Effect of Attachment Type on Implant Strain in Maxillary Implant Overdentures: Comparison of Ball, Locator, and Magnet Attachments. Part 1. Overdenture with Palate

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Purpose: Implant overdentures with attachments have been used in clinical practice and the effect of attachments on implant strain has been frequently reported. However, most studies have focused on mandibular overdentures; there are few reports on maxillary overdentures. The purpose of this study was to examine the influence of attachment type on implant strain in maxillary overdentures under various implant configurations. Materials and Methods: A maxillary edentulous model with implants and experimental overdentures were fabricated. Four strain gauges were attached to each implant, positioned in anterior, premolar, and molar areas. Three types of unsplinted attachments—ball, locator, and magnet—were set on the implants under various implant configurations. A vertical occlusal load of 98 N was applied through the mandibular complete denture, and implant strain was compared using the Kruskal-Wallis test. Results: Ball attachments caused the greatest amount of strain, while magnet attachments caused the least amount under all conditions. For all attachments, two anterior implants caused significantly more strain than four implants (P < .05). No significant difference was observed between subtypes in four-implant configurations except when using locator attachments. Conclusion: When using unsplinted attachments for maxillary implant overdentures, magnet attachments are recommended to reduce implant stress. Using only two implants, especially two anterior implants, is not recommended regardless of attachment type. Int J Oral Maxillofac Implants 2017;32:1308–1314. doi: 10.11607/jomi.5737

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Clinicians must select the most suitable attachment type for implant overdentures (IODs) on an individual basis. The criteria vary and major concerns must be considered, including available space for attachment, cost from initial treatment to maintenance, retention force, stress to underlying implants or tissue, chair or laboratory time, and patient satisfaction.1

The most important factor in terms of implant stability appears to be the amount of stress to the implant, and thus many researchers have focused on understanding the effect of various conditions on implant strain.2–5 From a mechanical point of view, implant stress from a splinted attachment, such as a bar attachment, is reported to be lower than that from an unsplinted attachment, such as a ball or magnet attachment.6,7 However, bar attachments are inferior to ball or magnet attachments with respect to cleansing and required space; therefore, bar attachments are considered to negatively affect the tissue around the implants and overdenture.1 Moreover, the resiliency of unsplinted attachments has greatly improved, resulting in less stress to the implant.5,8,9 However, previous studies focused mainly on mandibular IODs. The effects of attachment type on implants in maxillary IODs appear to differ from those in mandibular IODs, even if the same attachment is used, because implant stress is affected by denture deformation. Functional force in maxillary overdentures differs as well from that in mandibular overdentures. Previous studies also failed to consider how functional stress is transmitted to

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the abutment; that is, the effect of the height of the contact point between the denture base and the attachment. In general, the higher the contact point, the greater the stress to the implant. Therefore, the effect of attachment type on implants beneath maxillary IODs should be examined under the same experimental condition.

For mandibular IODs, two implants placed in the anterior area was reported to be the standard. In recent years, one implant placed in the midline area was reported to be equivalent to two implants. Although the recommended implant number and position for maxillary IODs have been reported in reviews, few reports on differences among various implant configurations, such as implant number and distribution, are available. The present authors previously reported that four or six implants widely distributed from anterior to posterior should be recommended for maxillary IODs to decrease both implant stress and deformation of the overdenture. However, healing abutments used in these studies cannot retain the overdenture; they only provide support. Moreover, healing abutments are not typically used in clinical practice for maxillary IODs. Attachments applied in clinical practice should be used to examine the real stress to implants under functional force. In vitro studies have not measured the stress to the implant directly; the strain, one of indices of the stress, has usually been used.

Therefore, this study was conducted to examine the effect of attachment type on implant strain under various configurations in maxillary IODs.

**MATERIALS AND METHODS**

**Experimental Model**

A maxillary experimental model was fabricated by duplicating a maxillary edentulous model (G2-402U, Nissin) in acrylic resin (Parapress Vario, Heraeus Kulzer) and covering it with silicone rubber (Fit Checker, GC) to simulate a 2-mm-thick mucosal lining. A mandibular edentulous plaster cast (G2-402L, Nissin) with simulated mucosa (Fit Checker, GC) was used as the opposing model. These two models were fitted with wax rims (NA-N4, Nissin) and mounted on a semiajustable articulator (Proarch IIG, Shofu).

Four strain gauges (KGF-1N-120-C1-11L1M2R, Kyowa Electronic Instruments) were attached to the four surfaces of the implants (Mk III TiU RP: 4.0 mm diameter × 10 mm length, Nobel Biocare) 2 mm below the shoulder, and the grooves were filled with acrylic resin (Unifast III, GC) (Fig 1). Six implants were placed bilaterally in three regions of the maxillary model. They were symmetrically placed in the lateral incisor, first premolar, and first molar positions using the duplicated maxillary denture as a surgical guide and with the four strain gauges facing each other mesiodistally and palatobuccally/labially (Fig 2). The strain gauges were connected to sensor interfaces (PCD-300A, Kyowa Electronic Instruments) controlled by a personal computer (Endeavor NJ5500, Seiko Epson).

