Effect of Preparation Taper and Height on Strength and Retention of Zirconia Crowns

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This study aimed to determine the effect of the taper and height of tooth preparations on the fracture strength and retention of zirconia crowns. Sixty-four dies were designed to simulate a crown preparation. Dies were machined with a height of either 4 mm (n = 16) or 7 mm (n = 16) and a taper of either 6 degrees (n = 16) or 20 degrees (n = 16). Copings were created from Lava zirconia blanks. Retention tests were performed using a universal testing machine. Copings were recemented on the dies, thermocycled, and tested for fracture strength. Data were analyzed using factorial analysis of variance. Retention was greater in the taller and less-tapered preparation designs. Taller preparations showed superior fracture strength. Preparing posterior teeth with higher axial walls and less taper is recommended to achieve increased retention and strength for zirconia crowns. *Int J Prosthodont 2012;25:582–584.*

The failure rate of posterior all-ceramic crowns has been reported to be 3% to 4% after 5 years, which indicates complex mechanical scenarios other than overloading.[1] The primary clinical goals have been to determine the optimal amount of tooth preparation and to minimize both tensile stress on the cement and rotational dislodgement. Proper preparation characteristics help counteract the negative dislodging forces that affect the restoration-cement-tooth complex.[2] To achieve adequate retention for dental restorations, clinicians must take into account the magnitude and direction of dislodging forces, geometry of the tooth preparation, and physical properties of the luting agent. The taper of the vertical axial walls affects the retention and rotational resistance of crown preparations.

There is disagreement in the literature regarding the necessary amount of taper and vertical axial wall height for sufficient retention and strength of all-ceramic crowns. The purpose of this study was to investigate the effects of tooth preparation taper and height on the fracture strength and retention of Lava zirconia crowns (3M ESPE).

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Materials and Methods

Sixty-four stainless steel dies were designed to simulate all-ceramic full-crown preparations for mandibular first molars. The dies were machined with an occlusocervical height of either 4 mm (n = 16) or 7 mm (n = 16), a taper of either 6 degrees (n = 16) or 20 degrees (n = 16), and a 1-mm margin with a rounded shoulder. Dies were scanned (Lava ScanST, 3M ESPE), and copings (Lava Frame Zirconia, 3M ESPE) were fabricated (0.6 mm thick) with a loop (4-mm diameter) on the center of the occlusal surface.

Copings were temporarily cemented (TempBond NE, Kerr) under 5 kg of static load centrally applied for 10 minutes. One hour after cementation, specimens were stored in a water bath at 37°C for 1 week. Tensile forces were applied along the long axis of the preparation with a universal testing machine (Lloyd Instruments) at a crosshead speed of 1 mm/min.

All copings were ultrasonically cleaned (Amsco Steris) to remove the temporary cement and then recemented on their respective dies with self-etch/self-adhesive resin cement (Maxcem Elite, Kerr). Coping-die assemblies were kept under static load as applied previously and thermocycled for 3,500 cycles at 5°C to 55°C with a dwell time of 30 cycles in each bath. All specimens were placed on a 30-degree platform and tested for fracture strength via loading from the distoocclusal surface with a universal testing machine at a crosshead speed of 1 mm/min (Fig 1).

Data were analyzed using factorial analysis of variance.

Fig 1 Coping-die assembly placed on a 30-degree platform to test the fracture strength.

Table 1 Retention (MPa) and Fracture Strength (MPa) After Thermocycling (MPa) of Zirconia Copings Placed on Different Preparation Designs

	7-mm height/ 6-degree taper	7-mm height/ 20-degree taper	4-mm height/ 6-degree taper	4-mm height/ 20-degree taper
Retention	4.0–5.8	2.6–3.8	1.8–2.9	1.2–2.8
Fracture strength	3.0–3.6	3.5–4.4	5.0–6.0	4.5–6.5

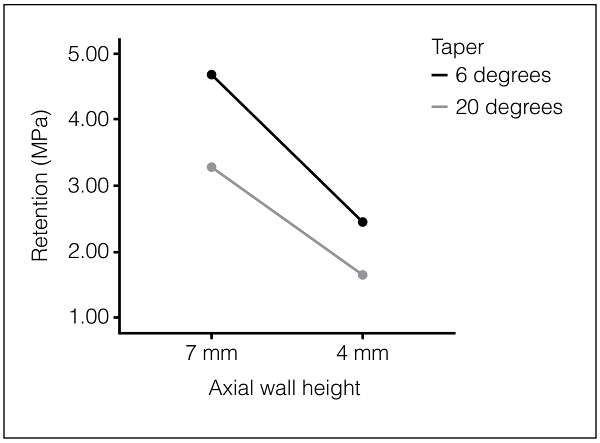

Fig 2 Retention values according to the axial wall height and taper of tooth preparations.

