Masticatory performance improves after maxillary overdenture treatment: a 1-year randomized controlled trial
Abstract

**Background** The effect of maxillary overdentures on masticatory performance in edentulous patients with complaints regarding their conventional maxillary dentures is unknown.

**Purpose** To assess the change in objective masticatory performance (mixing ability index, MAI), patient reported masticatory performance (questionnaire) and patient satisfaction (GSS) after maxillary overdenture treatment with either locator attachments or bars.

**Material and methods** Two groups randomly received four-implant maxillary overdentures on either locator attachments (group I, n=25) or bars (group II, n=25). The MAI, questionnaire and GSS were scored before (T0) and 12 months (T12) after treatment.

**Results** After treatment, both groups had significantly better MAI outcomes, better questionnaire scores and better GSS. Post-treatment questionnaire scores and GSS were significantly better for group II. Before treatment a strong, positive correlation between the MAI and the questionnaire was found for all patients who had had full conventional dentures combined (group I, n=17; group II, n=3).

**Conclusions** Mixing ability was the same for all the patients treated with maxillary overdentures on either locator attachments or bars. Patient reported masticatory performance and satisfaction was better for patients treated with maxillary overdentures on bars. There was a correlation between MAI and patient reported masticatory performance in patients with full conventional dentures.
Introduction

When patients are provided with conventional dentures, improvements are reported with regard to aesthetics, comfort and speech, but the improvement in masticatory performance is often unsatisfactory and patient satisfaction is thereby often rather low (1). A common way to try to improve masticatory performance and patient satisfaction is to place implants to retain a mandibular (2,3) and/or maxillary (4,5) denture. It has been shown that patients treated with implant-retained mandibular overdentures can chew better, (6,7) need fewer chewing cycles (8) and can eat hard food better (9) than patients with conventional dentures. Also masticatory performance and bite force are improved by overdenture treatment, but neither of them work at the same level as individuals with natural dentitions (10). However, no studies have assessed the masticatory performance of a full set of maxillary and mandibular overdentures yet (1,6,8,9,11).

A variety of methods are used to measure masticatory performance and the degree of breakdown can be measured using real test foods (peanuts, carrots, etc.) (6,12,13) or artificial materials (e.g., Optosil® and Optocal®) (14,15). The consistency of the latter two materials is more standardized than that of real test foods. Studies have shown that subjects with a compromised oral function are not always able to fragment the real or artificial test food; their maximum bite force can be below the force needed to break the test food particles. Other methods to assess masticatory performance include the evaluation of: mandibular border movements during chewing and chewing patterns(16); swallowing threshold(2); jaw muscle activity and maximum bite force(8); blood plasma levels of homocysteine, vitamin B12, vitamin B6, albumin, serum folate and C-reactive protein concentrations; questionnaires to rate the difficulty associated with chewing foods of various textures (1); body mass index (11,17); and two-coloured gum mixing ability tests (9,11). Of all these tests, the two-coloured wax mixing ability test is much better at discriminating between people with compromised masticatory performance (18). Therefore, this test was chosen for the current study.

As mentioned above, no studies have assessed the masticatory performance of a full set of maxillary and mandibular overdentures (1,6,8,9,11). Therefore, the aim of our study was to assess the objective
masticatory performance (mixing ability test), the patients’ reported (subjective questionnaire) masticatory performance as well as the patient satisfaction (general satisfaction score) with the provided maxillary implant-retained overdentures one year after placement. These parameters were assessed for two groups of patients from a randomized controlled trial (RCT) about the treatment outcome of maxillary overdentures on a bar attachment system or a solitary attachment system (Locator®; Zest Anchors Inc., Escondido, Calif).

Material and methods
Patient population
Between January 2013 and January 2016, a total of 50 consecutive patients were approached and included in this randomized controlled trial with parallel design at the Department of Oral and Maxillofacial Surgery (University Medical Centre Groningen, The Netherlands (UMCG)). All the patients were referred to the UMCG because of persistent complaints regarding their conventional maxillary dentures. The patients in our trial had to have been edentulous in the maxilla for at least one year and they had to have sufficient bone volume to place the implants. All the subjects received a written explanation of the study and written informed consent was obtained from each patient after a further explanation in person of the clinical trial. The study was approved by the Medical Ethical Committee of the UMCG (ABR NL43293.042.13) and was registered in the Netherlands National Trial Register (NTR3813). The patients were randomly divided into two groups by the means of sealed envelopes. Group I: patients receiving maxillary overdentures on a locator attachment system (n=25); Group II: patients receiving maxillary overdentures on a bar attachment system (n=25). GCB generated the random allocation sequence, enrolled participants and assigned participants to interventions.

