A Study on the Fracture Strength of Implant-Supported Restorations Using Milled Ceramic Abutments and All-Ceramic Crowns

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Purpose: The purpose of this study was to compare five different abutment-crown combinations for single implant-supported restorations regarding their capabilities to withstand loads. Materials and Methods: Fifty implants were placed into resin blocks, and the restorations were connected to the implants. The five tested restorations were: (1) metal-ceramic crowns cemented to titanium abutments, (2) In-Ceram crowns cemented to titanium abutments, (3) Celay feldspathic crowns cemented to titanium abutments, (4) In-Ceram crowns cemented to milled ceramic abutments, and (5) Celay feldspathic crowns cemented to milled ceramic abutments. The specimens were loaded at 0- and 45-degree angles to the long axis, and the load values at the moment of failure were recorded using a universal testing machine. Results: The fracture strengths under vertical loading were greater than those under oblique loading. The fracture strengths of metal-ceramic crowns cemented to the titanium abutments were higher than those of all-ceramic crowns cemented on the milled ceramic abutments, regardless of loading direction. There were no differences in the fracture strengths of the ceramic crowns between the two different abutment types under oblique loading. Conclusion: All-ceramic crowns on the milled ceramic abutments were weaker than the metal-ceramic crowns on the titanium abutments under oblique loading. Int J Prosthodont 2002;15:9–13.

Materials and Methods

Ceramic Abutment and Crown Fabrication

Fifty implant fixtures (3.75 mm × 10 mm SDCA 001, Nobel Biocare) were placed into resin blocks. Five kinds of restorations composed of two different abutments and three types of crowns were attached to the implants (Table 1 and Fig 1). Thirty titanium abutments and 20 milled ceramic abutments were attached to the implants with gold abutment screws (DCA 118, Nobel Biocare) and tightened at 32-Ncm torque (Table 2).
The ceramic abutments were fabricated by copy milling using the Celay system. The titanium abutment was scanned and simultaneously milled from a sintered aluminum oxide blank (AC-12). After the milling process, the abutments were glass infiltrated at 1,100°C for 40 minutes and air abraded using 50-µm Al₂O₃ powder at 2-bar pressure. The milled abutments were inspected under a magnifying glass and connected to the implant with gold abutment screws.

A conventional metal-ceramic crown resembling the average maxillary right central incisor was fabricated onto the titanium abutment (Fig 2). Visible light–cured resin patterns (Celay-Tech, Vita) were fabricated by a cut-back method and used as prototypes for metal copings and alumina cores. For the metal-ceramic crowns, 10 metal copings were cast in Ni-Cr alloy, veneered with opaque and dentin porcelain (Vita VMK 95), and glazed.

For the In-Ceram crowns, the cores were milled from presintered alumina blanks (AC-12) to the dimensions of the prototype and glass infiltrated. The In-Ceram cores were veneered with Vitadur-alpha porcelain. The dimensions of the crowns were controlled using a silicone index. The Celay feldspathic crowns were milled from the ceramic blanks (A2M-12) to the size of the crown and glazed with Vita shading paste.

All crowns were luted to the abutments with a resin cement (Panavia 21, Kuraray), and the specimens were stored at 37°C in a water bath for 24 hours.
Fracture strength measurements were carried out using a universal testing machine (Z020, Zwick) at a cross-head speed of 2 mm/min. The specimens were loaded at 0- and 45-degree angles to the long axis. The loading point was at the incisal edge in vertical loading (0 degrees). A 1-mm-thick tin foil was placed between the crown and the loading device. In oblique loading (45 degrees), the specimens were mounted on the 45-degree metal stand and loaded with a rod of 10-mm diameter at the lingual surface, 2 mm cervical from the incisal edge of the crown (Fig 3). The failure loads were recorded when the incisal edge of the crown was deflected 1.0 mm following abutment deformation, or when the ceramic crown or abutment fractured.

Analysis of variance (ANOVA) was selected to assess the effects of loading direction and the type of implant-supported restoration. Multiple comparisons according to the Scheffé F test were performed to illustrate differences between groups.

