Evaluation of Fracture Load of Cement-/, Screw-, and Multiscrew-Retained Abutments for Implant-Supported Fixed Partial Dentures

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Purpose: The purpose of this in vitro study was to evaluate the load-to-fracture values of cement-, screw-, and multiscrew-retained abutments for implant-supported fixed partial dentures (FPDs). Materials and Methods: Thirty-six implants with a diameter and length of 4.5 and 13 mm, respectively, were used to prepare 18 samples of FPDs. Based upon the variations on abutment design, the FPDs were divided into three categories as follows: cement-retained, screw-retained, and multiscrew screw-retained abutments. Using a chewing simulator, cyclic loads of 1,250,000 load cycles with a load of 70 N were applied on all samples to simulate 5 years of human functional chewing. The samples were loaded until failure using an electromechanical test machine. Sample-size estimation was done, and fracture-load values were recorded as means and corresponding standard deviations; group comparisons were done using one-way analysis of variance and Tukey post hoc tests. A P value < .01 was considered as an indicator of statistical significance.

Results: The fracture-load values for cement-, screw-, and multiscrew screw-retained abutments were 2,109.2 ± 139.6 N, 3,888.8 ± 70 N, and 3,319.4 ± 218.9 N, respectively. The load-to-fracture values were significantly higher in screw-retained abutments (3,888.8 ± 70 N; P < .001) than in cement-retained (2,109.2 ± 139.6 N) and multiscrew screw-retained abutments (3,319.4 ± 218.9 N). Conclusion: Screw-retained implant-supported FPDs withstand higher occlusal forces compared with cement- and multiscrew screw-based retention techniques. However, the results should be cautiously interpreted, as they were based on a relatively small sample size. Int J Oral Maxillofac Implants 2021;36:55–58. doi: 10.11607/jomi.8575

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Several evidence-based studies1–3 in indexed literature have reported that dental implants can demonstrate success and survival rates of up to 100%. Nevertheless, the risk of complications from biologic and prosthodontic perspectives continues to challenge clinicians and researchers in the field of implant dentistry.4–6 It has been reported that the presence of microgaps at the implant-abutment junction (IAJ) increases the risk of peri-implant soft tissue inflammation and crestal bone loss.7,8 Excessive occlusal forces may jeopardize the structural integrity of the implant and its components, which may result in mechanical complications, such as prosthesis fracture.9,10 For instance, postloading implant exposure to high occlusal forces (as observed in patients with bruxism) can lead to complications including abutment fracture and prosthesis loosening/failure.11,12 In this context, there is an ongoing debate regarding selection of the most reliable mode of retention that should be used at the IAJ to minimize the risk of complications associated with exposure to high occlusal forces.

Fixation at the IAJ can be achieved using cement- or screw-retained implant abutments.13–15 In a nonlinear finite element analysis, Mao et al16 assessed the influence of sizes of abutments and fixation screws on immediately loaded dental implants. Although the results showed that screws can be successfully used to retain the abutment in the implant, the selection of screw diameter should be determined with caution, as inappropriately sized screws may induce stress and cause deformation of the implant system. Nevertheless, this study was based on single-unit implant-supported prostheses. There are no studies related to the fixation of multiscrew implant abutments. It has also been proposed that cements can be used for the fixation of abutments in the implant system;17 however, the likelihood of occlusal loads to induce microcracks and ultimately prosthesis loosening cannot be overlooked.

In vitro evaluation of cyclic loading is a clinically relevant test approach, as it virtually simulates masticatory function.18–20 It has been reported that dental prostheses fail more under cyclic-load tests that are well below...
the ultimate flexural strength of these materials as opposed to the application of a single and relatively high static load.\(^{21}\) In an in vitro study, Vafaee et al\(^{22}\) assessed fracture load of three-unit implant-supported fixed partial dentures (FPDs). The results showed that the fracture strength values obtained after cyclic loading were significantly higher than the maximum mean masticatory load.\(^{22}\) Screw- and cement-retained implant restorations have been addressed in implant dentistry with an emphasis on prosthesis retention and related complications (such as crestal bone loss and soft tissue inflammation)\(^{23–25}\), however, there are no studies that have assessed the fatigue load of cement-, screw-, and multunit screw-retained abutments. The present study is based on the null hypothesis that there is no difference in the fatigue load and its corresponding load-to-fracture values of cement-, screw-, and multunit screw-retained abutments supporting FPDs. The purpose of the present study was to evaluate the load-to-fracture values of cement-, screw-, and multiscrew-retained abutments for implant-supported FPDs.

**MATERIALS AND METHODS**

**Ethical Guidelines**

The present study was based on an in vitro design. Since no humans, animals, or living tissues were involved in the study, the present study was exempted from prior ethical approval.

**Samples and Construction of Models of Fixed Partial Dentures**

Thirty-six grade 4 titanium dental implants (Astra, 4.5 × 13 mm) machined with a parallel geometry and a tapered apex were used. The implant-abutment had an internal, double hex conical connection. Eighteen samples of FPDs were fabricated from the implants (n = 36). Six holding jigs were designed and fabricated by a trained and calibrated technician (Kappa score 0.92). The jigs were milled out of stainless steel composed of a 3:1 mixture of Teflon, and light-cured for 40 seconds to restore the occlusal-gingival direction.\(^{27,28}\) The position of the antagonist touched the center of the pontic in the occlusal-gingival direction.\(^{27,28}\) The occlusal tooth anatomy.