Surgical and prosthetic procedures
All the surgical procedures were performed by one oral and maxillofacial surgeon (GMR) at the UMCG. The prosthetic procedures were accomplished by one prosthodontist (HJAM). Manufacturing of the superstructure was done by a single experienced dental laboratory. All the patients received 4 dental implants (NobelActive™ Narrow Platform (Nobel Biocare USA, LLC, Yorba Linda, CA, USA)) in the maxillary anterior region (group I and II). Patients who were fully edentulous before treatment had
two mandibular implants (NobelReplace™ Select TC (Nobel Biocare USA, LLC, Yorba Linda, CA, USA)) placed simultaneously as the ones in the maxilla (17 patients in group I and 3 patients in group II). The implants in the maxilla were placed according to a two-stage surgical protocol.

After a 3-month osseointegration period, second stage surgery was performed and healing abutments were placed and the prosthetic procedures were initiated. A bilateral balanced occlusion concept was followed. The final superstructure consisted of a locator attachment system (group I) or a milled titanium egg-shaped bar with distal extensions, screw-retained to abutments (group II), and an overdenture with, respectively, Locator® male self-aligns and pivots (group I) or a cobalt chromium reinforcement structure and gold retentive clips (19) (group II). Regarding the locator attachments, the nylon male elements are available in different color-coded designs with different retention forces (blue 6.7 N [light], pink 13.4 N [medium], and clear 22.3 N [strong]). In the present study, all the patients were initially provided with pink inserts, providing possibilities for strengthening or loosening the retention force. The maxillary overdentures were designed with full coverage of the alveolar process, but without palatal coverage. The superstructures of the maxillary and mandibular overdentures placed in fully edentulous patients were the same whereby both overdentures had either a bar attachment system or locator attachments.

Outcome measures
The primary outcome measure of this analysis was masticatory performance by means of the mixing ability test. The secondary outcomes were self-reported masticatory performance (for details of the tests see below) and patient satisfaction according to their general satisfaction score. All the parameters were scored before treatment and 12 months after placement of the overdenture. All the measurements were done by one researcher (GCB) not involved in the treatment of the patients.

Mixing ability test
The mixing ability test (18,20) measures how well a subject mixes a tablet (diameter 20 mm), which consists of a red and a blue wax layer (3 mm each), after 20 chewing strokes. The wax tablets were offered to the subjects at room temperature (20°C). The chewed wax was rinsed,
dried and stored. To measure the amount of mixing, the chewed wax was brought up to a temperature of 28°C and placed between two sheets of stiff and clear foil. The sandwich of foil and wax was pressed between two thick brass plates to a thickness of 2.0 mm. Then, both sides of the wax were optically scanned using a high-quality scanner (Epson® V750, Long Beach, CA, USA.). The images of the wax were processed using Adobe Photoshop, CS3 extended (Adobe, San Jose, CA, USA.). The spread of the colour intensities in the combined image of both sides is the measure of mixing. If the wax tablet has not been chewed, one side is red and the other is blue (Figure 1), and the spread of the intensities of both colours is maximal. Chewing the tablet mixes the colours, whereupon first intermediate intensities appear and the more the tablet is chewed (Figure 2), the more the spread of the intensities decreases. So, a high spread intensity of, for example, 30 is caused by the red and blue layers of the wax tablet being badly mixed, which means a low mixing performance. This spread is referred to as the mixing ability index (MAI).

Figure 1. Pristine wax tablet

Masticatory performance questionnaire
All the patients were asked to complete a masticatory performance questionnaire.(21) In this questionnaire, patients have to rate their opinion about their ability to chew nine different food items on a 3-point rating scale (0 = good, 1 = moderate, 2 = bad). The items were grouped into three categories: (1) ‘soft food’ (boiled vegetables and potatoes, crestless bread, minced meat); (2) ‘tough food’ (crusty bread, steak, Gouda cheese); (3)
Figure 2. Wax tablets with various degrees of mixing after chewing ‘hard food’ (apple, carrot, peanuts). The category total score and each item’s total score were reported. The maximum score was 18 points.

Patient satisfaction
Patient satisfaction with the maxillary overdenture was measured with a general satisfaction score ranging from 0 to 10, with 0 representing a bad outcome and 10 a good outcome.

Data analysis
Inter-group differences with regard to the scores of the mixing ability test (continuous data) were analysed using the student T-test. Intra-group differences for the scores of the mixing ability test before and 1 year after treatment were analysed with paired sample t-tests.

