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RESEARCH AND EDUCATION

Fracture resistance of cingulum rest seats in CAD-CAM tooth-colored crowns for removable partial denture abutments

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ABSTRACT

Statement of problem. The prevalent use of computer-aided design and computer-aided manufacturing (CAD-CAM) for tooth-colored ceramic materials has led to several case reports and retrospective clinical studies of surveyed crowns used to support removable partial dentures. How the specific contour of a cingulum rest seat affects the fracture resistance of these CAD-CAM tooth-colored materials is unknown.

Purpose. The purpose of this in vitro study was to compare the fracture resistance of monolithic CAD-CAM tooth-colored mandibular canine–surveyed ceramic crowns with cingulum rest seats of different designs.

Material and methods. Five groups (n=24/group) of CAD-CAM tooth-colored crowns were milled from the same standard tessellation language (STL) file: group EM, lithium disilicate–based material (IPS e.max CAD CEREC blocks); group SM, zirconia-based material (NexxZr T); group LP, zirconia-based material (Lava Plus High Translucency); group ZC, zirconia-based material (ZirCAD LT); and group MZ, composite resin (MZ100 CEREC blocks), used as a control. Crowns from each group were divided into 2 subgroups representing 2 shapes of cingulum rest seat design: round design subgroup (n=12) with 0.5-mm radius of curvature and sharp design subgroup (n=12) with 0.25-mm radius of curvature for the rest seat preparation. The crowns were cemented with resin cement to a composite resin die on a steel nut. After 24 hours of storage in water at 37°C, the specimens were statically loaded to fracture with a custom metal retainer on top of the cingulum rest seat by using a universal testing machine at a crosshead speed of 1.5 mm/min. Two-way ANOVA and the Tukey honestly significant difference tests were used to control the familywise error rate (α=.05). Representative specimens were examined using an optical stereomicroscope at ×10 magnification and a scanning electron microscope to determine the failure patterns and fracture mechanism.

Results. The results of the ANOVA test indicated statistically significant differences by materials and rest seat designs (P<.001). The mean ±standard deviation maximal load capacity was 773.5 ±255.0 N for group MZ, 1124.9 ±283.9 N for group EM, 2784.1 ±400.5 N for group SM, 2526.9 ±547.1 N for group LP, and 3200.8 ±416.8 N for group ZC. The round design subgroups had an approximately 30% higher mean failure load than the sharp design subgroups for all surveyed crowns.

Conclusions. The present in vitro study demonstrated that zirconia-based groups fractured at twice the load as the lithium disilicate group. Of the 3 zirconia-based groups, group ZirCAD had a statistically greater fracture resistance than the other groups. Designing the cingulum rest seat to have a broad round shape provides a statistically significant higher fracture resistance than a sharp-shape design (P<.05). (J Prosthet Dent 2019;121:828-35)

The use of computer-aided design and computer-aided manufacturing (CAD-CAM) technology and tooth-colored materials for removable partial denture (RPD) abutment crowns has been reported since the early 2000s.[1] Before the advent of ceramic crowns, metal-ceramic restorations represented the gold standard in

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Clinical Implications

Cingulum rest seats with a round-shape design provide higher fracture resistance than a sharp-shape design in CAD-CAM surveyed crowns for removable partial denture abutments.

restorative dentistry because of their reliable mechanical properties, acceptable esthetics, and clinically acceptable marginal and internal adaptation.[2-4] The use of ceramic crowns has increased because of improved esthetics, ease of fabrication, biocompatibility with the oral environment,[5,6] and the increased cost of fabricating metal-ceramic restorations with precious metals.[7] As a result, lithium disilicate glass-ceramics and zirconia-based ceramics have gained popularity in restorative and prosthetic dentistry.[8-10] Lithium disilicate glass-ceramic and zirconia-based crowns have been reported as alternatives to metal-ceramic surveyed crowns for RPDs.[11-15] A retrospective study of 37 veneered zirconia-based single crowns used as abutment teeth for clasp-retained RPDs reported that 11% of the crowns had fractures of veneering porcelain and that 3% of cingulum rest seats fractured over an average period of 4.2 years in clinical service.[13]

Single crowns and fixed partial denture retainers used to support clasp-type RPDs have been referred to as surveyed crowns.[16] The surveyed crown is an important restoration for integrating fixed and removable prosthodontics.[17] Techniques for fabricating ceramic surveyed crowns with CAD-CAM technology have been described.[11-16] Depending on the materials and methods used, monolithic ceramic crowns can be fabricated by either heat-pressing the ceramics or manufactured with CAD-CAM from a block of machinable ceramic material. RPD abutments have been described in which rest seats and guide planes were made of either sintered aluminum oxide or zirconia.[11-14] Others have demonstrated a method of fabricating monolithic lithium disilicate crowns without veneering porcelain.[15,16] Surveyed crowns are used to distribute the forces of the RPD on an abutment tooth and can enhance the longevity of both the oral structures and the RPD.[18,19] A rest seat, which is designed to accept the cast rest portion of an RPD framework, directs the masticatory forces and provides vertical support to transmit occlusal forces through the long axis of the abutment tooth.[19,20] The form of the abutment tooth and rest seat allows for appropriate masticatory force transmission, retention, and the stability of supporting structures.[19,21,22] Rest seats are considered to be stable when prepared from enamel or restorative materials such as composite resin or amalgam.[23] However, owing to the properties of ceramic materials, especially their brittleness, the design for the cingulum rest seat should be appropriate and strong enough when a monolithic ceramic crown is planned, particularly since rests do not adapt well to the rest seat.[24]

