Short Communication

Comparison of Load-Fatigue Testing of Ceramic Veneers with Two Different Preparation Designs

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The concept of tooth preparation for ceramic veneers remains controversial regarding whether the use of a palatal chamfer would affect the longevity of restorations. This study aimed to evaluate the load-fatigue testing of ceramic veneers using two different preparation designs—an incisal shoulder finish line with or without a palatal chamfer. A pressable ceramic veneer was bonded to the prepared maxillary central incisor using resin cement. The number of cycles until fatigue failure for each tooth-veneer specimen was recorded. Results revealed that using a palatal chamfer margin design significantly increased the fatigue failure cycle count. *Int J Prosthodont 2009;22:573–575.*

The concept of tooth preparation for ceramic veneers remains controversial. It is believed that the incisal shoulder finish line should not extend into a palatal concavity since an extending preparation with a palatal chamfer did not provide increased strength for ceramic veneers and generated a thin extension of ceramic in an area of maximum tensile stress.[1,2] In contrast, an incisal edge extension preparation with a palatal chamfer showed a better stress distribution[3] and clinical success rate when compared to an incisal shoulder finish line alone.[4] Therefore, this study aimed to evaluate the load-fatigue testing of ceramic veneers using two different preparation designs.

Materials and Methods

Extracted intact human maxillary central incisors were selected for this study. The teeth were divided into two groups: a 4-mm incisal reduction with a shoulder finish line (group BM, n = 7) and a 4-mm incisal reduction with a palatal chamfer (group BM-P, n = 7) (Fig 1). This tooth preparation design closely represents dentition resulting from wear or trauma. All facial tooth preparations were completed entirely in the enamel.

Following the tooth preparation, the incisal reduction width was measured. An impression of each prepared tooth was made and poured using a die stone. A custom waxing jig was used to provide a standardized notch located on the waxed veneer where the fatigue load was applied (Fig 2a). Veneers were fabricated in a pressable ceramic (IPS Empress, Ivoclar Vivadent) and bonded to the prepared teeth using resin cement (Variolink II, Ivoclar Vivadent). A strain gauge was cemented over the tooth-veneer interface to register the preliminary fatigue failure of the restoration (Fig 2b).[5] The strain gauge was connected to one arm of a Wheatstone bridge circuit. Voltage output from this circuit was proportional to the movement of the restoration margin in relation to the tooth as measured by the gauge.

A fatigue load was applied on each tooth-veneer specimen (Fig 2c). Initially, the amplitude was small and regular, indicating that the movement of the restoration during loading was elastic. However, as the crack in the cement layer grew larger, the movement increased. Finally, the movement of the restoration margin reached a magnitude beyond the range of the strain gauge. This point was deemed as the preliminary failure of the restoration. The independent variable recorded was the number of load cycles required to induce failure of the veneering cement.

The cyclic load failure data were subjected to a Student *t* test ($\alpha = .05$). In addition, a linear correlation analysis was used to compare the incisal reduction width with the number of cycles until preliminary failure. After a cycle of preliminary failure was recorded, the specimens were examined under an optical microscope to obtain the mode of failure. The mode for preliminary failure was classified in accordance with one

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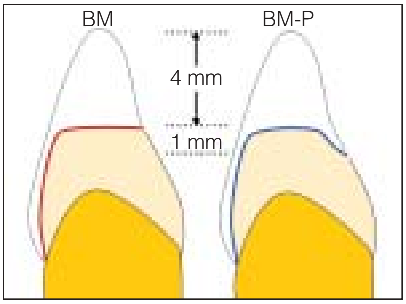
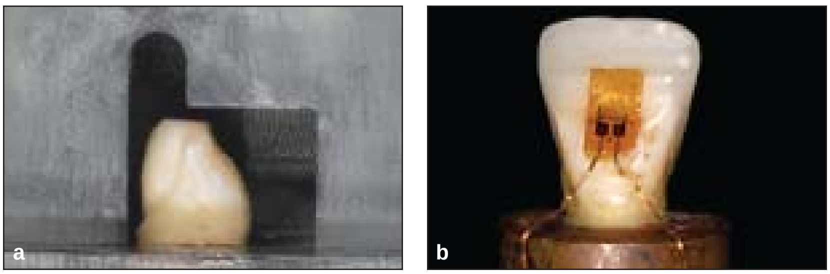


Fig 1 *(left)* Schematic representation of preparation designs of each group. Group BM *(left)*, incisal reduction with incisal shoulder finish line. Group BM-P *(right)*, incisal reduction with incisal shoulder finish line and a palatal chamfer.



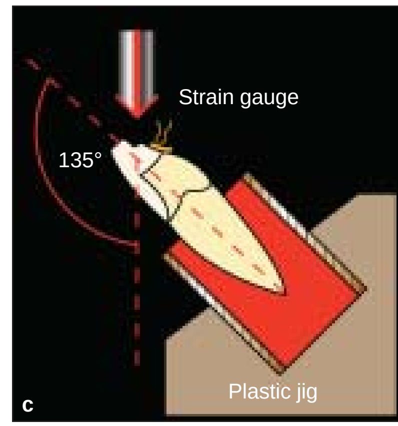


Fig 2 Representative photographs of **(a)** custom waxing jig used to provide a standardized notch location for fatigue load application; **(b)** strain gauge cemented over the tooth-ceramic veneer interface to register the preliminary fatigue failure of restorations; and **(c)** diagram of specimen in the positioning jig and location of the load. Note that a fatigue load of 40 N with a frequency of 72 cycles per minute was applied at 135 degrees to the long axis of the tooth.

