Influence of Palatal Coverage and Implant Distribution on Denture Strain in Maxillary Implant Overdentures

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\textbf{Purpose:} As maxillary implant overdentures are being increasingly used in clinical practice, prosthodontic complications related to these dentures are also reported more often. The purpose of this study was to examine the influence of palatal coverage and implant distribution on the shear strain of maxillary implant overdentures. \textbf{Materials and Methods:} A maxillary edentulous model with implants inserted in the anterior, premolar, and molar areas was fabricated. Two kinds of experimental overdentures, with and without palatal coverage, were also fabricated, and two strain gauges were attached at the midline of the labial and palatal sides. A vertical occlusal load of 98 N was applied through a mandibular complete denture, and the shear strain in each denture was compared by analysis of variance (\( P = .05 \)). \textbf{Results:} In all situations, the shear strain in palateless dentures was significantly higher than in dentures with palate on both sides (\( P < .05 \)). In dentures with palate, the shear strain was lower when anterior implants were present. \textbf{Conclusion:} Palateless maxillary implant overdentures exhibited much higher strain than overdentures with palate regardless of the implant distribution; this may cause more prosthodontic and implant complications. The most favorable configuration to prevent complications in maxillary implant overdentures was palatal coverage that was supported by more than four widely distributed implants. \textbf{Keywords:} implant, load, maxillary implant overdenture, palateless denture, strain

\textbf{Purpose:} As maxillary implant overdentures (IODs) have been a major treatment modality for edentulous patients since the 1980s. Although they were initially a form of “rescue” treatment (that is, they were redesigned following fixed implant restorations for various reasons), they are now one of the treatment options considered in terms of decreasing surgical stress and financial burden. In addition, IODs may be more suitable than fixed implant prostheses for patients with severely resorbed jaws, large antra, and unfavorable arch relations. In fact, maxillary IODs have been used in many cases with high levels of patient satisfaction and successful implants. However, implant and prosthodontic complications, such as implant loss, abutment screw loosening, attachment fracture, and denture fracture, have also been reported in many studies. Complications may occur when the denture base is deformed by functional loading, and this stress is transmitted to the underlying structures through the denture base.

In maxillary IODs, palateless dentures are often selected from the aspect of improving the wearer's oral sensory function. However, palateless dentures are reported to be more easily deformed than conventional dentures with palatal coverage, and more strain stress could be transmitted to the underlying structure, causing more complications. Some researchers have reported that palatal coverage is advantageous in reducing the wear of attachments and minimizing the risk of base fracture. In addition, Palmqvist et al\textsuperscript{13} and Widbom et al\textsuperscript{8} indicated that IODs without palatal coverage could be a considerable risk for future implant loss. However, these suggestions were all based on clinical and case reports, and there was insufficient evidence to examine the mechanical behavior

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of IODs and the differences between the presence and absence of palatal coverage.

Therefore, the purpose of this study was to examine and compare the shear strain in two types of maxillary IODs supported by variously distributed implants and to examine the differences in denture strain among the implant distributions.

**MATERIALS AND METHODS**

**Experimental Model**

A maxillary edentulous model (G2-402U, Nissin) was duplicated in acrylic resin (Parapress Vario, Heraeus-Kulzer) and covered with silicone rubber (Fit Checker, GC) to simulate a 2-mm-thick mucosal lining. A plaster cast of a mandibular edentulous model (G2-402L, Nissin) was also fabricated as an opposing model. These two models were mounted on a semi-adjustable articulator (Proarch IIG, Shofu) using a pair of wax rims (NA-N4, Nissin). The vertical distances between the mandibular and maxillary ridge were 25 mm in the anterior and 21 mm in the posterior.

Six implants (Mk III TiUnite RP: 4.0 mm diameter × 10 mm length, Nobel Biocare) were placed bilaterally in three regions of the maxillary model after model fabrication. They were symmetrically placed in the position of lateral incision, first premolars, and first molars using the aforementioned duplicated maxillary denture as a surgical guide (Fig 1).