**Experimental Denture**

Maxillary and mandibular complete dentures were fabricated to fit the edentulous models using acrylic resin (Parapress Vario, Heraeus Kulzer). Anterior and posterior composite resin artificial teeth (Veracia SA anterior and posterior, Shofu) were arranged in both dentures in bilateral balanced occlusion. Maxillary experimental dentures were fabricated by duplicating this maxillary complete denture in acrylic resin (Parapress Vario, Heraeus-Kulzer).

**Attachments**

Three types of unsplinted attachments—ball, locator, and magnet—were used in the present investigation. For the ball attachments, ball abutments (Ball abutment RP, 2 mm height, Nobel Biocare) were set on implants with 15 N cm, and retaining metal caps (Gold cap, Nobel Biocare) were indexed in the experimental denture. For the locator attachments, locator abutments (Locator abutment Bmk RP, 3 mm height, Nobel Biocare) were set on implants with 35 N cm, and male parts (Locator retention disc, blue, Nobel Biocare) were placed in the experimental denture. For the magnet attachments, keepers...
Loading and Measurement of Strain
Two main implant configurations were tested: denture supported independently by two implants (type II) and denture supported independently by four implants (type IV). Types II and IV were divided into three subtypes, respectively, as follows: supported by two anterior implants (IIa); supported by two premolar implants (IIp); supported by two molar implants (IIm); supported by two anterior and two premolar implants (IVap); supported by two anterior and two molar implants (IVam); and supported by two premolar and two molar implants (IVpm). These six conditions were tested with each attachment type.

After setting the mandibular and maxillary experimental dentures on each model on the articulator, a vertical load of 98 N, which is reported to be the maximal bite force for patients with IODs, was applied to the mandibular dentition through the articulator with a loading apparatus (Ito Engineering) (Fig 4). Implant strain was recorded for 10 seconds at 50-ms intervals, and all measurements were repeated five times for each condition. Two directions of bending strain, mesiodistal and palatobuccal/-labial, were calculated. A negative value indicated that the implant was registering strain in a distal to mesial or buccal/labial to palatal direction; a positive value indicated the implant was registering strain in the reverse direction.

Statistical Analysis
The bending strain of implants under each condition was compared using the Kruskal-Wallis test with a post-hoc test ($P = .05$). All statistical analyses were performed using SPSS Statistics Ver.22 (IBM).

RESULTS
Effect of Attachment Type on Implant Strain
The direction of implant strain was almost the same regardless of attachment type, except for mesiodistal strain of premolar implants. In particular, anterior implants were strained distally and posterior implants were strained buccally. Moreover, implant strain when using magnet attachments exhibited the same direction and moved away from the midline (Fig 5).

Ball attachments caused the greatest amount of implant strain and magnet attachments caused the least strain under most conditions, regardless of direction; however, no significant differences were observed under any conditions. Implant strain caused by locator attachments tended to range between that of ball and magnet attachments. However, differences between locator attachments and the other two attachment types were not significant under most conditions (Fig 5).

Effect of Implant Number and Distribution on Implant Strain
For ball attachments, implant strain using only two implants was significantly greater than that using four implants ($P < .05$). However, when comparing the
subtypes of four-implant configurations, significant differences were generally not observed (Fig 6).

For locator attachments, implant strain tended to be similar to that of ball attachments. Implant strain using premolar and molar implants was lower than that using anterior and molar implants under some conditions when comparing the subtypes of four-implant configurations (Fig 6).

For magnet attachments, implant strain tended to be similar to that observed with the other two attachments. There was no significant difference between the subtypes of four-implant configurations (Fig 6).

For all attachments, implant strains using only two anterior implants were much higher than that under other conditions. Implant strains using four implants were almost the same under all conditions (Fig 6).

**DISCUSSION**

There are both advantages and disadvantages to any attachment type used for IODs, and clinicians must consider these when selecting the attachment type for each patient. Although a general consensus on implant number and distribution in mandibular IODs has been reached, the optimal conditions for maxillary IODs remain unclear. Therefore, this study was conducted to determine differences in implant stress in maxillary IODs using various attachment types and implant configurations.

The results of the present investigation demonstrated that the directions of implant strain were almost the same for all attachment types, moving away from the midline. Moreover, implant strain was highest when...
Fig 6  Bending strain of the implants (± standard error) with various implant configurations for each attachment. Differences in mean values were analyzed using the Kruskal-Wallis test with post-hoc comparison. *Denotes a significant difference (P < .05).

