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Masticatory Function with Implant-supported Overdentures

ABSTRACT

The type of attachment that is used in implant-supported mandibular overdentures may influence the retention and stability of the prosthesis and, thus, masticatory function. In this within-subject cross-over clinical trial, we examined the hypothesis that greater retention and stability of the overdenture improve the masticatory function. Eighteen edentulous subjects received 2 oral implants, a new overdenture, and, successively, 3 different suprastructure modalities: magnet, ball, and bar-clip. Masticatory performance, masticatory efficiency, and swallowing threshold were measured. The masticatory function significantly improved after implant treatment with each of the 3 attachments. We observed small differences in masticatory function among the 3 attachment types: slightly better masticatory performance with ball and bar-clip than with magnet attachments. The number of chewing cycles until swallowing hardly decreased after implant treatment. We conclude that significantly better masticatory performance, combined with a slightly smaller number of chewing cycles after implant treatment, results in smaller food particles being swallowed.

KEY WORDS: masticatory performance, swallowing threshold, oral implant, mandibular overdenture, attachment.

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INTRODUCTION

Complete-denture wearers frequently report problems with oral function, typically caused by retention and stability problems of the mandibular prosthesis. Masticatory function of these subjects is quite poor in comparison with that of healthy dentate subjects (Slagter *et al.*, 1993; Fontijn-Tekamp *et al.*, 2000). Complete-denture wearers need up to 7 times more chewing strokes than subjects with a complete natural dentition to reduce the food to half of the original particle size. Oral function significantly improves after mandibular implant overdenture treatment. Most studies on implant treatment and oral function showed a significant improvement of the objective masticatory performance in the mandible (Haraldson *et al.*, 1988; Geertman *et al.*, 1994, 1999; Pera *et al.*, 1998; Fontijn-Tekamp *et al.*, 2000; Bakke *et al.*, 2002). Subjects with mandibular implant-supported overdentures need 1.5 to 3.6 times fewer chewing strokes than complete-denture wearers to obtain an equivalent reduction in food particle size (Geertman *et al.*, 1994). However, in another study, no significant advantage in masticatory performance was found for implant-supported overdentures compared with conventional dentures (Garrett *et al.*, 1998).

The degree of mandibular overdenture support, 2 *vs.* 4 implants (Geertman *et al.*, 1994), or fixed *vs.* removable prostheses (Feine *et al.*, 1994; Tang *et al.*, 1999) did not influence the masticatory performance. Nevertheless, the attachment type in implant-supported mandibular overdentures may influence the retention and the stability, and thus the oral function, of the prosthesis. This aspect has never been studied within the same subjects. Therefore, we designed a within-subject cross-over clinical trial to study the effects of 3 mandibular implant overdenture suprastructure modalities using magnet, bar-clip, and ball attachments. We demonstrated that maximum bite force nearly doubles after implant treatment with these 3 suprastructure modalities, while no significant differences in maximum bite force occur among the 3 attachment types (van Kampen *et al.*, 2002). How this affects masticatory function remains unclear.

The aim of the present study was to test the hypothesis that mandibular conventional denture treatment, implant-supported overdenture treatment, and attachment type affects masticatory performance and efficiency as well as swallowing threshold. Therefore, we measured these variables in 18 subjects before and after treatment with 2 oral implants in the mandible using the 3 suprastructure modalities. These suprastructures were worn successively in a randomized order by all subjects, so we could make a within-subject comparison of the masticatory function obtained with the 3 attachment types.

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MATERIALS & METHODS

Subjects

Eighteen edentulous subjects from the Royal Dutch Army and Air Force participated in this randomized cross-over clinical trial. They were referred to the Center for Special Dental Care at the Central Military Hospital in Utrecht because of persistent complaints with their conventional mandibular dentures. The group consisted of one female and 17 male subjects with a mean age of 51.6 yrs (range, 33 to 56 yrs), all fit for military service. This cohort of subjects is a convenience sample. They had been edentulous in the mandible for an average of 18 yrs and had worn, on average, 3 mandibular dentures. Their bone height in the inter-foraminal region of the mandible exceeded 15 mm. The Ethics Committee of the University Medical Center approved the protocol. Written informed consent was obtained from each subject after a full explanation of the clinical trial.