When mandibular canines serve as RPD abutments, the cingulum rest seat must project outside the normal lingual contour of the crown because of its anatomic shape. Techniques for bonding composite resin, etched metal, or modified orthodontic brackets to the lingual surface of intact teeth have been described.[25-28] This coronal design was chosen to test the limits of the CAD-CAM tooth-colored materials. The design of the floor of the rest seat may have implications for stress at the sharp junction of surfaces.[29-31] In addition, in assessing the fracture strength of monolithic crowns, the thickness of the crown material becomes an important factor. Lan et al[32] reported that a thickness of 0.7 mm of a nonanatomic crown was adequate for resisting cyclic fatigue loading at an axial and 10-degree oblique load of an implant-supported zirconia crown. Sun et al[33] studied the fracture resistance of different thicknesses of monolithic zirconia crowns in the anatomic form of mandibular molars where the antagonistic force targeted the central fossa, within the contour of the crown. The fracture strength values of the monolithic zirconia crowns were 1814.6 ±68.21 N for the 0.8-mm group and 4109.93 ±610.18 N for the 1.5-mm group. The physiological incisal force in the anterior region has been reported to range from approximately 90 to 370 N.[34-36] However, measurements of the maximum occlusal force of bruxers were determined to be 668 N for women and 1009 N for men.[37]

To the best of the authors' knowledge, studies that evaluated the fracture resistance of CAD-CAM tooth-colored crowns with respect to the different designs of the cingulum rest seat are lacking. Therefore, the purpose of this in vitro study was to compare the fracture resistance of CAD-CAM ceramic materials with a CAD-CAM composite resin material in the application of RPD surveyed crown abutments with cingulum rest seat of a mandibular canine. The null hypotheses tested were that no significant differences would exist in the fracture resistance of cingulum rest seats between tested CAD-CAM tooth-colored crowns and that no significant difference in the fracture strengths would exist between the sharp and round cingulum rest seat design in CAD-CAM tooth-colored crowns for RPD abutments.

MATERIAL AND METHODS

One hundred twenty crowns milled from 5 different tooth-colored materials were used and divided into 5 groups: group EM, lithium disilicate-based material (IPS e.max CAD Planmill MT A1 C14; Ivoclar Vivadent AG);

Table 1. Materials and codes used

Group	Material	Composition	Manufacturer	Rest Seat Design
MZ	MZ100 Shade E	Composite resin	3M ESPE	Sharp
				Round
EM	IPS e.max CAD MT A1	Lithium disilicate	Ivoclar Vivadent AG	Sharp
				Round
SM	NexxZr T	Zirconia	Sagemax Bioceramics	Sharp
				Round
LP	Lava Plus HT	Zirconia	3M ESPE	Sharp
				Round
ZC	IPS e.max ZirCAD LT	Zirconia	Ivoclar Vivadent AG	Sharp
				Round

group SM, zirconia-based material (NexxZr T; Sagemax Bioceramics); group LP, zirconia-based material (Lava Plus High Translucency; 3M ESPE); group ZC, zirconia-based material (IPS e.max ZirCAD LT; Ivoclar Vivadent AG); and group MZ, composite resin material (MZ100 Blocks; 3M ESPE) used as a control (Table 1). Crowns from each of the groups were divided into 2 subgroups representing 2 shapes of cingulum rest seat design: round-shape subgroup (n=12) with 0.5-mm radius of curvature and sharp-shape subgroup (n=12) with 0.25-mm radius of curvature for the rest seat preparation (Fig. 1).

An extracted human mandibular left canine was embedded in clear acrylic resin (Orthodontic Resin; Dentsply Sirona), so the cementoenamel junction was 2 mm above the acrylic resin base. A cingulum rest seat was waxed to ideal cingulum-like contour with dental wax (Thowax; Yeti Dental) and duplicated with silicone material (PolyPour PVS; GC America). It was poured twice in Type IV stone (Fujirock; GC America). A second stone cast duplicate was prepared for a ceramic crown with a diamond rotary instrument (no. 6856; Brasseler USA) and low-speed handpiece (KaVo). The stone cast tooth was prepared with a 1.0-mm axial and facial reduction, a 2.0-mm incisal reduction, and a 1.0-mm rounded shoulder margin circumferentially and a total occlusal convergence angle of approximate 12 degrees. The average thickness at the center of the floor of the rest seat was determined to be 0.85 mm among all crown groups. Both the prepared and the unprepared casts with wax rest were scanned with a 3-dimensional (3D) laboratory scanner (3Shape D2000 scanner; 3Shape). Standard tessellation language (STL) files were designed for both round and sharp cingulum rest seats with design software (3Shape Dental System; 3Shape).

The specimens of each tested groups were milled using CAD-CAM technology. All zirconia crowns were sintered according to the manufacturer's instructions. After sintering, the zirconia crowns were airborne-particle abraded on the external surface with 50-μm aluminum oxide at 0.2-MPa for 10 seconds and ultrasonically cleaned in acetone solution for 5 minutes. A thin layer of glaze (Noritake CZR Glaze; Kuraray Noritake Dental) was then applied.

