O-Ring Attachments on One-Piece Mini Dental Implants: In-Vitro Analysis of Retention Force Reproducibility Using Different Pristine Matrix-O-Ring Combinations

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ABSTRACT

Purpose: To analyze the influence of pristine matrix and O-ring dimensions on retention force and reproducibility in single one-piece mini dental implants (MDIs) with ball patrices under in vitro conditions. Materials and Methods: Three different matrix and O-ring combinations (MH1–MH3) were evaluated (n = 50 per group) on 1.8-mm–diameter implants. The matrices were manually mounted on the implants and were subsequently removed in a vertical linear manner using a metal pin with two strain gauges, recording the maximum force during disconnection. After five disconnections, the O-rings were exchanged, and the mean retention force was calculated, resulting in 50 values for each matrix and O-ring combination. Mean retention forces, SDs, and 95% CI were calculated. Analysis of variance was used to test the global differences, and post hoc pairwise comparisons were subsequently applied. The level of significance was set to \( P < .05 \). Results: ANOVA (global \( P < .0001 \)) and pairwise comparisons (all \( P < .0001 \)) demonstrated statistically significant differences among the three different matrix and O-ring combinations, with mean values of 5.18 N (MH 1), 6.73 (MH 2), and 9.08 (MH 3). Within each combination, retention force variations of > 1 N could not be demonstrated; ie, by exchanging O-rings, a similar retention force can be reestablished. Conclusion: Matrix and O-ring dimensions have a significant influence on retention forces in one-piece MDIs. Pristine O-rings demonstrated highly reproducible initial retention forces in all matrices. Int J Prosthodont 2021. doi: 10.11607/ijp.7055

INTRODUCTION

One-piece mini dental implants (MDIs) with a diameter of < 3mm, retaining mandibular overdentures are increasingly applied in clinical routine, especially in the severely resorbed mandible, when the placement of two standard diameter implants necessitates bone
augmentation procedures.\textsuperscript{1,2} In medically compromised, or age-advanced patients those procedures are usually accompanied by an increased risk of biological complications.\textsuperscript{3–6} As bone augmentation procedures can be avoided by using smaller diameter implants, MDIs have gained increasing popularity.

MDIs have proven their reliability in various clinical studies, providing high implant survival rates, peri-implant bone stability, and high patient satisfaction.\textsuperscript{1,7,8,9} However, due to the one-piece design, the male part is an inseparable implant component that cannot be replaced when severely worn.\textsuperscript{10} Therefore, O-rings, commonly made of an elastomer, might be an ideal attachment in these types of implants, as they can reduce the stress on the male part, and consequently its’ wear.\textsuperscript{11,12} Under in-vitro conditions, clinically sufficient retention forces, using varying matrix-O-ring combinations from different manufacturers have been demonstrated.\textsuperscript{13–16} Furthermore, the wear behavior of O-rings in overdentures has been documented in short and long-term simulations.\textsuperscript{14–16} Under in-vivo conditions, it has been shown that the initial retention forces in one-piece MDI retained overdentures can be reestablished, just by exchanging the O-rings, even after a 5-year period, which proves the theory of the male parts’ and matrices’ low wear in this kind of system.\textsuperscript{17} But due to the pronounced deformation of O-rings during the connection and disconnection from patrices, the reproducibility of the retention forces, even of pristine O-rings has been questioned.\textsuperscript{14} Furthermore, the influence of the matrix- and the O-ring diameter on the retention forces and its’ reproducibility has not been scientifically evaluated. Therefore, the present study compared the retention forces of three different matrix-O-ring combinations, with varying dimensions. The alternative hypothesis (H1) was that the retention forces would be different for the varying matrix-O-ring combinations. Furthermore, the reproducibility of the retention forces with pristine O-rings was evaluated.

MATERIALS and METHODS
Three one-piece MDIs (MDI, condent GmbH) with a 1.8mm diameter and a length of 13 mm were uprightly embedded in polymethacrylate resin of 8 mm height. The resin blocks, including the implants, were mounted in a holding device and covered with sterile draping, that only the unembedded implant surface remained uncovered. For evaluating the retention force, metal eyelets were laser fused to three titanium matrices of different heights and diameters (MH1 – MH 3, condent GmbH), with two different types of according O-rings (O-rings for MH 1 or MH2/ MH3 matrix respectively, condent GmbH) incorporated. The specifications of the matrix-O-ring combinations are given in table 1 (Tab 1). For the MH2 and the MH3 matrices, the same type of O-ring was used. The matrices were gently mounted on the implants by hand, and a metal pin including two strain gauges was plugged into the eyelet (Fig. 1a). Subsequently, the matrices were manually removed from the implant in a vertical linear manner using the metal pin, while the maximum force during the disconnection was recorded with respective software (Dasylab® 7.0; National Instruments) (Fig. 1b), as described in a previous study. The disconnections were not performed at a predefined speed. Each type of matrix was tested on a pristine implant. 50 O-rings in each matrix were used. After, five disconnections the mean retention force was calculated, and the applied O-ring was exchanged, resulting in 50 retention force values per matrix-O-ring combination. Five disconnections roughly simulated two days of use, assuming two or three connections and disconnections per day. The recording system had a resolution of 0.01N, and was calibrated after every O-ring exchange.

