Masticatory Function of Immediately Loaded Two-Implant Mandibular Overdentures: A 5-year Prospective Study

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Purpose: To treat mandibular edentulous patients by fitting immediately loaded two-implant overdentures via guided flapless surgery and evaluate their masticatory performance. Materials and Methods: Nineteen patients who presented with edentulous mandibles (mean age: 69.8 years; range: 60 to 85 years) at the Dental Hospital, Tokyo Medical and Dental University, were enrolled in this study. A newly fabricated complete denture was used as a radiographic guide. Computer planning followed the design procedure, and surgical guides were fabricated for each patient. Flapless surgery was performed using this guide, and two implants were placed in the canine positions. On the day of surgery, a removable overdenture supported by two ball attachments was fitted. Masticatory function was evaluated on the basis of masticatory performance with a color-changeable chewing gum, maximum occlusal force with an occlusal force meter, and occlusal contact area with an occlusal diagnostic system. Results: The masticatory performance significantly improved from 48 months after surgery. The maximum occlusal force significantly increased 24 months after surgery. The occlusal contact area significantly increased from 6 months after surgery. This prospective study indicated that maximum occlusal force and occlusal contact area significantly improved at a comparatively earlier period after implant surgery and were maintained for up to 5 years with the immediate loading of two-implant overdentures with stud attachments. However, masticatory performance took more time to improve than maximum occlusal force and occlusal contact area. Conclusion: According to this 5-year prospective study, masticatory performance, maximum occlusal force, and occlusal contact area showed significant improvement after 4 to 5 years, 2 years, and 6 months postsurgery, respectively. Int J Oral Maxillofac Implants 2019;34:1434–1440. doi: 10.11607/jomi.7565

Keywords: immediately loading, masticatory function, overdenture, prospective study, two-implant overdenture

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and inadequate nutrition. Poor masticatory performance has been shown to be correlated with poor denture satisfaction. Enhanced methods for quantitative assessment of masticatory performance would be useful with regard to the reliable evaluation of the success of dental prostheses. Complete denture wearers do not always exhibit improvement of masticatory performance with their new dentures. Many previous studies have reported improvement of masticatory performance and increased satisfaction or comfort during mastication after the application of implant overdentures. With regard to occlusal force and implant overdentures, one study that included very old patients wearing mandibular two-implant overdentures showed higher maximum occlusal force for two-implant overdenture wearers than for complete denture wearers, and in another study, implant overdenture wearers exhibited twice the occlusal force of complete denture wearers. On comparison of different types of attachments, improvements in masticatory efficiency obtained with bar-clip and ball attachments were higher than those obtained with magnet attachments, and maximum occlusal force was associated with ball attachments. With regard to masticatory performance, improvements determined via two-color paraffin wax were apparent 3 months after surgery involving fitting of the telescopic crown attachment–retained implant overdentures with early loading (within 1 to 3 weeks). It has also been reported that neuromuscular adaptation was close to that of subjects with healthy dentition after the fitting of conventionally loaded two-implant overdentures with a telescope in a 10-year follow-up study. In a study involving subjective assessment via a questionnaire, 66.9% of patients with complete dentures experienced more difficulty biting, and 75.7% experienced more difficulty chewing, whereas among patients with implant overdentures, 33.3% experienced more difficulty biting and 24.3% experienced more difficulty chewing. These improvements in masticatory function with implant overdentures are considered to be due to increased retention or stability achieved via the attachment of the implant. The two-implant overdenture is a useful and reliable treatment for mandibular edentulous patients, particularly with regard to improving masticatory performance.

Various loading protocols for mandibular implant overdentures have been investigated, and many positive outcomes, including successful osseointegration, have been demonstrated in previous long-term clinical studies using a conventional loading protocol. Recently, attempts have been made to reduce the time between the surgical phase and prosthesis insertion in order to increase satisfaction and achieve more rapid rehabilitation. Therefore, early or immediate loading of implant overdentures has been gaining preference recently.

With early or immediately loaded mandibular implant overdentures, sufficient peri-implant soft tissue, bone resorption, and implant stability have been observed in 2- and 3-year follow-up studies, and the survival or success rates reported in those studies were the same as those associated with conventionally loaded implant overdentures. In addition, there were no significant differences in patient satisfaction associated with the number of implants fitted. However, in one long-term study designed to evaluate the recovery of masticatory function associated with immediately loaded two-implant overdentures from 1 to 3 days after surgery, masticatory performance measured via artificial test food was not improved immediately after surgery. In that study, improvements in masticatory performance and muscle activity were only observed after 3 months of adaptation to the new denture.

