline (T0), there was no significant improvement (T0 versus T1) in particle size reduction within group III.

Patients in group I (TMI) received mainly implant-supported overdentures (with five clips), while patients in groups II and III were provided with an implant-mucosa-borne overdenture (with three clips). Nevertheless, masticatory function in group I did not significantly differ from that in groups II and III, respectively. Apparently, the two cantilevers and clips did not enhance masticatory function. This implies that stabilization rather than support or retention of the implant-retained mandibular overdenture is the dominant factor in the observed improvement of masticatory function. An additional explanation could be the limiting retention and/or stability of the maxillary denture. These results are in accordance with the study of Fontijn-Tekamp (25), although in a cross-over study described by Tang (12) patients preferred a (mainly) implant-supported overdenture. This preference was reflected in the present study by the significantly decreased effort the patients in group I (mainly implant supported) needed to chew the test food after treatment.

There was only a weak relationship between the results of the masticatory performance test and the appreciation of masticatory function by the patients. Predicting masticatory performance from the subjective chewing ability or vice versa appears to be hazardous. From this study, it can be concluded that the perception of patients of their chewing ability is not related to their ability to comminute test food. This is in accordance with other studies where only weak relationships could be detected between patient-based and laboratory assessed parameters (6, 7, 21).

Although the mandibular height was restored in patients treated with an autologous bone graft in combination with endossous implants (group II), this did not appear to result in significant differences in masticatory function when compared with the other two treatment groups. As there were no significant differences in masticatory function between the three treatment groups, the implant treatment protocol does not appear to be decisive for the masticatory rehabilitation of the patient with an extremely resorbed mandible.

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