Surgical and Prosthetic Procedures

The subjects received 2 oral implants (Frialit-2, Friadent, Friedrichsfeld, Germany; diameter, 3.8 mm; length, 13 or 15 mm). The implants were placed in the region of the 2 former cuspids, according to a standardized two-stage surgical protocol. New conventional dentures in the maxilla and mandible were made following first-stage surgery. The dentures were made in centric occlusion with balanced articulation and anatomically shaped acrylic teeth (Bonartic, Ivoclar, Schaan, Liechtenstein). In each quadrant, 1 bicuspid and 2 molars were used. Subjects started to wear their new dentures without attachment 2 mos after first-stage surgery, for a three-month period. After second-stage surgery, 5 mos after implantation, the mandibular dentures were successively fitted with magnets (Dyna Magnet ES, Dyna Dental Engineering, Bergen op Zoom, the Netherlands), bar-clips (IMZ, Friadent Friedrichsfeld, Germany), or ball (Frialit-2, Friadent Friedrichsfeld, Germany) attachments. The sequence in which the 3 attachments were applied was randomized (van Kampen *et al.*, 2002). All 6 possible sequences were used, so that possible cross-over effects could be studied. In that way, 6 groups of three subjects were formed, each group having a different sequence of successive attachments. Each attachment type was used during a three-month period.

Masticatory Function and Swallowing Threshold

We measured the masticatory function of all subjects by asking them to chew on cubes of a dental impression material. This material (Optosil plus, Bayer AG, Leverkusen, Germany) was specially prepared to make it more brittle, so that it could be fragmented by all participants (Fontijn-Tekamp *et al.*, 2004). The subjects chewed on portions of 17 cubes with an edge size of 5.6 mm (approximately 3 cm^3) for 15 and 30 chewing strokes. We determined the degree of fragmentation of the chewed food portions by sieving the food through a stack of 8 sieves, with square apertures between 5.6 and 0.5 mm and a bottom plate. The degree of fragmentation of the food (chewing performance) is given by the median particle size, X_{50}, which is the aperture of a theoretical sieve through which 50% of the weight of the comminuted food could pass (van der Bilt *et al.*, 1993). The number of chewing strokes needed to halve the initial median particle size (chewing efficiency), denoted as $N_{1/2}$, was calculated from the initial size and the size after 15 and 30 chewing strokes (van der Bilt *et al.*, 1987).

We examined the swallowing threshold by having the subjects chew on a piece of breakfast cake. The subjects chewed the breakfast cake (4 g; size 20 x 20 x 20 mm) normally and swallowed it. The examiner counted the number of chewing strokes needed until swallowing occurred. This measurement was performed twice, and the number of chewing strokes was averaged for each subject.

Procedure

We measured the masticatory performance and the swallowing threshold at 5 moments during the 14-month treatment period. The first measurement was performed with the old denture, just prior to the first-stage surgery. The second measurement was performed just prior to the second-stage surgery, after the newly made denture without attachments had been used for 3 mos. We performed the next 3 measurements at the end of each three-month period during which the various attachment types were incorporated into the dentures.

Statistical Analysis

We applied repeated-measures analysis of variance (ANOVA) to test the null hypothesis that there would be no statistical difference between the results obtained at the 5 occasions. Subsequently, *post hoc* tests (least significant difference multiple-comparison test) were used for pairwise comparisons of results. Pearson correlations were calculated between the change in masticatory performance due to the treatment and the masticatory performance with the old denture.

RESULTS

Masticatory Performance

Values of the average median particle sizes after 15 and 30 chewing cycles (masticatory performance) are listed for the 5 measuring moments (Table). Repeated-measures ANOVA showed a significant effect ($p < 0.001$) of the 5 situations—old and new dentures, and dentures attached with a magnet, bar-clip, or ball attachment—on median particle size after 15 and 30 chewing cycles. *Post hoc* analysis showed that the median particle size obtained with the unsupported new denture was significantly larger than that for the old denture ($p < 0.05$). The masticatory performance significantly improved with the implant-supported new denture in comparison with that of the old and new dentures without implant support ($p < 0.001$). The masticatory performance obtained with the magnet attachment

Table. Masticatory Function of 18 Subjects Wearing Unsupported and Implant-supported Dentures