The results of each group’s masticatory performance questionnaires and general satisfaction scores (ordinal data) were analysed with a Wilcoxon Matched Pairs Signed Ranks test. Inter-group differences were analysed by applying the independent samples Mann-Whitney U test.

Spearman’s correlation was used to determine the relationship between the total score of the masticatory performance questionnaire and the MAI outcome. A p-value of less than 0.05 was considered statistically significant. Pairwise deletion was used for missing data. All analyses were performed with the SPSS 23.0 software (SPSS, Inc., Chicago, IL, USA).
Results
Fifty patients with a mean age of 62.4±7.3 years (range 37.5-75.0 years) were initially included in this study. 25 were placed in group I and 25 in group II (both groups 13 male/12 female patients, mean age group I 60.1±8.6 years (range 37.5 – 75.0 years), mean age group II 63.8±5.4 years (range 53.0 – 72.6 years)). Then, two patients deceased before the 1-year follow up and one patient was lost to follow-up (moved without leaving an address). Consequently, 47 patients were available for the 1-year evaluation: 23 patients in group I and 24 patients in group II. Pairwise deletion was used for missing data and inter-group comparisons. List-wise deletion was used for missing data and intra-group comparisons.

Three patients in group I lost one implant during the osseointegration phase (96.9% survival). Two patients in group II lost one implant during the osseointegration phase (98.0% survival). We decided to continue and used the remaining three implants for the construction of the superstructure. One patient in group I requested to replace the lost implant after three months of functioning with the overdenture on three implants.

Objective mixing ability test
Both groups had significantly better post-treatment than pre-treatment MAI outcomes (Table 1). There was no significant difference in the amount of improvement between the groups (Table 1). Also, there was no significant difference in pre- and post- MAI outcomes between the groups (Table 2).

Patient reported questionnaire
Both groups had significantly better post-treatment scores on the masticatory performance questionnaires compared to the pre-treatment ones; both groups’ ability to chew soft, tough and hard foods had improved significantly (Table 1). However, there was a significant difference between the groups in the amount of improvement at the scores on the masticatory performance questionnaires and the ability to chew hard foods, in favour of group II (Table 1).

There was no significant difference between both groups’ total scores on the pre-treatment masticatory performance questionnaires. There was a significant difference between the groups’ post-treatment total scores and
Table 1. Mean and standard deviation (SD) of the outcomes of the mixing ability index (MAI) and median and inter-quartile range (Q1 – Q3) of the total score and the scores on of the three items of the masticatory performance questionnaire (MPQ); and of the general satisfaction score (GSS) before (T0) and after treatment (T12); difference in score between T0 and T12; and comparative analyses.

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th></th>
<th>Group II</th>
<th></th>
<th>Group I Difference in score between T0 - T12</th>
<th>Group II Difference in score between T0 - T12</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T0, n = 25</td>
<td>T12, n = 23</td>
<td>T0, n = 25</td>
<td>T12, n = 24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MAI</strong></td>
<td>20.5 (3.4)</td>
<td>18.0 (1.7)</td>
<td>20.2 (3.5)</td>
<td>17.8 (2.6)</td>
<td>0.001**,a</td>
<td>2.5 (3.4)</td>
<td>0.917a</td>
</tr>
<tr>
<td><strong>Total score MPQ</strong></td>
<td>8 (4-14)</td>
<td>4 (2-7)</td>
<td>9 (8-12)</td>
<td>0 (0-3)</td>
<td>0.001**,b</td>
<td>4 (1-9)</td>
<td>8 (6-10)</td>
</tr>
<tr>
<td><strong>Soft food</strong></td>
<td>1 (0-5)</td>
<td>0 (0-1)</td>
<td>2 (1-3)</td>
<td>0 (0-0)</td>
<td>0.003**,b</td>
<td>1 (0-4)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td></td>
<td>1 (1-4)</td>
<td>0 (0-1)</td>
<td>2 (1-3)</td>
<td>0 (0-0)</td>
<td>0.003**,b</td>
<td>1 (0-4)</td>
<td>2 (1-2)</td>
</tr>
<tr>
<td><strong>Tough food</strong></td>
<td>6 (4-6)</td>
<td>3 (2-6)</td>
<td>5 (5-6)</td>
<td>0 (0-2)</td>
<td>0.007**,b</td>
<td>1 (0-4)</td>
<td>5 (3-6)</td>
</tr>
<tr>
<td></td>
<td>4 (1-6)</td>
<td>8 (7-9)</td>
<td>4 (2-6)</td>
<td>9 (8-10)</td>
<td>0.000**,b</td>
<td>4 (2-6)</td>
<td>5 (4-7)</td>
</tr>
<tr>
<td><strong>Hard food</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>GSS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*: p<0.05; **: p<0.01; ***: p<0.001; a: paired samples t-test; b: Wilcoxon Matched Pairs Signed Ranks test
their ability to chew hard, tough and soft foods in favour of group II (Table 2).