**Cyclic Fatigue Test**

The cyclic load test was performed by using a chewing simulator (CS-4.4, SD Mechatronik) containing four chambers. Samples with their holding jigs were attached to the customized adapter and embedded into the standard sample holders of the chewing simulator. The load applicator (antagonist, a cone of 30 degrees of stainless-steel tip with 1-mm radius) was fitted into the antagonist bar. The vertical bar of the device was moved downward using the hand-controller until the antagonist touched the center of the pontic in the occlusal-gingival direction.\(^{27,28}\) The load-to-fracture was applied using an electromechanical test machine (Tabletop Model 3369 Series, Instron). Load measurements were done by a 50-kN electronic load cell.

**Statistical Analysis and Sample-Size Estimation**

The Statistical Package for the Social Sciences (SPSS) for Windows (Version 18, SPSS) was used to analyze the results. One-way analysis of variance and the Tukey post hoc test were used for comparisons. A P value < .05 was considered as an indicator of statistical significance. The
sample-size calculation was done using computer-based software (G*Power, Version 3.1.9.2 software). It was estimated that the inclusion of six FPDs for each group would provide a power of 94% to the study with an alpha of .05.

RESULTS

There was a total of 18 samples (6 samples per group). All samples survived the fracture test following the application of 1,250,000 load cycles. The fracture-load values for cement-, screw-, and multiunit screw-retained abutments were 2,109.2 ± 139.6 N, 3,888.8 ± 70 N, and 3,319.4 ± 218.9 N, respectively. The load-to-fracture values were significantly higher for screw-retained (3,888.8 ± 70 N; \( P < .001 \)) compared with cement-retained (2,109.2 ± 139.6 N) and multiunit screw-retained (3,319.4N ± 218.9 N) abutments (Table 1).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Cement-retained abutments</th>
<th>Screw-retained abutments</th>
<th>Multiunit screw-retained abutments</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of samples</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Fracture-load (N)</td>
<td>2,109.2 ± 139.6 N</td>
<td>3,888.8 ± 70 N</td>
<td>3,319.4 ± 218.9 N</td>
</tr>
</tbody>
</table>

*Compared with cement-retained (\(P < .001\)) and multiscrew-retained abutments (\(P < .001\)).

DISCUSSION

Studies\(^1\)\(^6\)\(^,\)\(^2\)\(^8\) have assessed the role of cements and screws in relation to stability of prostheses; however, the primary focus of these studies was on the retention of the implant-supported crowns. Moreover, from a clinical perspective, implant-abutment connections have mainly been assessed in relation to the occurrence of peri-implant clinoradiographic inflammatory parameters including but not limited to peri-implant gingival inflammation, probing, and bone loss.\(^2\)\(^9\)\(^,\)\(^3\)\(^0\) To the authors’ knowledge from published indexed literature, there are no studies that have assessed the influence of abutment retention on the fracture load of implant-supported FPDs. The null hypothesis proposed in the present experimental in vitro study was that there is no difference in the fatigue load and its corresponding load-to-fracture values of cement-, screw-, and multiunit screw-retained implant abutments supporting FPDs. Therefore, the authors aimed to evaluate the load-to-fracture values of three implant-abutment retention techniques for implant-supported FPDs. In summary, the results showed that the retention (reflected by fracture-load values) of screw-retained abutments was significantly superior compared with cement- and multiunit screw-retained implant abutments supporting FPDs. In this regard, the null hypothesis was rejected. The significant increase in the load-to-fracture value of the screw-retained abutment could be because the screw-retained abutments are attached to the framework as one entity, whereas in the cement-retained or the screw-retained multiunit abutments, the abutments are separated from the framework. Nevertheless, it is anticipated that all the tested abutment designs function well in the posterior jaws, as these values are higher than the reported maximum occlusal force in the molar region, which ranges from 597 to 847 N. The authors contemplate that excessive occlusal forces for prolonged durations can also likely induce microcracks in cement-retained implant abutments, which may compromise the stability of the restoration from a biologic as well as prosthodontic perspective. Further studies are needed to test this hypothesis.

Cyclic loading is considered a clinically relevant test approach, as it simulates masticatory function in vitro. Under physiologic conditions, an individual performs an average of 250,000 chewing cycles on a yearly basis.\(^3\)\(^1\) In the present study, the FPDs were exposed to 1,250,000 cycles, which were performed with loads of 70 N to simulate 5 years of human physiologic chewing function as reported by DeLong and Douglas.\(^3\)\(^1\) It is notable that these cyclic loads were five times higher than normal physiologic mastication. This suggests that FPDs with screw-retained implant abutments can withstand excessively high occlusal loads without undergoing fracture or deformation. This may potentially be advantageous in patients exposed to abnormally high occlusal forces, such as patients with bruxism, and a well-designed and power-adjusted randomized controlled clinical trial may help verify this speculation.

A limitation of the present study is that the results were based on laboratory-based results. In an experimental study, Gehrke et al.\(^3\)\(^2\) assessed the frequency of identification of residual cement after luting of zirconia crowns on CAD/CAM custom molar abutments at varying depths. The results showed that residual cement remnants were identified in every depth of the crown-abutment complex, even though excess cement was initially manually removed by the investigators.\(^3\)\(^2\) It is worth mentioning that in the present experiment, the excessive cement was removed by the investigators using handheld instruments; however, the likelihood of stagnation of cement microgranules at the IAJ cannot be disregarded. This situation in a clinical scenario could act as an initiator of peri-implant diseases. In this context, the screw- and
multiscrew-retained implant abutments seem to be reliable in terms of minimizing the risk of peri-implant diseases; however, further well-designed and power-adjusted studies are needed to justify this association.

CONCLUSIONS
Screw-retained implant-supported FPDs withstand higher occlusal forces compared with cement- and multunit screw-based retention techniques. However, the results should be cautiously interpreted, as they were based on a relatively small sample size.

ACKNOWLEDGMENTS
The authors reported no conflicts of interest related to this study.

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