Attachment	Denture	Performance $X_{50}(15)$ (mm)[a]	Efficiency $X_{50}(30)$ (mm)[b]	Swallowing $N_{1/2}$[c]	$N_{swallow}$[d]
None	old	4.5 ± 0.8[e]	3.3 ± 0.7	47.0 ± 23.9	35.5 ± 13.7
None	new	4.9 ± 0.9	3.5 ± 0.8	50.9 ± 23.9	32.3 ± 13.9
Magnet	new	3.9 ± 0.9	2.7 ± 0.8	32.7 ± 22.2	28.8 ± 9.7
Bar-clip	new	3.7 ± 0.5	2.4 ± 0.4	24.6 ± 6.0	29.1 ± 14.9
Ball	new	3.6 ± 0.6	2.4 ± 0.5	25.5 ± 12.9	31.6 ± 10.8

a Median particle size after 15 chewing cycles.
b Median particle size after 30 chewing cycles.
c Number of chewing cycles needed to halve the initial size of the artificial test food.
d Number of chewing cycles needed to prepare the breakfast cake for swallowing.
e Values are means ± standard deviation.

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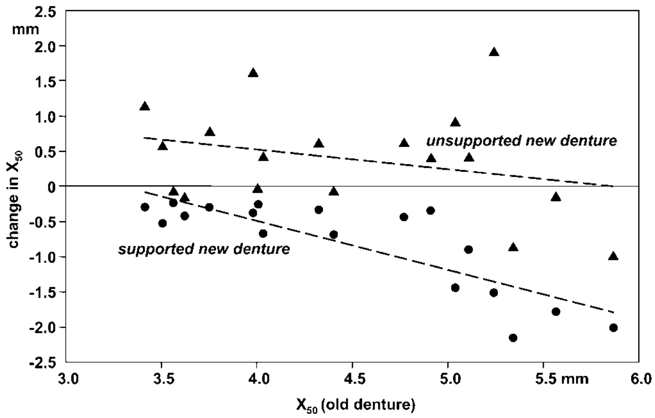

Figure. Changes in the median particle size for the unsupported (triangles) and supported new dentures (bar-clip attachment; circles) as compared with the old denture are plotted as a function of the median particle size (X_{50}) obtained with the old denture for 18 subjects. The results were obtained after 15 chewing cycles. Linear regression is indicated by the dashed lines. The changes in median particle size due to implant treatment and the median particle size before treatment were significantly correlated for the bar-clip and ball attachments (both p-values < 0.001) and for the magnet attachment ($p < 0.05$).

was less effective than that with the bar-clip and ball attachments ($p < 0.05$), whereas no differences were observed between performances with the bar-clip and ball attachment.

The individual changes in the median particle size after 15 chewing cycles for the unsupported and supported new denture as compared with the old denture are shown as a function of the median particle size obtained with the old denture (Fig.). The majority of the subjects had larger median particle sizes, thus poorer masticatory performance, with the unsupported new denture than with the old denture, whereas all subjects had smaller median particle sizes when the new denture was supported by the bar-clip attachment. Similar results were obtained for the magnet and ball attachments but are not shown so that congestion of data points can be avoided. A significant correlation between the change in median particle size and the median particle size, as obtained with the old denture, was observed when the new denture was supported by the bar-clip and ball attachment ($r = -0.8$; $p < 0.001$) and by the magnet attachment ($r = -0.5$; $p < 0.05$) for the measurements after 15 and 30 chewing cycles.

Masticatory Efficiency

Values of the average number of chewing cycles needed to halve the initial size (masticatory efficiency) are listed for the 5 measuring moments (Table), which did not significantly change from old to new dentures. However, a significant decrease occurred after implant treatment: from 50 to 25 for the bar-clip and ball attachments ($p < 0.001$) and to 33 for the magnet attachment ($p < 0.005$).

Swallowing Threshold

The numbers of chewing strokes that subjects needed before they swallowed a piece of breakfast cake were tracked (Table). Repeated-measures ANOVA showed a significant effect ($p < 0.05$) for the 5 situations on the swallowing threshold. *Post hoc* analysis showed that the number of chewing cycles until swallowing with the old denture was slightly larger than with the supported new denture ($p < 0.10$ for all 3 attachments).