The purpose of the present study was to treat mandibular edentulous patients by fitting of immediately loaded two-implant overdentures via guided flapless surgery and to evaluate their masticatory performance from 1 month to 5 years after surgery. The null hypothesis was that there would be no difference in the masticatory performance between the baseline (ie, prior to surgery, with a conventional complete denture) and at several time points following the immediately loaded two-implant overdenture procedure.

MATERIALS AND METHODS

The present prospective study was conducted with the approval of the Ethics Board of the Dental Hospital, Tokyo Medical and Dental University (TMDU), under the registration number 441 and released on the University Hospital Medical Information Network (UMIN) Center (UMIN-CTR Clinical Trial, Unique trial Number: UMIN000032836).

Participants

The participants were 19 patients who visited the Dental Hospital, TMDU, from 2009 to 2011, who were edentulous in the mandibular arch, and who were willing to have mandibular two-implant overdentures fitted. Exclusion criteria were uncontrolled systemic disease that did not meet the predetermined criteria aimed to avoid complications or deterioration due to the implant surgery, a past history of chemical cure or radiation therapy in the head and neck area, and a past history of treatment with bisphosphonates. Every patient received a verbal explanation and document about this prospective study and signed the letter of consent.
prosthodontist (M.K.) conducted all the prosthesis-related procedures, and the same implant specialist (D.S.) who was associated with the Dental Hospital, TMDU, placed all the implants. Details of the procedures used to fabricate two-implant overdentures have been reported previously by Sato et al. Therefore, the procedures are only summarized below in this paper.

**Before the Surgical Procedure**

All patients received new conventionally fabricated mandibular complete dentures before implantation. To prepare the radiographic guide, gutta percha was placed in the new complete dentures. The optimum position of the two implants (Nobel Speedy Groovy RP, Nobel Biocare) in the intraforaminal region was virtually simulated using a commercially available planning software application (Procera, Nobel Biocare). Each patient had a surgical guide (Nobel Guide, Nobel Biocare) fabricated for the implant surgery.

**Implant Surgical Procedures**

All surgical treatments were conducted with intravenous sedation induced via propofol. Lidocaine hydrochloride 2% was the local anesthetic that was injected through the guide hole of the surgical guide. Flapless surgery was conducted with a surgical guide by the Nobel Guide protocol. The surgical guide was placed in position with fastening screws, and the drilling was conducted with the guide sleeves. The drilling procedure was considered to occur with inserted torque of at least 35 Ncm, in response to the bone quality, hardness, and thickness. Two screw-threaded-type implants (Speedy Groovy, Nobel Biocare) were placed between the lateral incisor and canine positions. Following the insertion of implants, the ball abutments were positioned.

**Prosthetic Procedures**

On the operation day, the ball attachment (ball abutment and gold cap, Nobel Biocare) was positioned into the mandibular complete denture. First, the gold caps were tested in the ball abutment in the mouth. The back of the denture was trimmed with an acrylic bur to make space for the gold caps. The gold caps were intraorally placed into the mandibular denture with autopolymerizing resin (Unifast 3, GC) (Fig 2).

Patients were directed to retain the denture for the first week after the operation. For this time period, the operator wiped off the denture and implants thoroughly on alternate days. From 1 to 3 weeks after the operation, patients removed the dentures 3 times a day and brushed the implants. The patients wore the dentures at any time other than during brushing. The new implant overdentures were fabricated at 6 months after the operation.

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**Fig 1** Flow diagram of the treatment and assessment procedure.

**Fig 2** Fixing of gold caps to the denture.
Outcome
The outcomes investigated included objective masticatory performance, maximum occlusal force, and occlusal contact area. Each patient was examined at eight time points: before the insertion of implants with mandibular complete dentures (baseline), and then at 1, 6, 12, 24, 36, 48, and 60 months after surgery.