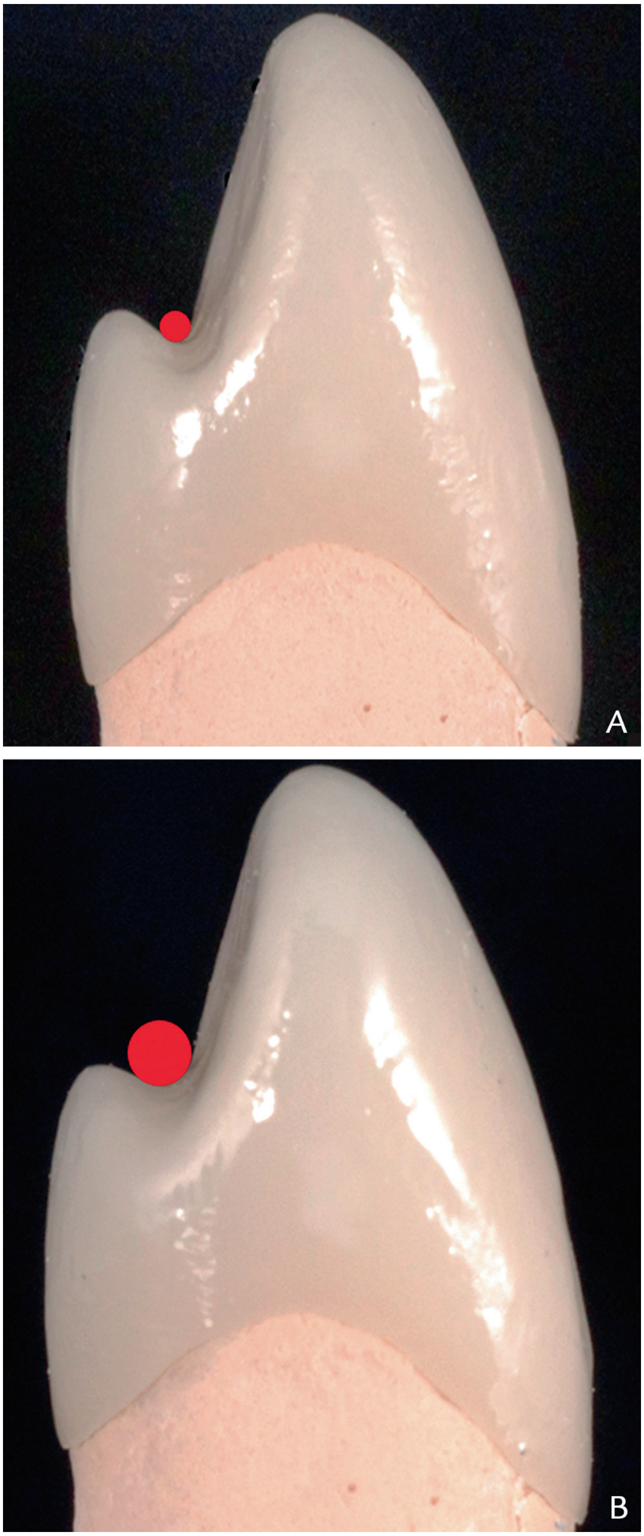

Figure 1. Wax patters of 2 cingulum rest seat designs. A, Sharp shape with 0.25-mm radius (*red circle*) curvature. B, Round shape with 0.5-mm radius (*red circle*) curvature.

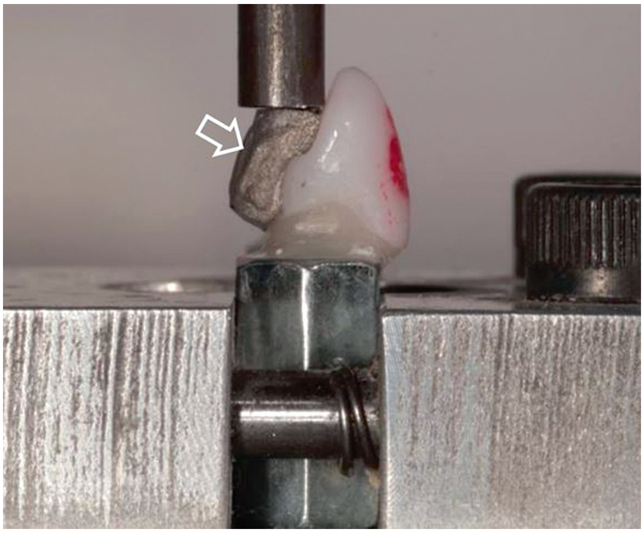

Figure 2. Specimen with metal rest retainer (*arrow*) in position for compression test.

Each specimen had a corresponding die made from composite resin (Z100; 3M ESPE) and a steel coupling nut. The composite resin dies were polymerized using a light-polymerizing unit (3M Elipar Deep Cure; 3M Oral Care) for 60 seconds. The crowns were removed from the composite resin dies, and all groups were treated according to the manufacturers' recommendations. For the 3 zirconia groups (group SM, LP, and ZC), the intaglio surfaces of the test crowns were airborne-particle abraded with 50-μm aluminum oxide at 0.2 MPa for 10 seconds and then conditioned with a universal adhesive agent (Scotchbond Universal Adhesive; 3M ESPE) for 20 seconds. The composite resin die was also treated with the same adhesive agent for 20 seconds, and then air-dried for 5 seconds. The crowns were cemented with a dual-polymerizing adhesive resin cement (RelyX Ultimate Adhesive Resin Cement; 3M ESPE). The crowns of group MZ were cleaned with a 70% ethyl alcohol wipe on the intaglio surface and then conditioned and cemented as the zirconia groups. The intaglio surfaces of group EM were treated with 5% hydrofluoric acid for 20 seconds, rinsed, placed in distilled water, and ultrasonically cleaned for 5 minutes according to the manufacturer's recommendations.