**Experimental Denture**

Maxillary and mandibular complete dentures were fabricated in acrylic resin (Parapress Vario, Heraeus-Kulzer) to fit the edentulous models. Anterior and posterior composite resin artificial teeth (Veracia SA, Shofu) were arranged in both complete dentures in bilateral balanced occlusion. The dimensions of both dentures were shown as follows: the distances between the fossae of both sides of the first molar teeth were 46 mm in the maxillary denture and 41 mm in the mandibular denture; those between the incisal and distal edges of the second molar teeth were 43 mm in the maxilla and 40 mm in the mandible. The overjet and overbite in the anterior teeth were 3 mm and 1 mm, respectively. The thickness of both denture bases was 1.5 mm, and the height from the ridge to the central fossa of the maxillary first molar tooth was 9 mm, and that of the mandibular first molar tooth was 12 mm. Two types of experimental dentures were fabricated, with and without palatal coverage, by duplicating the maxillary complete denture (Fig 2). The design of the palateless denture was the same as in a previous report.®

Strain gauges (KFG-02-120-C1-L1M3R, Kyowa Electronic Instruments) were attached to the labial and palatal polished surfaces of each experimental denture at the anterior midline (Fig 3), and were connected to sensor interfaces (PCD-300A, Kyowa Electronic Instruments) controlled by a personal computer (Endeavor NJ5500, Epson).

**Loading and Measurement of Strain**

Three main types of support configurations were tested: supported by two implants (Type II), supported by four implants (Type IV), and supported by six implants (Type VI). Types II and IV were divided into three subtypes: 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 seven types of support were tested in both experimental dentures with and without palate. In each support type, healing abutments (Rp, 3 mm height, Nobel Biocare) were mounted on the implants, and both types of experimental dentures were relined to fit the abutments and the residual ridge in each implant distribution before measuring the strain.

After setting both maxillary and mandibular experimental dentures on the models mounted on the articulator, a vertical load of 98 N was applied to the lower dentition through the articulator with a loading apparatus (To Engineering; Fig 4). The strain was recorded for 10 seconds at 50-millisecond intervals, and all measurements were repeated five times for each configuration. The shear strain at each measuring point was calculated from the values of the strain gauges.

**Statistical Analysis**

Comparisons were made of the shear strain for each configuration and for two types of dentures via an analysis of variance (ANOVA) with a post hoc comparison using the Bonferroni method and t test, respectively (P = .05). All statistical analyses were performed with SPSS Statistics Version 22 (IBM).

**RESULTS**

In the denture with palate, the shear strain on the labial side was highest in IIm (187.0 × 10⁻⁶) and IVpm (191.4 × 10⁻⁶) and lowest in IIa (36.4 × 10⁻⁶). Shear strain levels on the labial side were approximately three times higher than those on the palatal side, although the same tendencies were evident; that is, IIm and IVpm were the highest (70.2 × 10⁻⁶ and 61.4 × 10⁻⁶), and IIa was the lowest (21.7 × 10⁻⁶). On both the labial and palatal sides, shear strain was significantly lower in IIa, IVp, IVm, and VI than in the other configurations (P < .05). Thus, the authors concluded that the shear strain was lower in dentures supported by anterior implants (Fig 5).
Fig 1  Maxillary edentulous model with simulated mucosa and six implants.

Fig 2  Two types of experimental overdentures: (a) conventional denture with palatal coverage; (b) palateless denture.

Fig 3 (left, above) Two strain gauges attached to the experimental denture: (a) occlusal view; (b) labial view.

Fig 4 (right) Experimental maxillary denture mounted on the articulator attached to the loading apparatus.

Fig 5  Graphs showing the shear strain (± standard deviation) in dentures with different configurations. Differences in mean values were analyzed using ANOVA with Bonferroni post hoc comparison. * Denotes a significant difference (P < .05). (a) Labial side of conventional denture; (b) palatal side of conventional denture; (c) labial side of palateless denture; (d) palatal side of palateless denture. CD = conventional denture; PD = palateless denture; Ila = supported by two anterior implants; Ilp = 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.
In the palateless denture, the shear strain was highest in IVap (403.1 × 10^{-6}) and IVam (404.7 × 10^{-6}) and lowest in IIm (267.2 × 10^{-6}). These levels were more than twice as high as those of dentures with palate in all configurations. On both sides, there was a tendency for the shear strain to be higher in dentures supported by premolar implants.

In both types of dentures, the shear strain was significantly lower in dentures supported by only two anterior implants or six implants than in any other configuration (P < .05; Fig 5).

Comparing the shear strains with and without palatal coverage, there were significant differences in all situations on both the labial and palatal sides (P < .05; Fig 6).