Results

The statistical analysis revealed that the load data were related to loading direction and restoration type according to two-way ANOVA (P < .0001). The F test showed the interaction to be significant (P < .0001). The mean fracture strengths of the three types of crowns on the titanium abutments under vertical loading were not significantly different (Table 3). There were no significant differences between the In-Ceram and Celay feldspathic crowns on ceramic abutments. However, the fracture strengths of groups 1 and 3 were significantly higher than those of groups 4 and 5.

Under oblique loading, there were no significant differences in fracture strengths among the ceramic crowns on any of the abutments. The fracture strength of the metal-ceramic crown on the titanium abutment was significantly higher than any of the other combinations. Under vertical loading, the veneer porcelain was sheared off the metal coping in group 1, and from the In-Ceram core in group 2. The ceramic crown was fractured in half and separated from the abutment in group 3. In groups 4 and 5, cracks were initiated from the ceramic abutment collar near the junction between the abutment and the implant, and they fractured eventually.

Under oblique loading, a gap formed at the lingual side of the implant-abutment junction. Permanent bending of the abutment screw occurred in groups 1 and 2. While no porcelain fracture was observed in group 1, two fractures were noted in group 2. These fractures involved both the veneer ceramic material and the sintered ceramic core. The crowns in group 3 exhibited predominantly catastrophic failure, with some instances of permanent screw deformation toward the facial side. However, in groups 4 and 5, horizontal fracture often occurred on the ceramic crowns and the ceramic abutments at a level slightly lower than the abutment screw head.

<table>
<thead>
<tr>
<th>Group</th>
<th>Vertical loading</th>
<th>Oblique loading</th>
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<tbody>
<tr>
<td>1</td>
<td>1,812 (312)</td>
<td>333 (36)</td>
</tr>
<tr>
<td>2</td>
<td>1,269 (232)</td>
<td>298 (35)</td>
</tr>
<tr>
<td>3</td>
<td>1,628 (419)</td>
<td>231 (117)</td>
</tr>
<tr>
<td>4</td>
<td>858 (91)</td>
<td>182 (55)</td>
</tr>
<tr>
<td>5</td>
<td>786 (236)</td>
<td>170 (46)</td>
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</tbody>
</table>

*Standard deviations are in parentheses. Vertical lines denote no significant differences among groups.
Discussion

The fracture strengths of titanium abutment groups 1 and 3 were higher than those of milled ceramic abutment groups 4 and 5 under vertical loading. Even though the ceramic abutment groups showed lower fracture strengths than the titanium abutment groups, group 5 (with the lowest mean fracture strength of 786 N) had a sufficient capacity to endure the masticatory forces under vertical loading.13 The high values for axially loaded crowns resulted because the compressive strength of the veneering porcelain was higher than its flexural strength.9 Thus, the ceramic implant-supported restoration should be designed to be loaded axially.

The fracture strengths of ceramic crowns were not independent on the abutment type under oblique loading. The results of this study are in agreement with other investigators who reported that the fracture strengths of ceramic abutments might approach those of metallic abutments.2 The somewhat higher values reported by those authors may have been due to the larger size of their abutments. The smaller dimensions used in the present study were selected to be the same size and shape as the titanium abutment for comparison. Also, the failure load in this study was defined to occur when the deflection of the incisal edge of the crown was 1.0 mm, or when the ceramic crown started to fracture. Some researchers define the failure load as catastrophic failure of the ceramic restoration.2,6

The modes of failure were different among the groups tested under oblique loading. In groups 1 and 2, plastic bending of the abutment screws occurred, with formation of gaps at the lingual sides of the implant-abutment junctions before ceramic failure. Horizontal fracture in groups 4 and 5 often originated from the ceramic abutments at levels slightly inferior to the abutment screw heads. The horizontal fractures may have resulted from the tensile stresses around the screw head. Mean oblique forces causing plastic deformation of abutment screws have been reported to be between 80 and 190 N.2,7 For the implant systems used in this study, a tendency to fail by plastic bending of abutment screws at a mean level of 138 N is reported.14 In the present study, the plastic deformation of the abutment screws might have caused all-ceramic crowns to fracture on ceramic abutments owing to screw bending.

On the titanium abutments, the Celay feldspathic crowns showed a comparable strength with the In-Ceram and the metal-ceramic crowns, regardless of loading direction. These observations agree well with previously reported results.15 Further investigation is necessary to examine the clinical outcome of these ceramic crowns.