Table 1 Number of Cycles to Preliminary and Catastrophic Failure by Group

Specimen no.	Cycles to preliminary failure	Cycles to catastrophic failure
Group BM		
1	16,500	18,100
2	35,300	35,700
3	17,100	18,600
4	24,600	25,400
5	24,800	25,500
6	31,300	32,000
7	27,200	28,200
Mean	25,200	26,200
SD	6,800	6,500
Group BM-P		
1	45,400	47,800
2	46,100	49,500
3	48,800	51,400
4	55,900	57,900
5	44,700	46,200
6	54,200	55,300
7	60,700	61,700
Mean	50,800	52,800
SD	6,100	5,600

SD = standard deviation.

of the following criteria: no crack (type I) or crack in the ceramic (type II).

After mode of preliminary failure was recorded, the specimens continued loading until the catastrophic failure was found. The catastrophic failure was classified in accordance with one of the following mode criteria: adhesive failure along the ceramic surface (type III), cohesive failure with a thin layer of resin cement remaining on the ceramic surface (type IV), cohesive failure in the luting cement (type V), or ceramic fracture (type VI). The mode of failure data was subjected to a Fisher exact test ($\alpha = .05$).

Results

The number of cycles to failure of group BM-P was significantly higher than the number of cycles for group BM ($P < .001$) (Table 1). There was a significant linear correlation between the incisal reduction width and the preliminary fatigue failure cycle count ($P < .01$, data not shown). All ceramic veneers were intact after preliminary failure and cracks were found at the cervical area of three specimens in both groups (Fig 3a). Fisher exact analysis revealed significant differences in mode of failure at the point where catastrophic failure occurred ($P = .02$). In group BM, there were five specimens with adhesive failure along the ceramic surface, one specimen with cohesive failure in the cement, and one specimen with cohesive failure with resin cement on the ceramic surface (Fig 3b). In contrast, most specimens in group BM-P fractured at the loading area; there were only two specimens with cohesive failure in the cement (Fig 3c).

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Fig 3 Representative photographs of specimen failures. **(a)** Cracks *(arrows)* in the ceramic veneer at the cervical area after preliminary fatigue failure; **(b)** catastrophic failure in group BM, a cohesive failure with a thin layer of resin cement remaining on the ceramic surface *(left)* and an adhesive failure along the ceramic surface *(right)* observed after fatigue load; **(c)** catastrophic failure in group BM-P, ceramic fracture at loading area *(left)* and a cohesive failure in the luting cement *(right)* observed after fatigue load. Note that there was no tooth or root fracture in all specimens.

Discussion

The significant difference between the number of fatigue failure cycle counts of group BM-P and group BM may result from two factors. First, the ceramic that filled the palatal chamfer acted as a shear key, holding the veneer against a labial motion during loading. Second, during load application, the cement along the palatal chamfer underwent both shear and tensile stresses, with the tensile component being reduced over that in the incisal finish line due to the presence of the accompanying resisting shear stress. Since the shear strength of these resin cements is much higher than the tensile strength, it would be expected for failure to be initiated in the tension. For both designs, this initial tensile failure, or crack in the cement line, appeared at the palatal aspect. Thus, the proposed reduction in the tensile stress would increase the number of cycles to failure for the palatal chamfer design.

The loading machine was stopped after the preliminary failure of the cement was found with the veneer intact on the tooth. Continuously applying the fatigue load to the ceramic caused different catastrophic modes of failure. It appeared that the failure of the cement bonding happened before the ceramic fracture. Due to the relatively low flexural strength of the ceramic, the strength of all-ceramic restorations to resist incisal shear loads resulted from a reinforcement bond from the underlying tooth structure. In this situation, if the reinforcement bond failed, the ceramic would break because it was brittle and less resistant to the shear and strain forces.

It is important to note that there are limitations to the present study. The tooth preparation design of a 4-mm incisal reduction could possibly disclose some exposed dentin at the incisal surface and the preparation design may closely represent worn or traumatized dentition since the incisal reduction was larger than the usual 2 mm. This preparation was required in the present study for two reasons: to maintain adequate ceramic thickness for positioning a loading pin on the ceramic veneer and to maintain adequate space for placing a strain gauge over the palatal margin between the veneer and tooth (to record the failure). The extracted human maxillary incisors that were used may be disadvantageous due to great variations in age and quality, making the bonded interface of the samples difficult to standardize. Using a higher number of specimens could give more precise fatigue results for a veneer restoration system. Although the specimens were kept under moisture at all times, thermocycling with changing temperatures and artificial aging were not performed in the study. These influential parameters must be considered in future research.

Conclusion

Within the limitations of this study, it was found that increasing the lingual cement length between the tooth and veneer using a palatal chamfer margin significantly increased the fatigue failure cycle count for the resin cement.

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