DISCUSSION

Masticatory Function

Masticatory performance deteriorated significantly when the old dentures were replaced by new dentures without attachments. Eleven out of 18 subjects had larger median particle sizes, thus poorer masticatory performance, after the old dentures were replaced with unsupported new dentures (triangles in Fig.). The reduction in masticatory performance did not lead to a significant increase in the number of chewing cycles needed to halve the initial size, although some increase was observed (Table). In a previous study, we observed a reduction of about 20% in the maximum bite force after denture treatment (van Kampen *et al.*, 2002). This bite force reduction may be caused by mucosal soreness above the submerged implants and adjustment of the subjects to new dentures. Significant correlations between maximum bite force and masticatory performance were reported (Fontijn-Tekamp *et al.*, 2000). Thus, the reduced maximum bite force may partly explain the reduced masticatory performance. Deterioration of masticatory performance after denture treatment has been commonly observed (Lundquist *et al.*, 1986; Garrett *et al.*, 1996).

After the new overdenture was attached to the oral implants, we observed a significant improvement in masticatory function. All subjects chewed the food better, and thus achieved smaller median particle sizes after 15 as well as 30 chewing cycles. This is reflected in negative values for the change in median particle size for the supported new denture (circles in Fig.). We observed a significant negative correlation between the change in median particle size due to implant treatment and the median particle size obtained with the old denture. This means that the improvement in masticatory performance that can be expected depends on the masticatory performance before treatment. Subjects with a relatively large median particle size before treatment (bad chewers) benefited more from the implant treatment than did subjects with a smaller median particle size (good chewers). The negative correlation could be attributed to a so-called 'regression to the mean', where relatively large values obtained in the first measurement have a larger chance to be smaller in the second measurement, and *vice versa.* However, in a study on 81 healthy dentate subjects, where we measured the median particle size on 2 occasions with a three-month time interval, there appeared to be no significant correlation between the change in median particle size and the median particle size at the first measurement ($r = -0.19$; $p = 0.08$, unpublished observation). In a study on the effect on oral function of optimizing a denture, the subjects with the poorest pre-treatment values also benefited the most (Lundquist *et al.*, 1986).

The improvement in masticatory efficiency obtained with the magnet attachment was smaller than with the bar-clip and ball attachments. The number of chewing cycles needed to halve the initial size was 33 with the magnet *vs.* 25 with the bar-clip and ball attachments. We observed a similar trend in maximum bite force (van Kampen *et al.*, 2002). The maximum bite force obtained with the magnet attachment was significantly smaller than the force obtained with the ball attachment. This lower force may be caused by the much smaller retention force of the denture with the magnet

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attachment (van Kampen *et al.*, 2003). The lower retention of the mandible and the smaller resistance against horizontal movement (although the latter was not actually measured), in combination with the conventional maxillary denture, may lead to less denture stability during chewing and thus to a reduced masticatory performance. Indeed, subjects who received mandibular overdentures with magnet attachments preferred a more retentive solution because of the denture instability they experienced (Naert *et al.*, 1999).

Swallowing Threshold

The effect of implant treatment on the swallowing threshold was limited. The number of chewing cycles needed to prepare the food for swallowing with the implant-supported overdenture was only slightly smaller than with the old denture ($p < 0.10$). Since the masticatory performance increased significantly ($p < 0.001$), and the number of chewing cycles until swallowing hardly changed, we may conclude that, after implant treatment, the food is better-chewed before it is swallowed. This may have a positive effect on the digestion of the food. Indeed, improvement of the nutritional state of edentulous people was observed after mandibular overdenture treatment (Morais *et al.*, 2003). However, successful prosthetic treatment does not necessarily result in a satisfactory diet (Hamada *et al.*, 2001; Allen and McMillan, 2002; Shinkai *et al.*, 2002), so dietary advice will be needed if subjects are to take advantage of the improved masticatory performance.

We conclude that mandibular implant overdenture treatment, opposing conventional maxillary dentures, results in significantly better masticatory function. Only small differences in masticatory function were observed among the magnet, bar-clip, and ball attachments. The improved masticatory function after implant treatment resulted in food that was better-chewed when it was swallowed.

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