The intaglio of the crowns of group EM was then treated with Monobond Plus (Ivoclar Vivadent AG) for 60 seconds. A bonding agent (Adhese; Ivoclar Vivadent AG) was applied for 20 seconds and air thinned, and the crowns were cemented with resin cement (Variolink Esthetic DC; Ivoclar Vivadent AG) as recommended by the manufacturer. The specimens were stored at 37°C in distilled water for 24 hours before testing.

For each round-shape and sharp-shape subgroup of all 5 materials, 2 metal rest retainers were fabricated from autopolymerizing resin (GC Pattern Resin; GC America),

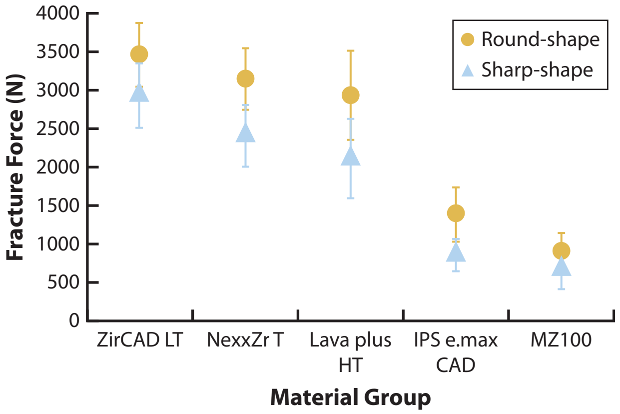

Figure 3. Results of static compressive load to crown fracture in Newtons (N).

Table 2. Two-way ANOVA results for materials and rest seat designs

Source	Sum of Squares	*df*	Mean Square	F	*P*
Design	9 635 430.11	1	9 635 430.11	61.31	<.001
Material	108 291 310.78	4	27 072 827.70	172.27	<.001
Material×design	1 298 038.96	4	324 509.74	2.06	.09
Within group	17 286 805.43	110	157 152.77		
Total	136 511 585.30	119			

invested (Cera-Fina; Whip Mix Corp), and cast in a nickel-chromium alloy (Rexillium III; Jeneric Pentron). The crowns were positioned in a universal testing machine (Model 5855; Intron Corp) with a vice holding the steel nut with the mounted specimen at a vertical orientation. The metal rest retainer was positioned on the crown, and the loading rod was lowered on to the flat surface of the retainer until 20 N was detected before testing (Fig. 2) at a crosshead speed of 1.5 mm/min.

The failure load of the specimen was defined as a 10% decrease in load or the visible presence of cracks or bulk loss of ceramics in the rest seat area. Representative specimens were examined using an optical stereomicroscope (SMZ-10; Nikon Corp) with ×10 magnification and a scanning electron microscope (JEOL 7000; JEOL) to determine the pattern of failure. The mean of maximum failure load values were statistically analyzed using 2-way ANOVA to compare the different groups with materials and rest seat designs and were evaluated for the homogeneity of variance with the Levene test. The Tukey honestly significant difference test was used for pairwise comparison (α=.05).

RESULTS

The mean ±standard deviation of maximum failure load values ranged from 3460.0 ±415.6 N for the round cingulum rest seat subgroup of group ZC to 683.1 ±268.7 N for the sharp cingulum rest seat subgroup of group MZ (Fig. 3). The results of the 2-way ANOVA test indicated that both material and rest seat design influenced the

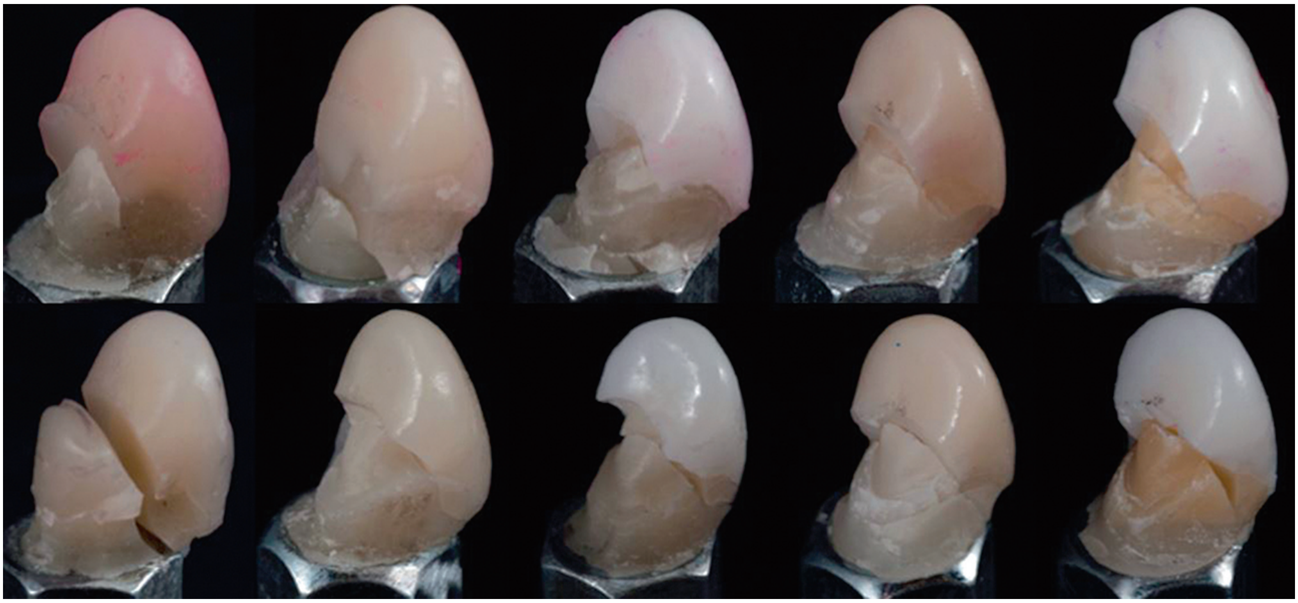

Figure 4. Representative fractured specimens from all test groups. Top row, round cingulum rest seat design specimens. Bottom row, sharp cingulum rest seat design specimens. From left to right side, e.max ZirCAD LT zirconia, NexxZr T zirconia, Lava Plus HT zirconia, IPS e.max CAD lithium disilicate, and MZ100 composite resin.

