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Effect of convergence angle and luting agent on the fracture strength of In ceram crowns

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This study compared the fracture strength of In ceram crown shapes fabricated with either 8 or 16° total occlusal convergence; and attached with either a commercial zinc phosphate cement or a glass ionomer cement. Thirty crown shapes (8 mm diameter and 8.5 mm high) were fabricated for each preparation design on a brass master die with approximately the same dimensions as a premolar. In ceram crown shapes were luted on to the die using zinc phosphate or glass ionomer. The crown shapes were fractured in a testing machine (Instron) using a steel ball, 4 mm in diameter, that contacted the occlusal surface and the resulting data were statistically analyzed using a Mann–Whitney test. The results indicate that there is no statistical difference in the fracture strength values between preparations with 8° total convergence compared with 16° using the same cement. However, crown shapes luted with zinc phosphate on preparations with 8 and 16° total occlusal convergence were significantly stronger than those luted using glass ionomer cements ($p < 0.05$).

1. Introduction

In the last few years, new dental materials and techniques have been developed and much attention has been focused on fabrication of crowns with improved physical and mechanical properties. The longevity of all-porcelain and glass ceramic crowns has been of concern to clinicians because the restoration may fracture suddenly and catastrophically, a phenomenon rarely seen in metal ceramic restorations [1].

Several studies have been made to evaluate the effect of tooth preparation design on the breaking of all-ceramic restorations. However, interpretation of the literature is extremely difficult due to the numerous different terms used to describe the total occlusal convergence and in some cases misuse of the terminology. It must be understood that the taper angle is a measure taken from only one axial wall of a preparation, while occlusal convergence is a measure of the combined taper angles of opposite axial walls [2].

Studies by Dykema *et al.* [3] and Tylman and Malone [4] have recommended minimal occlusal convergence of opposing prepared axial walls for all fixed prosthodontic restorations. Dodge *et al.* [2] and Kent *et al.* [5] found clinically, that the mean total occlusal convergence tooth preparation is more than the ideal value and depends upon location in the mouth and visual accessibility. However, the restorations were still clinically successful. Some authors have recommended 6–8° total occlusal convergence for Dicor crowns [6, 7].

Friedlander *et al.* [8] have reported that there is no difference in the strength of Dicor crowns made on preparations with 10 and 20° convergence and rounded axiogingival line angles. Doyle *et al.* [9] have reported that restorations fabricated with preparations of 5° occlusal convergence were significantly weaker than those made for preparations with 15° convergence.

Other authors have used total occlusal convergence for In ceram crowns and other types of dental porcelains, of 5° [9, 10], 8° [11–13], 10° [14], 12° [1], 14° [15], 16° [2], and 20° [16].

The purpose of this study is to compare the fracture resistance of In ceram crown shapes fabricated with 8 and 16° total occlusal convergence; and to determine whether different cements produce variations in strength.

2. Materials and methods

Master dies with approximately the same dimensions as a premolar were made from brass (Fig. 1).

Brass dies were coated with three layers of die spacer (Vita) and impressions were made using an addition polymerization silicone material (Express, 3M Dental Products, MN) with a metal ring. These impressions were poured with In ceram special plaster using a liquid :

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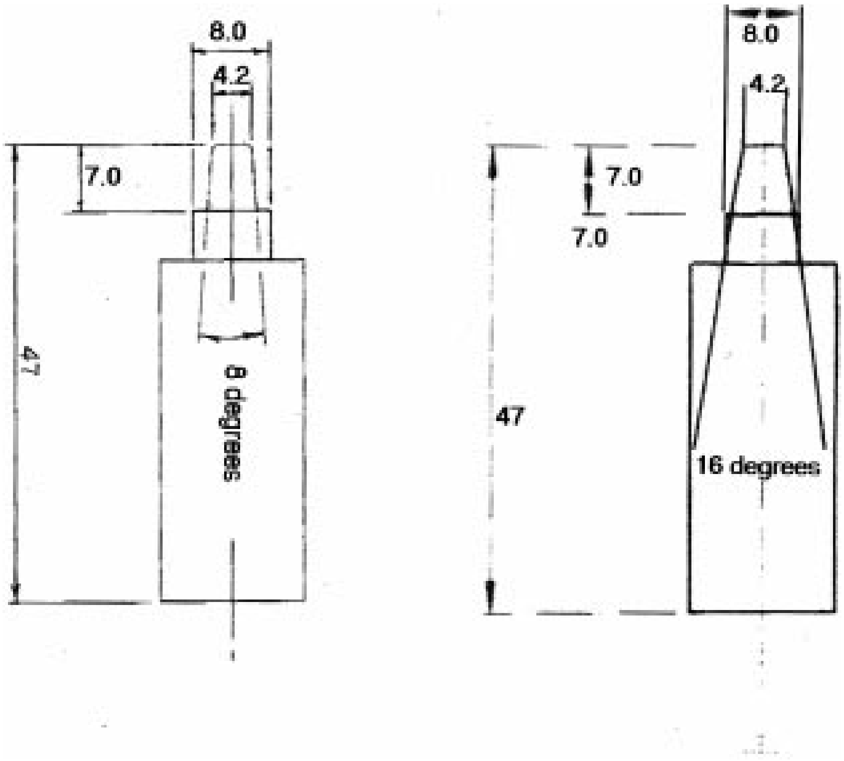

