ORIGINAL RESEARCH

Comparison of fracture resistance for chairside cad/cam lithium disilicate crowns and overlays with different designs- An original research

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ABSTRACT

Aim: The purpose of the research was to evaluate the fracture resistance of conventional full coverage crowns and two different designs of overlay restorations with margins located 2 and 4 mm above the gingival level.

Methodology: CAD/CAM lithium disilicate (IPS e.max CAD for CEREC/HT A1 C14, Ivoclar Vivadent) restorations (15 specimens/group) with 1.5 mm occlusal thickness and 1.0 mm chamfer were designed and fabricated with a chairside CAD/CAM system (CEREC, Dentsply Sirona). The restorations were prepared in three different designs: (1) full coverage crowns, (2) overlays with the margin located 2 mm above the gingiva, and (3) overlays with the margin located 4 mm above the gingiva. Restorations were cemented using conventional resin luting cement (Multilink, Ivoclar Vivadent) then finally loaded with a steel indenter until failure. Scanning electron microscopy observations of fractured surfaces were also conducted. Group results were analyzed with one-way analysis of variance, and the medians were evaluated independently with Kruskal-Wallis.

Results: The fracture force of CAD/CAM lithium disilicate restorations was significantly different ($p < 0.001$) depending on the design of the restoration. Full coverage crowns showed significantly higher force to fracture (1018.8 N) than both

types of overlays (p = 0.002 for overlay 2.0 mm and p < 0.001 for overlay 4.0 mm above gingiva).

Conclusion: Full coverage chairside CAD/CAM lithium disilicate premolar crown showed higher fracture resistance than overlay restorations.

Keywords: CAD/CAM; crown; overlay; restorations; lithium disilicate; fracture.

INTRODUCTION

Computer-aided design–computer-aided manufacturing (CAD–CAM) materials have offered numerous advantages in the field of dentistry compared with conventional crown fabrication in terms of time, precision,[1] and laboratory skill dependency.[2] CAD–CAM glass ceramic blocks, or lithium disilicate glass ceramics (LDGC, IPS e.max, IVOCLAR VIVADENT), were first introduced in an attempt to standardize workflow quality (material and shade) and have demonstrated high survival rates and aesthetic success over time.[3] However, their milling is both time and bur consuming[4] and can generate cracks and edge chipping.[5] The more recently introduced resin-based CAD–CAM blocks/disks have been designed as alternatives to CAD–CAM glass ceramics, they are easier to mill, provide a smoother final surface, and require fewer manufacturing steps.[4,5] There are two manufacturing techniques for resin ceramic blocks. Resin nano-ceramics (RNCs) comprise highly charged dispersed nanoceramic particles in a polymer network. Polymer-infiltrated ceramic network (PICN) materials involve infiltrating a pre-existing ceramic network with resin polymers. The diversity in resin ceramic ingredients and network design provides these materials with comparatively high flexural strength[6] that results in reduced chipping and fractures when compared to glass ceramics. The resilient resinous matrix acts as a shock absorber while the highly dense ceramic charge gives the material its strength and possible hydrofluoric acid surface treatment.[7]A proper marginal fit is crucial to ensure minimal cement film thickness, poor adaptation being closely associated with gum inflammation, secondary caries, and prostheses failure.[1] Since the hardness of a CAD/CAM material affects the amount of material removed during milling,[6] similar materials in structure design may respond differently during the same workflow and result in different gap values. Additionally, different materials have varying structural designs and physical properties and, therefore, do not respond equally to occlusal forces, thermal changes, and fatigue. Among different materials, lithium disilicate (LS) and polymer-infiltrated ceramic network (PICN) are two of the most commonly used materials for indirect bonded restorations. LS is a reinforced glass ceramic material that has been demonstrated to have excellent strength and optimal aesthetic properties.[8] Different studies have investigated its properties in both in vitro and in vivo scenarios. Malchiodi et al.[9] followed 43 LS onlays over a mean observational period of 32 months, finding a survival rate of 97.7%. Ghert et al. analyzed 104 LS single adhesive crowns over an observational period of 9 years.[10] Overlay preparations tend to keep the margin supragingival in order to preserve as much as tooth structure as possible. Previous studies have successfully evaluated bonding methods and different thicknesses of occlusal veneers. Unfortunately, there are few results available evaluating the fracture resistance of conventional full coverage crowns with the margin located at the gingival level in comparison with different overlay restoration designs with the margin located in different coronal positions relative to the gingival level.[11]

AIM OF THE PRESENT STUDY

The purpose of the research was to evaluate the fracture resistance of conventional full coverage crowns and two different designs of overlay restorations with margins located 2 and 4 mm above the gingival level.