**DISCUSSION**

Maxillary IODs are increasingly being used and have been shown to be a predictable method for long-term treatment of the edentulous maxilla. Numerous reports have been published suggesting that maxillary IODs should no longer be seen as a "rescue" treatment, but as a preplanned treatment option.

Although maxillary IODs have been used in many cases that highlighted potential difficulties and the necessity of careful planning, no guidelines or consensus for their design have been developed. Two types of denture designs, with and without palatal coverage, have mainly been used, but the selection criteria were unclear and seemed to be based on clinicians' personal experience or the patient's desire.

Palateless dentures are said to be more advantageous than dentures with palate in terms of pronunciation,14 masticatory performance,14 gustation,15 temperature, sensorimotor function,16 and gagging reflex.17 However, they also provide less retention and rigidity or strength than dentures with palate,9,18 and this may cause problems with the underlying structure. Past reports of IODs suggest that retention can be increased to a satisfactory level by using attachments, but the problem of the absence of rigidity or strength has not been resolved. In some clinical reports, palateless IODs were associated with more prosthetic and implant complications than dentures with palate.8,11

In the present study, the authors compared the shear strain of two types of maxillary IODs supported by different numbers of implants in different distributions. They found that the strain was much higher in palateless dentures than in dentures with palate. These results are consistent with previous reports about maxillary complete dentures9 and suggest that palateless dentures are more likely to exhibit denture base deformation and fracture than dentures with palate. Additionally, these results demonstrate that palateless IODs transmit more stress to the underlying structure and may cause complications as mentioned in previous reports. To prevent these problems, metal reinforcement embedded in the denture base or a rigid palatal metal frame is necessary, as is the case in palateless complete dentures.18

In dentures with palate, the strains of both sides tended to be larger when being supported by posterior implants, but there was not this tendency in dentures without palate. Also, the strains and number of implants were not associated in both dentures. Whereas any particular relationship between denture strain and implant distribution was not seen, another notable result revealed in this study was the importance of anterior implants under maxillary IODs. In
IODs with palate, the shear strain was significantly lower in dentures supported by anterior implants than in other configurations. Furthermore, the shear strain was significantly lower in dentures supported by only two anterior implants than in those supported by four implants other than anterior implants. This finding suggests that anterior implants can reduce denture deformation. Palateless IODs also displayed this tendency, but the differences among the configurations in palateless IODs were not as marked as in IODs with palate. This difference between the two denture types in the degree of influence of anterior implants may be due to differences in the deformation style. In the present authors’ studies about palateless complete dentures, it was found that they deformed from the buccal to the palatal side, whereas conventional complete dentures deformed from the palatal to the buccal side. In IODs, bilateral anterior implants appear to protect the denture base from deformation caused by functional loading as the strain is transmitted from the midline to both sides. However, some reports warn that IODs supported by only two anterior implants are not recommended because of denture rotation and overload to the implants. Considering these suggestions, more than four implants including anterior implants, and if possible, six implants distributed anterior to the molar region, are recommended to support overdentures. This support type was also recommended in the past study from the aspect of long-term success of implants in maxillary IODs.

A previous study showed that the maximal bite force of patients with maxillary IODs was about three times higher than for patients with conventional complete dentures, reaching 60 to 160 N. Based on this report, a load of 98 N was applied to the center of the dentition to be distributed evenly.

Although the authors examined various numbers and distributions of implants in this study, all the implants were unsplinted and were fitted with healing abutments, which provided only support and not retention. However, other studies have used different types of attachments that act as splints in clinical practice. Considering these reports, the concept of this study was not clinical, but there are few mechanical reports to examine on denture deformation with unsplinted implants, and the authors conducted this study to clarify the basal deformation of maxillary IODs. This study was a preliminary mechanical study to reveal the effects of reinforced structure; various types of attachments, such as ball, magnet, and locator; and splinting the distributed implants by comparing the results of this study. Further studies should be undertaken to investigate their effects and obtain more realistic results.

CONCLUSIONS

Within the limitations of this study, the authors found that the shear strain was much higher in palateless maxillary implant overdentures than in overdentures with palate, regardless of the underlying implant distribution, and this was decreased in those with support from more than four widely distributed implants in both types of dentures. In overdentures with palate supported by anterior implants, the shear strain was significantly lower than in other configurations. These results suggest that palatal coverage and support from more than four implants is recommended for maxillary implant overdentures to prevent deformation of the denture base, subsequent denture base fracture, and implant complications.

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