fracture resistance ($P<.001$) and that no interaction occurred between the 2 variables (F=2.06, $P=.09$) (Table 2). The Tukey honestly significant difference test revealed that, independent of rest seat design, IPS e.max ZirCAD crowns obtained a significantly higher maximum failure load compared with other tested material groups ($P<.05$). No significant difference was detected in the mean maximum failure load between Lava Plus HT and NexxZr T materials. Both zirconia-based groups were statistically significantly greater than IPS e.max CAD ($P<.05$).

The tested material groups exhibited statistically significant higher maximum failure loads for the round-shape rest seat design when compared with the sharp-shape rest seat design ($P<.05$). Representative fracture specimens from each test group are shown in Figure 4. Scanning electron microscope observation of the fracture patterns revealed that the fracture initiated from near the center of the greatest depth of the rest seat, regardless of the round or sharp cingulum rest seat design, and propagated toward the mesial and distal proximal surfaces (Figs. 5, 6).

DISCUSSION

The results of this in vitro study suggest that various CAD-CAM tooth-colored materials and 2 different rest seat designs have different fracture resistance for RPD abutments. Within the limitations of this study, the null hypotheses were rejected. Even though significant differences in the maximum load capacity existed in most of the groups, all of them exceeded the physiological incisal force in the anterior region.[34-36] The measurements from the current tested CAD-CAM zirconia crowns had sufficient strength to withstand the maximum occlusal forces measured in young dentate individuals; however, the lithium disilicate and composite resin material may not have sufficient strength in this prosthetic application.[37]

In the present study, CAD-CAM machinable dental zirconia, lithium disilicate glass-ceramic, and composite resin were used to fabricate monolithic crowns for RPD surveyed crowns. The average thickness at the center of the floor of the rest seat was comparable to that of the 0.8-mm group presented by Sun et al.[33] In the present study, the zirconia crown material groups fracture strength values were also concordant with their results. As a clinically relevant finding, the findings support that the surveyed crowns with broad and round cingulum rest seat design had an approximate 30% greater fracture resistance than the surveyed crowns with sharp cingulum rest seat design.

The dimensions of all the surveyed crowns in this investigation were standardized and reproducible because the crowns were fabricated with CAD-CAM technology using the same standard tessellation language file for all the crowns, instead of manufacturing manually. All the dies were made of composite resin and custom made for each individual crown, resulting in accurate fit upon cementation. A cross-sectional view of the representative zirconia-based crowns is shown in Figure 7. One phenomenon that occurred mostly in the

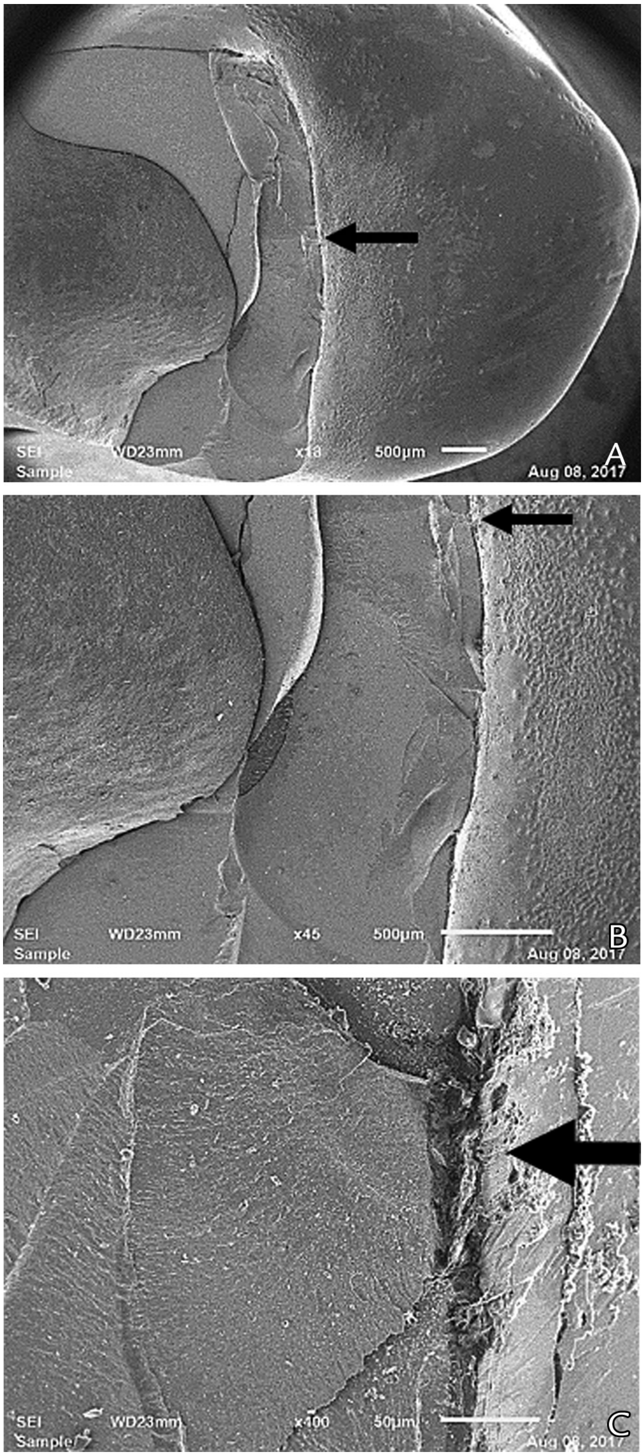

Figure 5. Scanning electron microscopy images of fracture Lava Plus HT sharp lingual rest seat design crown. Original magnification A, ×18; B, ×45; and C, ×400. Note initiation of fracture at center of crown (*arrows*).