Figure 1 Schematic drawing of the brass master dies: left, 8° and right, 16° total occlusal convergence (all corners were radiused to 0.5°).

powder (l : p) ratio of $0.23\,\mathrm{ml\,g^{-1}}$ to make refractory models. In ceram powder slip was prepared according to the manufacturer's instructions and was applied to the models. A sculpturing device similar to that used by Philp and Brukl [17] was utilized to ensure a uniform thickness of core (0.5 mm). After applying a stabilizer, the coping was fired on the plaster dies in a furnace (Inceramat, Vita) for 6 h at 120 °C and 4 h at 1120 °C. The copings were then glass infiltrated in a second firing process in the furnace (Inceramat, Vita) for 30 min at 120 °C and 4 h at 1100 °C. Excess glass was removed with a diamond burr. The veneer porcelain (Vita Alpha, dentine porcelain) was then applied to the core, which had been placed in a split brass mold to make a complete crown shape with 8.0 mm diameter and 8.5 mm height (Fig. 2). A total of 30 crown shapes were fabricated for each total convergence angle.

After glazing, the crown shapes were cemented on to the brass die with zinc phosphate cement (Orthostan, Stratford Cookson Co.); or one of two glass ionomer cements (RGI, Lutrex, Henry Schein; or Vivaglass Cem, Vivadent). All cements were mixed according to the manufacturer's instructions. The crown shapes were filled with cement, seated with firm pressure and excess cement was removed and immediately placed under a 2.7 kg static load for 10 min. All the samples were stored in distilled water at 37 °C for 24 h prior to testing.

The crown shapes were tested for fracture strength on an Instron universal testing machine. The point-of-force application was the center of the occlusal surface of the crown shape with 4-mm diameter stainless steel ball. A preload of 20 N was applied, and then at a crosshead speed of $1.0\,\mathrm{mm\,min^{-1}}$ the specimens were loaded until fracture occurred. The fracture surfaces of the crown shape were then examined using a scanning electron microscope (SEM; S90B, Cambridge Instruments).

Fracture strength data of the crown shapes were submitted to Mann–Whitney statistical analysis.

3. Results

The influence of total occlusal convergence angle is shown in Table I. The mean fracture load for In ceram crown shapes with 16° convergence angle was compared with the mean for In ceram crown shapes with 8° using the same cement. It was observed that no statistical difference was found.

Crown shapes luted using zinc phosphate on preparations with 8° total convergence angle, were significantly stronger than those luted using glass ionomer cements (RGI-Lutrex and Vivaglass Cem) ($p < 0.05$). No statistical difference was found when RGI-Lutrex was compared with Vivaglass Cem. The same result was

Figure 2 Split brass mold used to make the complete crown with Vita Alpha dentine porcelain. Samples of core on the left and complete crown shape on the right are also shown.

T A B L E I Mean load[a] (in newtons) at complete fracture of In ceram crowns (standard deviation in parentheses)

Convergence angle (°)	Zinc phosphate	RGI-Lutrex	Vivaglass Cem
8	1883.2(207.3) }	1145.5(155.5) }	1046.6(141.5) }
16	1916.5(248.3) }	1156.4(117.9) }	1150.1(174.0) }

[a]Values connected by braces are not significantly different at the 95% confidence level (Mann–Whitney test, $p < 0.05$).

T A B L E I I Mean load[a] (in newtons) at complete fracture of In ceram crowns, with 8 or 16° total occlusal convergence

Cement	Number of crowns	8° convergence angle	16° convergence angle
Zinc phosphate	10	1883.2(207.3)	1916.5(248.3)
RGI-Lutrex	10	1145.5(155.5) }	1156.4(117.9) }
Vivaglass Cem	10	1046.6(141.5) }	1150.1(174.0) }

[a]Values connected by braces are not significantly different at the 95% confidence level (Mann–Whitney test, $p < 0.05$).