**General satisfaction score**
Both groups had a significantly better general satisfaction post-treatment than pre-treatment score (Table 1). There was no significant difference in the amount of improvement between the groups (Table 1).

The inter group pre-treatment general satisfaction scores were not significantly different. The inter group post-treatment general satisfaction scores were significantly different, in favour of group II (Table 2).

**Table 2.** Mean and standard deviation (SD) of the outcomes of the mixing ability index (MAI) and median and inter-quartile range (Q1 – Q3) of the total score the scores of the three items of the masticatory performance questionnaire (MPQ); and of the general satisfaction score (GSS) before (T0) and after treatment (T12). A comparative inter-group analysis.

<table>
<thead>
<tr>
<th></th>
<th><strong>Group I</strong></th>
<th><strong>Group II</strong></th>
<th><strong>p-value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>MAI - T0</td>
<td>20.5 (3.4)</td>
<td>20.2 (3.5)</td>
<td>0.779a</td>
</tr>
<tr>
<td>Total score MPQ – T0</td>
<td>8 (4-14)</td>
<td>9 (8-12)</td>
<td>0.783b</td>
</tr>
<tr>
<td><strong>Soft food – T0</strong></td>
<td>1 (0-5)</td>
<td>2 (1-3)</td>
<td>0.933b</td>
</tr>
<tr>
<td><strong>Tough food – T0</strong></td>
<td>1 (1-4)</td>
<td>2 (1-3)</td>
<td>0.792b</td>
</tr>
<tr>
<td><strong>Hard food – T0</strong></td>
<td>6 (4-6)</td>
<td>5 (5-6)</td>
<td>0.822b</td>
</tr>
<tr>
<td>GSS – T0</td>
<td>4 (1-6)</td>
<td>4 (2-6)</td>
<td>0.607b</td>
</tr>
<tr>
<td>MAI - T12</td>
<td>18.0 (1.7)</td>
<td>17.8 (2.6)</td>
<td>0.628a</td>
</tr>
<tr>
<td>Total score MPQ – T12</td>
<td>4 (2-7)</td>
<td>0 (0-3)</td>
<td>0.001**,b</td>
</tr>
<tr>
<td><strong>Soft food – T12</strong></td>
<td>0 (0-1)</td>
<td>0 (0-0)</td>
<td>0.043*,b</td>
</tr>
<tr>
<td><strong>Tough food – T12</strong></td>
<td>0 (0-1)</td>
<td>0 (0-0)</td>
<td>0.016*,b</td>
</tr>
<tr>
<td><strong>Hard food – T12</strong></td>
<td>3 (2-6)</td>
<td>0 (0-2)</td>
<td>0.000***,b</td>
</tr>
<tr>
<td>GSS – T12</td>
<td>8 (7-9)</td>
<td>9 (8-10)</td>
<td>0.041*,b</td>
</tr>
</tbody>
</table>

*p<0.05, **p<0.01, ***p<0.001 Differences between study groups were tested with the independent Student’s t-test.

**Relation between patient reported (subjective) and objective masticatory performance**
A Spearman’s correlation was run to determine the relationship between the MAI outcome and the masticatory performance questionnaires’ total score.
The pre-treatment data (group I and II) demonstrated a statistically significant weak, positive monotonic correlation between the MAI outcome and the total score of the masticatory performance questionnaires ($rs = .38$, $n = 55$, $p = 0.002$).

The groups were combined and then split into patients with and patients without mandibular overdentures. The pre-treatment results of the patients with full conventional dentures gave a statistically significant, strong, positive monotonic correlation between the MAI outcome and the total score of the masticatory performance questionnaire ($rs = .61$, $n = 23$, $p = 0.001$). The pre-treatment results of the patients with mandibular overdentures gave no statistically significant correlation between the MAI outcome and the total score of the masticatory performance questionnaire ($rs = .18$, $n = 32$, $p = 0.160$).

There was no statistically significant post-treatment correlation between the MAI outcome and the total score of the masticatory performance questionnaire ($rs = .11$, $n = 50$, $p$ (one-tailed) 0.229).

**Discussion**

Wearing maxillary overdentures on four implants results in an improvement in objective masticatory performance, patient reported (subjective) masticatory performance and patient satisfaction one year after placement. There is a difference between maxillary overdentures with a bar attachment system or with a locator attachment system with regard to the patient reported masticatory performance and general satisfaction score in favour of the bar attachment system. There is no difference with regard to the objective masticatory performance.