zirconia-based groups was the simultaneous catastrophic fracture of both the crown and composite resin die. The rationale of selecting composite resin (Z100; 3M ESPE) for die construction was that it had an elastic modulus

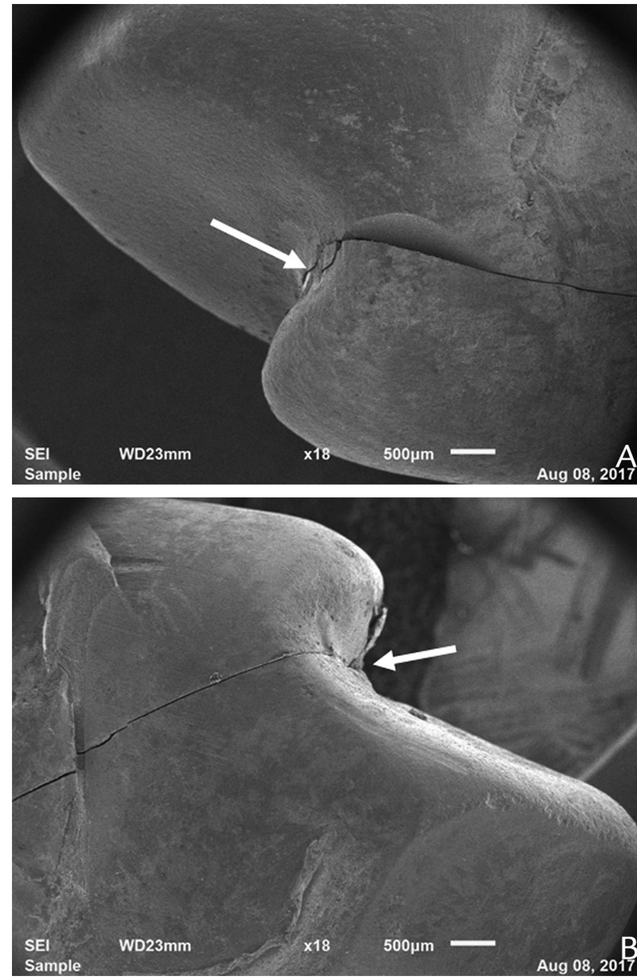

Figure 6. Scanning electron microscopy images (original magnification ×18) of representative fractured specimens. A, IPS e.max CAD sharp cingulum rest seat design crown. B, MZ100 round cingulum rest seat design crown. Note fracture line crossing through floor of rest seat (*arrows*).

similar to that of human dentin.[38] The effective modulus of the supporting abutment and the luting cement has been found to play a major role in the fracture resistance of the crown.[39]

This study had limitations. Only monotonic loading was used. Static loading may only be one type of force among many that can be applied to the abutment rest seat–RPD framework complex; thus, different results may be demonstrated when fatigue loading is applied. Thermocycling and cyclic loading in the presence of moisture, as it is in vivo, would have better simulated the clinical environment. One variable that was not standardized was the CAD-CAM milling machines that fabricated the crown specimens and composite resin specimens. Depending on the number of axes and cuts possessed by the milling machine and frequency of bur changes to adequate sharpness, the accuracy and precision of the crowns can change.[40] In the present study, the