IIa = supported by two anterior implants; IIp = supported by two premolar implants; IIm = supported by two molar implants; IVap = supported by two anterior and two premolar implants; IVam = supported by two anterior and two molar implants; IVpm = supported by two premolar and two molar implants.
using ball attachments and lowest when using magnet attachments. Lastly, implant strain using two implants was significantly higher than that using four implants, with no significant differences among the subtypes of four-implant configurations. These findings were similar regardless of attachment type or implant number and distribution.

**Effect of Attachment Type on Direction of Implant Strain**

In this investigation, retention power and abutment height from the simulated mucosa of all attachments were designed to be as similar as possible, because these factors affect implant strain. The retention powers of the locator and magnet attachments were 700 g and 750 g, respectively, and the ball attachment retention power was adjusted to 700 g. The abutment height was 2 mm in all attachments.

The direction of stress to underlying implants was affected by the behavior of the overdenture; ie, underlying implants were also deformed when the overdenture was deformed. The behavior of maxillary complete dentures when functional load is applied has been reported to be deformation away from the midline. The present authors previously observed that the behavior of maxillary IODs was similar to maxillary complete dentures, whereas that of mandibular IODs was different. Moreover, previous studies using healing abutments on implants found that healing abutments only support the overdenture. Therefore, the effect of attachments with retentive function is unclear. The present investigation found that the attachment type had no effect on the direction of implant strain in maxillary IODs. Most implant strains observed in the present investigation were positive, indicating that implants were predominantly strained from mesial to distal and from palatal to buccal. This behavior is similar to that observed in maxillary IODs. When magnet attachments were used on premolar implants, implants were deformed in a different manner than with the other two attachment types. This may be explained by the fact that magnets are not fixed on the implant and can move according to the amount of force applied, whereas the other two attachments cannot.

**Effect of Attachment Type on the Magnitude of Implant Strain**

The magnitude of implant strain was affected by how the functional force was translated to the attachment through the denture base and to the implant through the attachment. The former was mainly affected by the position of the contact point between the denture base and attachment, while the latter was affected by the attachment characteristics and the retention power of the attachment. The three attachment types used in the present investigation are commercially available in various abutment heights and retention powers. The authors attempted to maintain similar contact points and retention powers among the three attachment types. One of the most important characteristics is the stress-breaking ability of an attachment, and locator attachments and ball attachments with O-rings have this characteristic. Stress-breaking attachments can decrease stress to the implant; therefore, they are more commonly used in clinical practice. Although magnet attachments are not generally stress-breaking, magnet slides can be moved over the keeper, thereby allowing force to escape when lateral force is applied. Unlike these two attachment types, ball attachments with retentive metal caps are non–stress-breaking with adjustable retention power. Although retention parts of ball attachments were selected with an emphasis on retention power in the present investigation, implant strains when using ball attachments were the highest under most conditions regardless of whether attachments had stress-breaking ability. Comparing locator and magnet attachments, magnet attachments appear to have superior stress-decreasing ability.

**Effect of Implant Configuration on Implant Strain**

The following three recommendations for implant configuration in maxillary IODs were made in past studies: (1) at least four to six implants are necessary, (2) implants should be distributed widely from anterior to posterior, and (3) use of only two implants, especially two anterior implants, should be avoided because rotational movement of the overdenture can cause excessive stress to underlying implants. In the present investigation, implant strain using two implants was significantly higher than that using four implants. Additionally, labiopalatal strain when using only two anterior implants was much higher than that of other configurations regardless of attachment type. The present findings demonstrated implant strain using widely distributed implants was decreased under some conditions. Implant strain using four implants was not significantly different, and increased applied force would likely cause increased strain between implant distributions.

When considering implant stress, the direction of the implants is an important factor. In the present investigation, anterior implants were inclined while other implants were perpendicular to the occlusal plane of the overdenture. This difference may have affected implant strain. Therefore, careful attention should be paid to the direction of implants in clinical practice.

A six-implant configuration was not used in the present investigation, although four or six implants...
were recommended, because implant strain did not differ between four- and six-implant configurations in the authors’ preliminary studies. Moreover, a six-implant configuration is not realistic for clinical use because the retention power is too strong even if the weakest parts are used.

CONCLUSIONS

Within the limitations of this study, it was found that the direction of implant strain did not appear to change according to attachment type or implant configuration. Moreover, ball attachments caused the greatest amount of strain, while magnet attachments caused the least, regardless of implant number and distribution. Lastly, implant strain was significantly higher when using two implants compared with four implants. However, there were no significant differences between the subtypes of four-implant configurations under most conditions. Therefore, the authors recommend magnet attachments for implants in maxillary IODs because they can decrease implant stress regardless of implant distribution. However, magnet attachments have problems of wear and corrosion of the surface, and subsequently loss of retention, so maintenance and change of magnets are necessary.

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