Masticatory performance was determined with a color-changeable chewing gum (Xylitol Masticatory Performance Evaluating Gum, Lotte), with a mastication-induced gradual color change from green to red. Patients were allowed to chew this gum 100 times a second using their preferred style of chewing. The chewed gum was then wrapped with polyethylene films and pressed between two glass plates to a thickness of 1.5 mm for measurements using a colorimeter (CR-13 Konica-Minolta Sensing). Masticatory performance was calculated using a Masticatory Performance Index specifically developed for the color-changeable chewing gum (MIPG).8

Vertical interocclusal forces were measured bilaterally with an occlusal force meter (GM10, Nagano Keiki). The strain gauge was positioned in the first molar region. Maximum occlusal force was recorded as the larger of the force measurements (N) obtained from the right and left sides.

Occlusal contact area was measured with pressure-sensitive sheets (Dental Prescale) and an image scanner (Occluzer FPD707). The patients clenched their teeth for 3 seconds on a centric occlusion, and occlusal contact area (mm²) was calculated via the scanner.

Statistical Analysis
The median masticatory performance scores, maximum occlusal force, and occlusal contact area and the corresponding scores at each time point were compared with the baseline as the control using Steel’s test. The baseline (control) performance scores were measured with the conventional complete denture used by the patients prior to the implant surgery. The significance level was set at $P < .05$. All statistical analyses were performed on a personal computer using statistical software (JMP 10, SAS Institute).

RESULTS
Participants
Nineteen participants (10 women, 9 men) with a mean age of 69.8 years (range: 47 to 83 years) had implant surgery. In the maxilla, 11 patients were edentulous and 8 had used a partial denture. According to the American College of Prosthodontists (ACP) classification system for complete edentulism,45 26% of the participants were class I, 11% were class II, 21% were class III, and 42% were class IV. During the initial healing period (1 to 2 months), two implants failed in two patients 1 month after surgery. One failed case involved prosthetic complications, as against the instructions, the patient had removed the denture for approximately 24 hours 2 days after surgery, and since the gum around the implant had swollen up, it was not possible to place the denture back into position, and gingival plastic surgery was needed. The other failed case involved a smoker with diabetes.

One year after surgery, one patient was unable to be followed up. Two years after surgery, one patient could not attend the hospital due to mental illness. Three years after surgery, one patient declined follow-up and dropped out of the study.

Masticatory Function
Table 1 shows the MIPG values. Masticatory performance measured via a color-changeable chewing gum was significantly improved at 48 and 60 months after surgery. Table 2 shows the maximum occlusal force values. Maximum occlusal force was significantly improved at 24, 36, 48, and 60 months after surgery. Table 3 shows the occlusal contact area values. Occlusal contact area was significantly improved at 6, 12, 24, 36, 48, and 60 months after surgery.

DISCUSSION
The null hypothesis was rejected for masticatory performance at 4 and 5 years after surgery, for maximum occlusal force from 2 to 5 years after surgery, and for occlusal contact area from 6 months to 5 years after surgery. Notably, however, the null hypothesis was accepted for early time points after surgery.

In the present study, the masticatory performance score had improved twofold 5 years after surgery. For edentulous individuals, regaining masticatory performance is a critical problem. A previous study had reported improvement of masticatory performance with the use of new complete dentures fabricated via conventional methods; however, a higher rate of improvement was observed in the present study. In a different study, masticatory performance improved significantly as measured using two-color paraffin wax cubes with conventionally loaded two-implant overdentures between 3 months and 1 year after implant overdenture insertion, while in another study, masticatory performance measured via artificial test food had improved significantly with immediate loading of two-implant overdentures at 3 months after insertion. These studies suggested that masticatory performance could be improved earlier with immediate loading of implant overdentures rather than...
conventional loading of implant overdentures. However, in the present study, masticatory performance was significantly improved 4 and 5 years after the insertion of immediately loaded two-implant overdentures. This difference may be due to the different methods used to evaluate masticatory performance. In the present study, color-changeable chewing gum was used for measuring masticatory performance; notably, patients with complete dentures can masticate the gum relatively easily, which might explain the high score with conventional dentures at baseline and no significant improvement in masticatory performance until 4 years after insertion of the two-implant overdentures. With other comminution-based methods or with the use of harder food instead of the color-changeable chewing gum for the assessment, masticatory performance may have been significantly improved at earlier time points. In addition, in a previous study, masticatory performance was affected not only by the retention and stability of mandibular dentures with attachment, but also by the retention and stability of maxillary dentures.\(^26\) In the present study, 42% of the subjects were dentate in the maxilla, which may have resulted in the relatively constant higher masticatory performance.