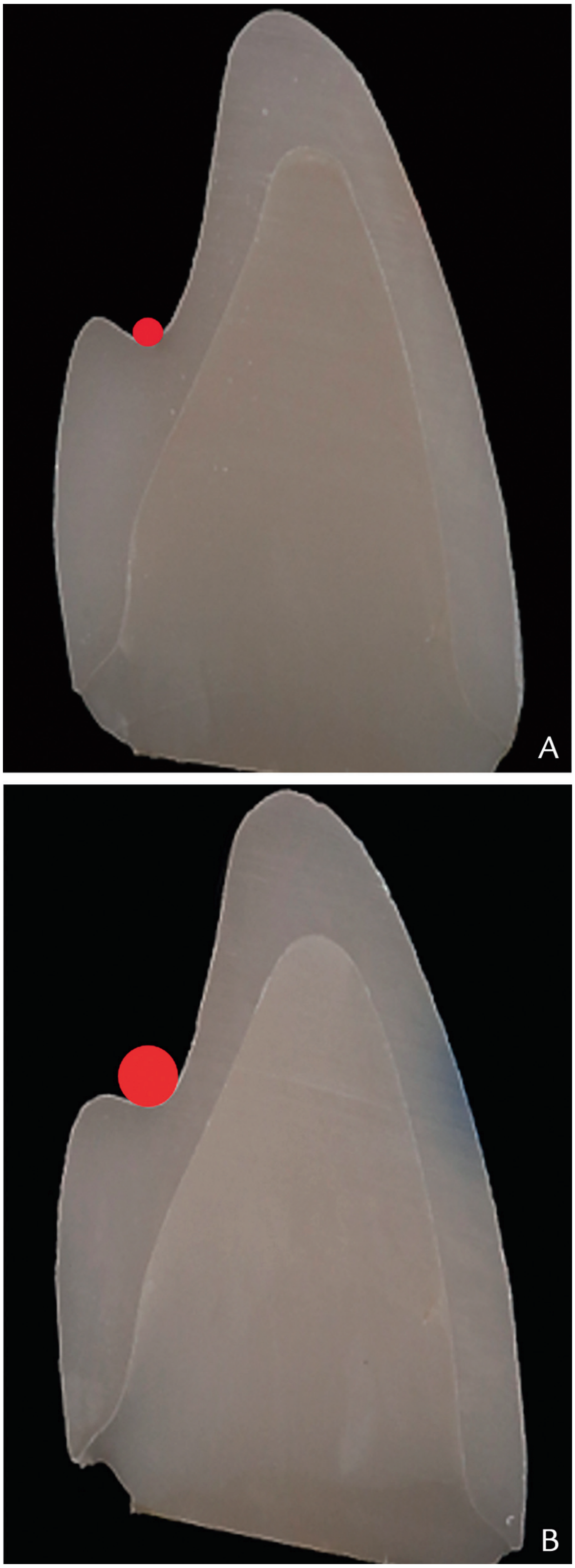

Figure 7. Cross-sectional macroscopic view of representative specimens from group Lava Plus HT cemented on composite resin. A, sharp-shape with 0.25-mm radius (*red circle*) curvature. B, round-shape with 0.5-mm radius (*red circle*) curvature.

level of accuracy in crown fabrication was determined by evaluating the fit of the crowns on the master die stone cast. All crowns tested were able to seat completely on the composite resin die as shown in Figure 7.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The CAD-CAM zirconia-based surveyed crowns showed superior fracture resistance than the CAD-CAM lithium disilicate–based surveyed crowns with cingulum rest seat design.
2. The shape of the cingulum rest seat design affected fracture resistance of ceramic surveyed crowns. Designing rest seats with greater radius of curvature statistically increases fracture resistance over the smaller radius groups, independent of the material used to fabricate the surveyed crown.
3. The monolithic CAD-CAM surveyed crowns with cingulum rest seats fractured during compression testing that initiated from the center of the floor of the rest seat and propagated toward the mesial and distal surfaces.

REFERENCES

1. Kancyper S, Sierraalta M, Razzoog ME. All-ceramic surveyed crowns for removable partial denture abutments. J Prosthet Dent 2000;84:400-2.
2. Walton TR. A 10-year longitudinal study of fixed prosthodontics: clinical characteristics and outcome of single-unit metal–ceramic crowns. Int J Prosthodont 1999;12:519-26.
3. Spear FM. The metal-free practice: myth? Reality? Desirable goal? J Esthet Restor Dent 2001;13:59-67.
4. Reitemeier B, Hänsel K, Kastner C, Walter MH. Metal–ceramic failure in noble metal crowns: 7-year results of a prospective clinical trial in private practices. Int J Prosthodont 2006;19:397-9.
5. Wettstein F, Sailer I, Roos M, Hämmerle CH. Clinical study of the internal gaps of zirconia and metal frameworks for fixed partial dentures. Eur J Oral Sci 2008;116:272-9.
6. Raigrodski AJ. Contemporary materials and technologies for all-ceramic fixed partial dentures: a review of the literature. J Prosthet Dent 2004;92:557-62.
7. Donovan TE. Factors essential for successful all-ceramic restorations. J Am Dent Assoc 2008;139:14S-8S.
8. Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of zirconia ceramics: basic properties and clinical applications. J Dent 2007;35:819-26.
9. Batson ER, Cooper LF, Duqum I, Mendonça G. Clinical outcomes of three different crown systems with CAD/CAM technology. J Prosthet Dent 2014;112:770-7.
10. Flinn BD, Raigrodski AJ, Singh A, Mancl LA. Effect of hydrothermal degradation on three types of zirconias for dental application. J Prosthet Dent 2014;112:1377-84.
11. Carracho JF, Razzoog ME. Removable partial denture abutments restored with all-ceramic surveyed crowns. Quintessence Int 2006;37:283-8.
12. Marchack BW, Chen LB, Marchack CB, Futatsuki Y. Fabrication of an all-ceramic abutment crown under an existing removable partial denture using CAD/CAM technology. J Prosthet Dent 2007;98:478-82.
13. Pihlaja J, Napankangas R, Kuoppala R, Raustia A. Veneered zirconia crowns as abutment teeth for partial removable dental prostheses: a clinical 4-year retrospective study. J Prosthet Dent 2015;114:633-6.
14. Joo HS, Park SW, Yun KD, Lim HP. Complete-mouth rehabilitation using a 3D printing technique and the CAD/CAM double scanning method: a clinical report. J Prosthet Dent 2016;116:3-7.
15. Patel D. Retrofitting a crown supporting a removable partial denture using "Biogenericcopy" to replicate tooth's preoperative condition. Comp Cont Ed in Dent 2016;37:126-30.