As mentioned, the objective masticatory performance (mixing ability test) improved after treatment in both groups. This means that patients with maxillary overdentures can mix better than patients without maxillary overdentures, regardless of the type of attachment system. The patients of both groups also reported personally an improvement in masticatory performance after treatment, which means that both the patients’ objective and subjective results show that they can chew better.
To our knowledge no other study has measured the effect of maxillary overdenture treatment on mastication and so a comparison is not possible. However, studies of patients receiving mandibular overdentures with maxillary conventional dentures (3,7–9,22,23) reported that masticatory performance had improved after treatment, both objectively and subjectively which is in line with our results.

In the present study, there is no significant difference between group I and II in the post-treatment results for objective masticatory performance. This is in line with other literature comparing mandibular overdentures on bar attachments or locator attachment systems (8,24). However, the patients’ inter-group post-treatment subjective results for masticatory performance are significantly different. Patients in group I felt an improvement in mastication, but this improvement is smaller than the improvement in group II. Post-treatment three of the patients in group II reported problems with chewing soft or tough foods (highest score 2, maximum score 6) whereas nine patients in group I reported a problem with chewing soft foods and ten patients with chewing tough foods (highest score 6, maximum score 6). Resulting in significantly different post-treatment scores on the masticatory performance questionnaires and with the biggest difference seen for the ability to chew hard foods.

It must be noticed that all patient in group I not only had a locator attachment system for the maxillary overdenture on four implants, but also for the mandibular overdenture on two implants. It has been reported that the stability of a mandibular overdenture with a bar attachment system is better than that with a locator attachment system (25). The design of the pivoting locator male allows a resilient connection. The retentive nylon locator male remains in contact with the abutment socket while its titanium denture cap has a full range of rotational movement over the male. When using two implants this results in a non-rigid connection, when using more than two implants the denture cap will have no possibility to move over the male anymore. The smaller improvement in group I for the ability to chew hard foods might be due to the design of the mandibular overdenture.

The patients are very satisfied with the maxillary overdenture treatment as represented by the general satisfaction score (median of 8 and 9 on a 10 point scale). The score is comparable to earlier reported studies on
maxillary overdentures (5). There is a difference in general satisfaction between a maxillary overdenture on locator attachments or a bar attachment system. Post-treatment, the GSS for the bar attachment system is slightly higher than the GSS for the locator attachment. Additionally, the amount of improvement does not differ between the groups. Showing that the evidence for additional value of a maxillary overdenture on bars compared to a locator attachment system to achieve a higher GSS is not very strong. To the knowledge of the authors there are no other studies published with regard to GSS comparing bar and ball attachment systems for maxillary overdentures and therefore a comparison with other data is not possible.

There is a statistically significant positive monotonic correlation between the subjective and objective results for masticatory performance. This correlation is weak for the total group, but is strong when comparing the pre-treatment results of the patients with complete conventional dentures (without any implants). No statistically significant correlation can be found anymore after the treatment, indicating that the worse the masticatory performance the better the correlation between the MAI and the masticatory performance questionnaire. This finding is in line with an earlier published study (26).

An explanation for the lack in correlation in the group with better MAI scores could be that the mixing ability test was developed for measuring differences in masticatory performance for groups of subjects with compromised oral functions (18), and is less suitable for subjects with better masticatory performance (27). The same applies to the masticatory performance questionnaire; this questionnaire might not discriminate enough between patients with better masticatory performance, as seen by the relatively low post-treatment scores.

Another factor contributing to the correlation between objective and subjective masticatory performance could be that the lower maximum bite force due to pain is the main contributor to the bad reports of masticatory performance by complete denture wearers and not due to their impaired mixing ability (28). It has been found that a higher bite force results in better chewing efficiency (29,30). However this statement mainly refers to methods that evaluate masticatory performance with brittle test foods,
which are usually hard (31).

Patients with impaired masticatory performance often cannot chew hard foods at all. The method with a softer wax tablet makes the association between masticatory performance and maximum bite force less coherent, but it is certainly more representative of the type of food denture wearers eat (11).

**Conclusion**

Implant-retained maxillary overdentures improve mixing ability, patient reported masticatory performance and patient satisfaction. Regarding patient reported masticatory performance and patient satisfaction, a post-treatment difference is seen between maxillary overdentures with locator attachments or a bar attachment system, in favour of the bar attachment system. There is a correlation between objective outcomes and subjective reports from patients with full conventional dentures.
References


14. Edlund J, Lamm CJ. Masticatory