The mean maximal biting force on osseointegrated implant fixed partial dentures has been reported to be 144 N, which improves significantly after 10 years.16,17 The all-ceramic crowns on ceramic abutments failed between 170 and 182 N under oblique loading. These values are slightly higher than the maximum physiologic forces on anterior teeth.13 Considering the mean maximum occlusal load on incisors and the cyclic loading condition of ceramic crowns in a hydrated environment, the results of the present study showed that all-ceramic crowns on milled ceramic abutments should be used very carefully for a single implant-supported restoration.

Conclusions

The fracture strengths of two types of ceramic crowns on titanium or ceramic abutments were compared with a metal-ceramic crown on titanium abutments as a control. The results led to the following conclusions:

1. Fracture strengths under vertical loading were greater than those under oblique loading.
2. Fracture strengths of metal-ceramic crowns cemented on the titanium abutments were higher than for ceramic crowns cemented on milled ceramic abutments, regardless of loading direction.
3. There were no differences in the fracture strengths of the ceramic crowns between the two different abutment types under oblique loading.
4. There were no differences among the fracture strengths of three different crowns on the titanium abutments.

References

Management of advanced mandibular osteoradionecrosis with free flap reconstruction.

The purpose of this study was to assess the effectiveness of free tissue transfer for the treatment of advanced mandibular osteoradionecrosis (ORN) in head and neck cancer patients. Twenty-nine patients who were treated for advanced mandibular ORN by radical resection and reconstruction with free flaps were reviewed. All patients had either failed to respond to conservative treatment, including hyperbaric oxygen therapy and debridement, or had pathologic fracture because of ORN. Twenty-four vascularized bone (17 fibular, five iliac, and two scapular), four rectus abdominis myocutaneous, and one radial forearm fasciocutaneous free flaps were used. Complications occurred in six of 29 patients (21%). A total of four flaps (14%) were lost. The mean follow-up was 2.75 years. All patients had complete resolution of ORN symptoms. No evidence of ORN recurrence was observed in any patient. For advanced ORN of the mandible, radical resection followed by reconstruction using a free flap provides a reliable means of obtaining good wound healing with acceptable esthetic and functional results.

Chang DW, Oh HK, Robb GL, Miller MJ. Head Neck 2001;23:830–835. References: 24. Reprints: Dr David W. Chang, Department of Plastic and Reconstructive Surgery, The University of Texas M. D. Anderson Cancer Center, 1515 Holcombe Boulevard, Box 443, Houston, Texas 77030. e-mail: dchang@mdanderson.org—Frankie Sulaiman, Seattle

The use of reinforced composite resin cement as compensation for reduced post length.

The authors evaluated the retention of two types of 1.5-mm-diameter stainless steel posts (serrated parallel-sided ParaPosts and tapered threaded Dentatus posts) in various lengths (5, 8, and 10 mm) luted with a titanium-reinforced resin and a zinc phosphate luting agent. The crowns of 120 extracted intact single-rooted human teeth were removed at the CEJ. The teeth were divided into four groups of 30: group A = ParaPosts luted with resin luting agent; group B = Dentatus posts luted with resin luting agent; group C = ParaPosts luted with zinc phosphate luting agent; group D = Dentatus posts luted with zinc phosphate luting agent. Each group was divided into three subgroups to test the effect of three different post lengths. The samples were tested on a tensile testing machine at 2 mm/min cross-head speed until failure. The effect of different luting agents was analyzed using ANOVA. The effect of post length on retention with the two cements was analyzed with one-way ANOVA with Scheffé contrast. The results indicated that: (1) the resin luting agent significantly increased retention when compared with zinc phosphate; (2) among different post lengths, no statistically significant difference was found in the resin luting agent group, but a statistically significant difference was found in the zinc phosphate group (10 mm > 8 mm > 5 mm); and (3) ParaPosts were more retentive than the Dentatus posts. The results of this study show that the resin luting agent enhanced the retention of shorter posts.

Nissan J, Dmitry Y, Assif D. J Prosthet Dent 2001;86:304–308. References: 44. Reprints: Dr Joseph Nissan, Department of Prosthetic Dentistry, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel. e-mail: nissandr@post.tau.ac.il—Ansgar C. Cheng, Toronto