METHODOLOGY

Three typodont teeth, upper right second premolar, were prepared as follows: (1) a full coverage crown with a 1.0 mm chamfer margin located at the gingival level, (2) an overlay preparation with a 1.0 mm chamfer located 2 mm above the gingival level, and (3) an overlay preparation with a 1.0 mm chamfer located 4 mm above the gingival level. All the typodont teeth were prepared so that the restoration would have an occlusal thickness of 1.5 mm. The typodont teeth were scanned with an intraoral scanner (Primescan, Dentsply Sirona, Charlotte, NC) and restorations were designed with digital software (CEREC, Dentsply Sirona). The restorative material tested in this study was lithium disilicate (IPS e.max CAD for CEREC/HT A1C14, Ivoclar Vivadent, Schaan, Liechtenstein). Forty-five dies were printed from 3D printing resin which is similar in modulus of elasticity to dentin. The restorations were then luted to the tooth dies with a conventional resin luting cement. Cyclic loading was performed on five specimens of each type of restoration in room temperature water using 2,000,000 load cycles at 1 Hz with 275 N force. Samples were secured with a steel jig in a vertical position and loaded against a polyoxymethylene ball (Delrin 6.28 mm, Dupont, Wilmington, DE) used to make contact with the occlusal surface of the restoration. At the end of the fatigue test, the crowns were examined to determine if any catastrophic failure had occurred. The fractured surfaces of the restorations were observed with field emission scanning electron microscopy (SEM). Statistical analysis of fracture strength data was conducted with a commercial statistical software package (SPSS Statistics 25, IBM, Armonk, NY). One-way analysis of variance with a Tukey post hoc honest significant difference test was used to analyze the data with a significance level of 0.05.

RESULTS

Two full coverage crowns with the margin located at the gingival level and three overlay restorations with the chamfer margin located 4 mm above the gingival level failed during the fatigue testing. The fracture load to surviving restorations was significantly different ($p < 0.001$) based on the design of the restoration. Overlay restorations with the margin located 2.0 mm above the gingival level had significantly higher fracture load resistance than overlay restorations with the margin located 4.0 mm above the gingival level ($p < 0.001$). Elapsed time until fracture of the restorations was significantly different ($p < 0.001$) depending on the design of the restoration. The full coverage crown restorations with the margin located at the gingival level showed a significantly longer time until fracture compared to the two different designs of overlay restoration ($p = 0.007$ for overlay 2.0 mm and $p = 0.002$ for overlay 4.0 mm above gingiva). On the fractured surfaces at 20× magnification, several major arrested lines were observed, regardless of the type of restoration, but the fracture appearance of full coverage crowns was much more complex than that of overlay restorations. (Table 1)

Table 1- Fracture force and elapsed time until fracture for chairside computer-aided design and computer-assisted manufacturing (CAD/CAM) restorations for premolars

Design of restorations	Number of surviving specimens	Fracture force (N)	Elapsed time until fracture (ms)
Full coverage crowns with margin located at gingival level	13	1018.8 (195.7)	68.7(24.7)
Overlay restorations with margin located 2.0 mm above the gingival level	15	813.8(125.8)	48.40(9.16)

Overlay restorations with margin located 4.0 mm above gingival level	12	436.1(95.70)	44.42(11.8)

******Values in parenthesis are standard deviations. The same lowercase letter in the same vertical column indicates no significant difference (p > 0.05).*

DISCUSSION

For many years, the full crown, which represents the most invasive preparation design according to the studies of Edelhoff and Sorensen, was considered the only treatment option to restore ETT.[12] Undoubtedly, ETT are disadvantaged in terms of mechanical resistance and substrate quality compared to vital teeth. In fact, a recent systematic review and meta-analysis by Dioguardi et al. compared indirect bonded restoration on vital and ETT, showed how the risk of failure is higher for ETT. However, with the advances of adhesive procedures and modern materials, indirect bonded restorations have started to be considered as an alternative treatment option for ETT. Studies about preparation designs on ETT are useful for answering the question of whether minimally invasive treatment can be used as an alternative to the traditional full crown workflow.[13]In this study, we compared the fracture resistance of chairside CAD/CAM lithium disilicate restorations in two different overlays and full coverage crown designs made from lithium disilicate ceramic blocks for premolars. A study using an optical fiber-based bite force measurement device reported that the maximum bite force on the premolar is 464.5 N for males and 395.0 N for females.[14] Another similar study reported that the maximum bite force on the premolar was 422.9 N for males and 359.5 N for females. Thus, overlay designed premolar restorations with margins 2.0 mm above the gingiva could be considered clinically feasible, as with full coverage crowns, while an overlay 4.0 mm above margin may be not suitable, as there is little or no safety margin between the fracture resistance and the maximum force likely to be encountered. The elapsed time until fracture of the restorations in the fracture test was much longer for full coverage crowns than for overlay restorations, regardless of the overlay design. This observation coheres with the SEM observations, where the fracture appearance of full coverage crowns was much more complex than that of overlay restorations. The results of these studies [15] and the present study could be explained by the theory of plates and shells: the whole restoration, and not only the top and bottom, is responsible for the load-bearing capacity, and as a result in full coverage crowns the stress may be evenly distributed throughout the entire restoration, so that the stress values are much lower and with a wider distribution than in a small restoration, which may concentrate all the stress in a smaller surface.

CONCLUSION

Full coverage chairside CAD/CAM lithium disilicate crowns with the margin at the gingival level have shown higher fracture resistance than overlay restorations with margins located at 2 and 4 mm above the gingival level.

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