In the present study, the mean maximum occlusal force was 106 N for complete dentures before surgery, increased significantly at time points after 2 years, and ranged from 65 N to 354 N (mean: 205 N) at 5 years. The present results are concordant with those of a previous study in which patients wearing implant overdentures exhibited greater occlusal force than those wearing

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**Table 1** Masticatory Performance Measured Using Color-Changeable Chewing Gum

<table>
<thead>
<tr>
<th>Baseline</th>
<th>1 mo</th>
<th>6 mo</th>
<th>12 mo</th>
<th>24 mo</th>
<th>36 mo</th>
<th>48 mo</th>
<th>60 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>19</td>
<td>19</td>
<td>17</td>
<td>17</td>
<td>15</td>
<td>14</td>
<td>14</td>
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<tr>
<td>Mean</td>
<td>57.3</td>
<td>70.5</td>
<td>67.1</td>
<td>64.5</td>
<td>86.9</td>
<td>90.5</td>
<td>92.8</td>
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<tr>
<td>SD</td>
<td>30.9</td>
<td>35.1</td>
<td>36.6</td>
<td>26.6</td>
<td>32.2</td>
<td>49.4</td>
<td>26</td>
</tr>
<tr>
<td>Median</td>
<td>57.1</td>
<td>66</td>
<td>60.3</td>
<td>59.7</td>
<td>84</td>
<td>73</td>
<td>90.9</td>
</tr>
<tr>
<td>IQR</td>
<td>40.3, 72.4</td>
<td>45.9, 92.4</td>
<td>40.8, 94</td>
<td>43.7, 80.8</td>
<td>63.1, 110.6</td>
<td>56.3, 128.1</td>
<td>79.8, 98.9</td>
</tr>
<tr>
<td>P values</td>
<td>.73</td>
<td>.99</td>
<td>.97</td>
<td>.084</td>
<td>.25</td>
<td>.013*</td>
<td>.00020*</td>
</tr>
</tbody>
</table>

Baseline is before the insertion of implants with a mandibular complete denture. SD = standard deviation; IQR = interquartile range; mo = months after surgery. *Significant difference (P < .05).

**Table 2** Maximum Occlusal Force Measured with an Occlusal Force Meter

<table>
<thead>
<tr>
<th>Baseline</th>
<th>1 mo</th>
<th>6 mo</th>
<th>12 mo</th>
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<td>17</td>
<td>17</td>
<td>15</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Mean</td>
<td>106.3</td>
<td>125.3</td>
<td>151.6</td>
<td>157.9</td>
<td>168.5</td>
<td>159.2</td>
<td>170.5</td>
</tr>
<tr>
<td>SD</td>
<td>43.4</td>
<td>34.5</td>
<td>53.1</td>
<td>60.3</td>
<td>62.2</td>
<td>61</td>
<td>68.6</td>
</tr>
<tr>
<td>Median</td>
<td>95</td>
<td>121</td>
<td>129</td>
<td>146</td>
<td>171</td>
<td>146</td>
<td>161.8</td>
</tr>
<tr>
<td>IQR</td>
<td>81, 128.5</td>
<td>104.5, 147</td>
<td>112, 181</td>
<td>110, 210</td>
<td>121, 199</td>
<td>118, 166.5</td>
<td>131.3, 205</td>
</tr>
<tr>
<td>P values</td>
<td>.52</td>
<td>.059</td>
<td>.085</td>
<td>.030*</td>
<td>.037*</td>
<td>.022*</td>
<td>.0050*</td>
</tr>
</tbody>
</table>

Baseline is before the insertion of implants with a mandibular complete denture. SD = standard deviation; IQR = interquartile range; mo = months after surgery. *Significant difference (P < .05).

**Table 3** Occlusal Contact Area Measured with Pressure Sensitive Sheets

<table>
<thead>
<tr>
<th>Baseline</th>
<th>1 mo</th>
<th>6 mo</th>
<th>12 mo</th>
<th>24 mo</th>
<th>36 mo</th>
<th>48 mo</th>
<th>60 mo</th>
</tr>
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<tbody>
<tr>
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<td>19</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Mean</td>
<td>2.5</td>
<td>3.9</td>
<td>5.8</td>
<td>7</td>
<td>7.6</td>
<td>8.1</td>
<td>6.3</td>
</tr>
<tr>
<td>SD</td>
<td>1.5</td>
<td>2.3</td>
<td>2.7</td>
<td>4.3</td>
<td>4.6</td>
<td>6.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Median</td>
<td>2.1</td>
<td>2.9</td>
<td>5.1</td>
<td>6.2</td>
<td>6.6</td>
<td>7.1</td>
<td>5.3</td>
</tr>
<tr>
<td>IQR</td>
<td>1.2, 3.5</td>
<td>2.2, 5.7</td>
<td>4.5, 7.5</td>
<td>3.7, 8.3</td>
<td>4.9, 9.4</td>
<td>4.1, 7.4</td>
<td>3.2, 7.6</td>
</tr>
<tr>
<td>P values</td>
<td>.3</td>
<td>.0010*</td>
<td>.0010*</td>
<td>.00040*</td>
<td>.0010*</td>
<td>.0090*</td>
<td>.0080*</td>
</tr>
</tbody>
</table>