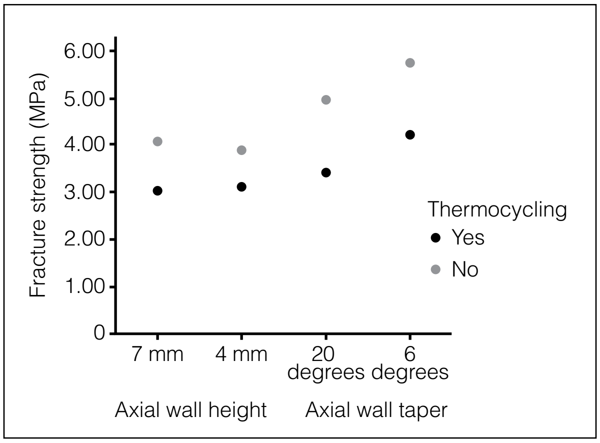

Fig 3 Fracture strength after thermocycling of tooth preparations in terms of axial wall height and taper.

Results

Table 1 shows the range of retention and fracture strength values. Height (F = 426.730, *P* = .00) and taper (F = 139.104, *P* = .00) significantly affected retention, and there was significant interaction between these factors (F = 10.572, *P* = .02). Retention increased in taller preparation designs but decreased in more tapered ones (*P* < .05). Retention increased in taller/less-tapered designs compared to shorter/less-tapered ones (*P* < .05). Retention decreased in the following order based on the preparation design: taller/less tapered, taller/more tapered, shorter/less tapered, and shorter/more tapered (Fig 2).

Thermocycling and height showed statistically significant effects on fracture strength (F = 71.81, *P* = .000), whereas taper alone was insignificant (F = .078, *P* = .78). The interactions between thermocycling and height (F = 4.85, *P* = .03) and height and taper (F = 8.71, *P* = .005) were statistically significant. Taller preparations had increased fracture strength (*P* < .05), and this increase was more prominent with less-tapered designs regardless of thermocycling (*P* < .05). Thermocycling decreased the fracture strength in taller preparations regardless of taper (*P* < .05). Fracture strength decreased in the following order based on preparation design: taller/less tapered, taller/more tapered, shorter/more tapered, and shorter/less tapered (Fig 3).

Discussion

A previous study reported that increasing the axial length of crowns fabricated with feldspathic porcelain, glass-ceramic, or alumina-reinforced glass led to enhanced fracture strength.[3] However, information on the stress distribution and fracture patterns in terms of load position, load direction, or variations in axial wall length was not provided. In another study,[4] reducing the proximal axial length of the tooth preparation led to concentrated stress at the crown margins, suggesting that this area may be vulnerable to damage during fit adjustment and function. The present study, in which the fracture resistance of Lava zirconia copings improved with increased axial wall height and reduced taper after thermocycling, supports these previous findings. In addition, this study suggests that there may be a minimum critical thickness required to achieve adequate strength for ceramic restorations. Traditional prosthodontics teachings have stressed the importance of keeping the thickness of ceramic veneered to copings below 2 mm[2,5] The goal of this guideline is to decrease the frequency of cohesive ceramic failures due to lack of support.

Molar tooth preparations usually possess the most excessive taper and shortest axial walls.[6] Excessive crown preparation may result in pulp exposure and a thin dentin core. The interaction of axial wall height and taper appears to support the use of smaller axial inclination angles and larger wall heights. In a previous study, the largest surface areas were found in the 5-mm-height groups at 2 to 10 degrees of taper.[7] Preparation designs with higher axial walls and less taper showed the best retention. Optimizing these factors will allow the clinician to produce the largest possible surface area, thus enhancing the performance of the luting agent and the resistance form of the restoration.

In a study by Zidan and Ferguson,[8] the mean retentive strength of crowns placed with resin cement on molar teeth prepared with 6, 12, or 24 degrees of taper was 6.5 MPa. These results are higher than those of the present study (4.0 to 5.8 MPa for 7-mm-tall, 6-degree-taper designs) but are still comparable. The discrepancy between the two studies may be the result of differences in the crown and die materials used.

Molar teeth can be difficult to access, resulting in wide variations in tooth reduction, increased taper for tooth preparations, and thus increased bulk of porcelain restorations. Hence, it is important to understand the potential risks of inadequate preparation. In the present study, the abutments were standardized on prepared dies for the application of Lava copings. In clinical practice, however, tooth preparations vary with natural tooth form. Additionally, further studies are needed to evaluate retention and fracture strength after long-term storage and mechanical cycling. The magnitude and direction of dislodging forces is an inherent patient factor that the dentist may not be able to adequately control.

Conclusion

Within the limitations of this in vitro study, tooth preparations designed with high axial walls and reduced taper provided the best retention and fracture strength for Lava zirconia crowns.

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