For descriptive analysis mean retention forces, standard deviations (SD), and the corresponding 95% confidence intervals (CI) were calculated. For testing the reproducibility of the retention forces, a clinically significant difference was assumed to be 1 Newton (N), based on a previous study, demonstrating SDs in Locator abutments of 0.75 N. An analysis of variance (ANOVA) was used to test the global difference of retention forces between the three matrix types. For pairwise comparisons, the mean differences between the groups were
calculated, and the p-values were adjusted using the Bonferroni Multiple Comparison Test. The level of significance was set to p < 0.05.

RESULTS

The mean retention forces of the different matrices were 5.18 ± 0.61 N (MH 1), 6.73 ± 0.68 N (MH 2), and 9.08 ± 0.71 N (MH 3) (Fig. 2). The ANOVA showed a statistically significant difference (global p < 0.0001). Retention force variations of > 1 N could not be demonstrated in any of the matrix-O-ring combinations. The results of the pairwise comparisons showed significant differences between each of the matrix-O-ring combinations (all p < 0.001) (Tab. 2).

DISCUSSION

All employed matrix-O-ring combinations showed significantly different retention forces, confirming the alternative hypothesis. Furthermore, all combinations demonstrated highly reproducible retention forces.

Retention forces of 5-7 N are described for achieving adequate denture stability.\textsuperscript{19} The retention forces of all matrix-O-ring combinations were quite within this range. Furthermore, all evaluated retention forces were similar to those of other implant attachments, reported in similar studies.\textsuperscript{18,20} Therefore, in terms of the overall retention force, the clinical application of all matrix-O-ring combinations can be recommended. The highest retention forces were found with the smallest diameter matrix (MH 3) and the small diameter O-ring (diameter: 3.5mm), whereas the lowest retention forces were found with the widest matrix (MH 1) and the bigger diameter O-ring (4.5 mm). It can be assumed, that the bigger diameter of the matrices and the O-rings provide higher elastic deformation potential and consequently lower retention forces.

The reproducibility of the retention force is a critical issue, as fulfilling a patients’ specific demands, for example providing sufficient denture stability but at the same time guaranteeing an easy denture removal, especially in manually handicapped persons, is barely
possible when there is much variation in the retention force of an attachment system.\textsuperscript{21} The variation in all matrices was similar or even lower, compared to the results of other studies using Locator (pink or blue inserts) or ball attachments with different commonly used metal retention inserts.\textsuperscript{18,20}

The set-up of the current study can be questioned as O-rings were continuously replaced by pristine ones after five connection/ disconnection cycles, whereas only three implants and three titanium matrices were used, that were not replaced. However, a recent study, applying the same materials that were used in the current study, demonstrated that the initial retention forces could be reestablished only by replacing the O-rings, while the titanium matrices and implants remained. Therefore, the wear of the matrices and implants seems neglectable, especially with a small number of loading and unloading cycles. The retention force testing under dry conditions can be considered a weakness, as the conditions might have a significant influence on O-ring attachments.\textsuperscript{22} Furthermore, the low number of 50 connection and disconnection cycles omits to report on long-term repeatability of the retention forces. However, the current study has not aimed to prove long term stability of O-rings as this has been extensively evaluated before,\textsuperscript{14-16,23} but to analyze the influence of matrix and O-ring diameter on the retention forces and its’ reproducibility using pristine O-rings. Furthermore, even when O-rings would not demonstrate highly repeatable retention forces over a longer time, exchanging the O-rings can easily be done, as it is a relatively low-priced and convenient procedure.

CONCLUSION

The retention forces of different titanium matrices with O-ring attachments depend on the matrix-, as well as on the O-ring diameter. Pristine O-rings demonstrated highly reproducible retention forces during a small number of loading- and unloading cycles in all matrices. A conclusion regarding retention forces of used components cannot be drawn from the current set-up.
REFERENCES:


TABLE/ FIGURE LEGENDS

Table 1. Specifications of applied matrix-O-ring combinations

Capture: Specifications of all evaluated matrices (MH1 – MH3) and O-rings in millimeter [mm]. Inner diameter (a) represents the diameter in the area of the O-ring’s final position, and inner diameter (b) the matrix aperture.

Table 2: Mean differences in retention forces between the applied matrix-O-ring combinations

Capture: Specifications of all evaluated matrices (MH1 – MH3) and O-rings in millimeter [mm]. Inner diameter (a) represents the diameter in the area of the O-ring’s final position, and inner diameter (b) the matrix aperture.

Figure 1: A, Metal pin plugged into the eyelet of an MH2 matrix before. B, and after disconnection from the implant

Figure 2: Mean retention forces of the different matrices (MH1 – MH3), as well as the according 95% confidence intervals and minimum and maximum values in Newton [N].
# TABLES AND FIGURES

Table 1

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<th>Height</th>
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Figure 1

Figure 2