Baseline is before the insertion of implants with a mandibular complete denture. SD = standard deviation; IQR = interquartile range; mo = months after surgery. *Significant difference (P < .05).
complete dentures and another in which patients with implant overdentures exhibited occlusal forces 2 times higher than those with complete dentures. Geckil et al reported that occlusal force in patients with two-implant overdentures with locator attachments ranged from 60.5 N to 305.5 N (mean: 127.2 N) at the 4-year time point, whereas in the present study, it ranged from 43 N to 325 N (mean: 171 N) 4 years after surgery. Van Kampen et al reported that the mean maximum occlusal force with old complete dentures was 220 N, and it significantly decreased to a mean of 170 N with implant overdentures without attachments and then significantly increased to a mean of 325 N with implant overdentures with attachments. Because of the immediate loading in the present study, however, maximum occlusal force constantly increased without a decrease after implant surgery. Occlusal force is one of the important factors that influence masticatory performance. The tendency of an improvement in the maximum occlusal force before significant improvement in masticatory performance was confirmed in the present study, in which the maximum occlusal force improved significantly before masticatory performance.

Occlusal contact area has been reported to influence masticatory performance. In a previous study, increased overall occlusal contact area was primarily related to increased occlusal contact area in the molar region, and occlusal contact area was strongly associated with mixing ability. The color-changeable chewing gum is considered to be easier to mix with the molar region than the premolar region because the occlusal contact area of the molars is bigger than the premolars. In addition, occlusal contact and clenching intensity during mastication increased the maximum occlusal force. These factors may contribute to the relationship between occlusal contact area and masticatory performance. In that study, the denture was made on the basis of bilateral balanced occlusion, with reference to the conventional complete denture, with hard-acrylic resin artificial teeth. Although the occlusal contact of the anterior teeth was adjusted weekly in earlier periods to avoid overload on the implants in the anterior region, significant increases in occlusal contact area from 6 months to 5 years after surgery were observed in that study. This result revealed abrasion of the occlusal surfaces of artificial teeth over time in two-implant overdentures.

While masticatory performance and maximum occlusal force were improved with implant overdentures in many previous studies, in one previous study, there was a reduction of approximately 20% in maximum occlusal force soon after surgery. However, in the present study, masticatory performance, maximum occlusal force, and occlusal contact area all tended to increase from the early period, which differs from the findings of the previous reports. This might be because most previous studies depended on conventional loading of implant overdentures, whereas the present study utilized immediate loading. Increases in masticatory performance and maximum occlusal force are strongly associated with the retention and support of removable dentures. In the case of conventional loading of implant overdentures, temporary decreases in masticatory performance and maximum occlusal force were found. This may be because there is little retention in dentures without attachments, and in addition, implant surgery is associated with pain in the mucosa. In the case of immediate loading of implant overdentures, the denture can gain retention and support with attachments that are set immediately after surgery. The significant increase from 2 years to 5 years after surgery in the present study suggests that immediate loading of two-implant overdentures could yield prolonged improvement, initiating at early time points.

The present study had several limitations, including a small sample size and low statistical power. Only a color-changeable chewing gum was used for measuring masticatory performance; other test foods or materials may have yielded different results. In addition, further research comparing two-implant overdentures with other abutment systems is needed to evaluate long-term masticatory performance.

**CONCLUSIONS**

Although there is a limit to this study, with immediate loading of two-implant overdentures, masticatory performance evaluated via color-changeable chewing gum was significantly improved 4 and 5 years after surgery, maximum occlusal force was significantly improved 2 years after surgery, and occlusal contact area was significantly improved 6 months after surgery.

**ACKNOWLEDGMENTS**

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**REFERENCES**