16. Yoon TH, Chang WG. The fabrication of a CAD/CAM ceramic crown to fit an existing partial removable dental prosthesis: a clinical report. J Prosthet Dent 2012;108:143-6.
17. Chandler HT, Brudvik JS, Fisher WT. Surveyed crowns. J Prosthet Dent 1973;30:775-80.
18. Seals RR, Stratton RH. Surveyed crowns: a key for integrating fixed and removable prosthodontics. Quintessence Dent Tech 1987;11: 43-9.
19. Rehmann P, Orbach K, Ferger P, Wöstmann B. Treatment outcomes with removable partial dentures: a retrospective analysis. Int J Prosthodont 2013;26:147-50.
20. Rudd RW, Bange AA, Rudd KD, Rudd RM. Preparing teeth to receive a removable partial denture. J Prosthet Dent 1999;82:536-49.
21. Luk NK, Wu VH, Liang BM, Chen YM, Yip KH, Smales RJ. Mathematical analysis of occlusal rest design for cast removable partial dentures. Eur J Prosthodont Restor Dent 2007;15:29-32.
22. Burns DR, Unger JW. The construction of crowns for removable partial denture abutment teeth. Quintessence Int 1994;25:471-5.
23. De Aquino AR, Barreto AO, de Aquino LM, Ferreira AM, Carreiro Ada F. Longitudinal clinical evaluation of undercut areas and rest seats of abutment teeth in removable partial denture treatment. J Prosthodont 2011;20:639-42.
24. Dunham D, Brudvik J, Morris J, Plummer K, Cameron S. A clinical investigation of the fit of removable partial dental prosthesis clasp assemblies. J Prosthet Dent 2006;95:323-6.
25. Latta GH. A technique for preparation of lingual rest seats in light-cured composite. J Prosthet Dent 1988;60:127-8.
26. Yard RA, Butler GV, Render PJ. Bonded composite rests: a fabrication method. J Prosthet Dent 1988;60:128-9.
27. Seto BG, Caputo AA. Bond strength of etched-metal resin-bonded cingulum rest seats. J Prosthet Dent 1987;58:458-62.
28. Wong R, Nicholls JL, Smith DE. Evaluation of prefabricated lingual rest seats for removable partial dentures. J Prosthet Dent 1982;48:521-6.
29. Kamposiora P, Papavasiliou G, Bayne SC, Felton DA. Stress concentration in all-ceramic posterior fixed partial dentures. Quintessence Int 1996;27: 701-6.
30. Fischer H, Weber M, Marx R. Lifetime prediction of all-ceramic bridges by computational methods. J Dent Res 2003;82:238-42.
31. Plengsombut K, Brewer JD, Monaco EA, Davis EL. Effect of two connector designs on the fracture resistance of all-ceramic core materials for fixed dental prostheses. J Prosthet Dent 2009;101:166-73.
32. Lan TH, Liu PH, Chou M, Lee HE. Fracture resistance of monolithic zirconia crowns with different occlusal thicknesses in implant prostheses. J Prosthet Dent 2016;115:76-83.
33. Sun T, Zhou S, Lai R, Liu R, Ma S, Zhou Z, et al. Load-bearing capacity and the recommended thickness of dental monolithic zirconia single crowns. J Mech Behav Biomed Mater 2014;35:93-101.
34. Gibbs CH, Mahan PE, Mauderli A, Lundeen HC, Walsh EK. Limits of human bite strength. J Prosthet Dent 1986;56:226-9.
35. Paphangkorakit J, Osborn JW. The effect of pressure on a maximum incisal bite force in man. Arch Oral Biol 1997;42:11-7.
36. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol Scand 1977;35:297-303.
37. Cosme DC, Baldisserotto SM, Canabarro SA, Shinkai RS. Bruxism and voluntary maximal bite force in young dentate adults. Int J Prosthodont 2005;18:328-32.
38. Chung SM, Yap AU, Tsai KT, Yap FL. Elastic modulus of resin-based dental restorative materials: a microindentation approach. J Biomed Mater Res B Appl Biomater 2005;72:246-53.
39. Yucel MT, Yondem I, Aykent F, Eraslan O. Influence of the supporting die structures on the fracture strength of all-ceramic materials. Clin Oral Investig 2012;16:1105-10.
40. Kirsch C, Ender A, Attin T, Mehl A. Trueness of four different milling procedures used in dental CAD/CAM systems. Clin Oral Invest 2017;21:551-8.

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Noteworthy Abstracts of the Current Literature

Influence of glass ceramic coating on composite zirconia bonding and its characterization

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Objective. The aims of this study were to compare micro-tensile bond strength and characterize the bond of ceramic-coated versus air-abraded and chemically treated zirconia specimens.

Methods. Eight zirconia blocks were fabricated and assigned to two groups as follows: AA-alumina air-abrasion; and CC-DCM hot bond coating followed by alumina air-abrasion and hydrofluoric acid etching. For each group, two identically pre-treated zirconia blocks were applied G-Multi Primer, cemented together with G-Cem Linkforce cement and cut into 30 stick-shaped specimens ($1\times1\times9 mm^3$). A total of 120 specimens were stored in distilled water for 24h and then assigned to three groups: (i) short-term test, (ii) thermocycling for 5000, and (iii) thermocycling for 10,000 cycles. The specimens were tested in tensile mode. The bond strength results were analyzed using two-way ANOVA, followed by one-way ANOVA and Dunnett T3 (α=0.05). Failure mode and surfaces were analyzed with optical microscopy and SEM. The EDS, FTIR, XRD, and FIB-SEM were used for chemical, crystalline phase analyses.

Results. The AA groups recorded higher mean bond strength than the CC groups in all aging conditions. Thermocycling did not affect the bond strength of the AA groups, whereas the bond strength of the CC groups decreased significantly after aging. The MDP monomer and silane in G-Multi Primer chemically reacted with mechanically pre-treated AA and CC surfaces via the absorption of P-O and Si-O groups.

Significance. The bond strength of a conventional protocol involving alumina air-abrasion was greater than ceramic coating technique.