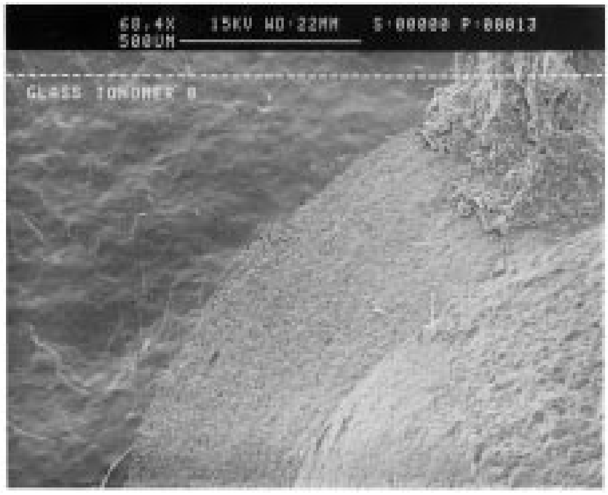

Figure 3 SEM image of the fracture surface of the In ceram crown shape. The In ceram is in the bottom right-hand corner and the Vita Alpha dentine porcelain is in the top left of the image.

found when crown shapes were luted on preparations with 16° total occlusal convergence angle (Table II).

Fig. 3 shows an SEM image of the fracture surface of an In ceram crown shape, showing the bonding between the high alumina core and Vita Alpha dentine porcelain.

4. Discussion

Several studies have demonstrated that preparations with different total occlusal convergence angles can produce different results.

It has been reported that Dicor crowns made for tooth preparations with 5° total occlusal convergence were weaker than those made for preparations with 15° convergence [9]. Friedlander *et al.* [8] observed that two of three finish line design preparations for Dicor crowns with 10° total occlusal convergence were weaker than preparations with 20° total occlusal convergence, but no statistical difference was found. However, Dodge *et al.* [2] showed that preparations with 10° total occlusal convergence were stronger than gold crown preparations with 16 and 22° total convergence with a statistical difference.

In our study, it was observed that In ceram crown shapes made with 8° total occlusal convergence and rounded axiogingival line angle were weaker than those made for preparations with 16° total convergence angle, but no statistical difference was found. Friedlander *et al.* [8] showed that there is no statistical difference in the strength of Dicor crowns made on preparations having 10 and 20° total occlusal convergence and a rounded axiogingival line angle. Manufacturers give recommendations for convergence angles and the effect of these on the crown in terms of stress distribution can easily be envisaged. With increasing angle, stress concentrations will increase at radii at or near the inner occlusal surface. This problem may be further exacerbated by insufficiently radiusing the corners of the inner occlusal surface. However, in this study, it appeared that an increase in convergence angle from 8 to 16° does not affect the In ceram system with glass ionomer and zinc phosphate cements

On the other hand, when different cements were compared, our study showed that crown shapes luted with zinc phosphate on preparations with 8 and 16° total occlusal convergence were significantly stronger at $p < 0.05$ (1883.2 and 1916.5 N) than those luted with glass ionomer RGI-Lutrex (1145.5 and 1156.4 N) and Vivaglass Cem (1046.6 and 1150.1 N). No statistical difference was found between RGI-Lutrex and Vivaglass Cem. However, Bernal *et al.* [14] obtained higher values with glass ionomer (104.8 kg) than zinc phosphate (98.35 kg). Correr Sobrinho *et al.* [18] obtained higher values with glass ionomer Fuji (2183 N) and zinc phosphate (2030 N). An explanation for the difference must be sought, by considering the cements used. Two factors may be influencing the mechanical properties. The first is the viscosity of the cements and the second is their mechanical properties when set. The viscosity may affect the mechanical properties, because if the viscosity is low, the cement may easily flow and fill any defects on the inner surface of the crown shapes. This is of importance as it is this inner surface where stresses concentrate. Secondly, the mechanical properties of the cements may affect the fracture strength as they will change the mechanical properties of the system dependent on the properties of the cements. Dental luting agents have poor wetting properties and, as the cements set, they contract and pull away from the restoration and the tooth [19]. This inability to fill the space between a crown and the tooth completely, compounds the problem of stress transfer. It may be that a thin cement layer, characteristic of better adapted crowns, is more relevant to the practical strength of a porcelain crown than the relative strength of the materials themselves [12].

Although the use of a brass die does not reproduce natural teeth, because of the mismatch in mechanical properties compared to teeth, it does provide a reproducible support. Furthermore, the die does eliminate the variability seen with natural tissues and this was felt to aid this study, particularly due to the inherent unpredictability of ceramics. Future research, however, aims at using bovine dentine as a base.

5. Conclusions

The results of this study show that:

1. There is no statistical difference in the fracture resistance values between preparations with 8° total occlusal convergence compared with 16° using the same cement.
2. Crown shapes luted using zinc phosphate on preparations with 8 and 16° total occlusal convergence, were significantly stronger than those luted using RGI-Lutrex and Vivaglass Cem cements ($p < 0.05$).

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