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Fatigue Behavior of Different CAD/CAM Materials for Monolithic, Implant-Supported Molar Crowns

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Abstract

Purpose: To evaluate the fracture resistance after the thermal and mechanical fatigue of feldspathic, lithium disilicate, and resin-modified CAD/CAM monolithic crowns cemented onto a universal post abutment.
Materials and Methods: A right second mandibular molar was designed in CAD/CAM software, and 30 crowns were machined using three different materials ($n = 10$): feldspathic ceramic, finished only with a glaze cycle (G1); lithium disilicate, sintered and finished with a glaze cycle (G2); and resin, modified by nanoceramic and finished with rubber (G3). All crowns were cemented under a constant 50 N load, the excess cement was removed, and the crowns were light-cured for 30 seconds. After being immersed in deionized water for 7 days, the crowns were submitted to thermal cycling, which consisted of varying the temperature from 2 to 50°C for 350,000 cycles, and mechanical cycling in a fatigue simulator, where a 250 N load was applied for 1,000,000 cycles at 2 Hz. The resistance of each crown was verified in a compression-to-failure test at 1 mm/min in a universal test machine. The groups were compared using one-way ANOVA with a Bonferroni post hoc test and Weibull statistics.
Results: The resin-modified group was the least resistant group (1755 ± 124 N), followed by the feldspathic (2147 ± 412 N) and lithium disilicate groups (2804 ± 303 N). The Weibull statistics demonstrated that lithium disilicate is the most reliable material and has the lowest fracture probability.
Conclusions: It was possible to conclude that all of the tested CAD/CAM materials can be used as monolithic, implant-supported molar crowns.

Computer-aided design/computer-assisted manufacturing (CAD/CAM) technologies allow the chairside fabrication of esthetic, implant-supported prostheses.[1] This CAD/CAM process allows an adequate marginal gap and the absence of air bubbles inside the structure of the material,[2] increasing the fracture resistance of prostheses manufactured from CAD/CAM blocks compared to those that are hand-processed by a technician.[3] However, the implants' success depends on the reliability of the prosthetic components and crown materials to support the occlusal loading, especially in the posterior regions of the jaw, where the average masticatory force reaches 538 N in women and 651 N in men.[4]

The chairside approach of CAD/CAM systems usually leads to monolithic restorations that do not include a feldspathic cover layer.[5] These monolithic crowns are less vulnerable because they do not present a feldspathic/core material interface.[6] While zirconia has a high flexural strength and would be indicated for the posterior region, its high opacity prevents its use as a monolithic crown in patients with high esthetic demands.[7] Feldspathic and lithium disilicate ceramic CAD/CAM blocks are more translucent and show adequate marginal integrity with no fractures when the occlusal thickness is at least 2 mm.[8,9] Although feldspathic ceramic (118 MPa flexural strength) is a more fragile material than lithium disilicate (609 MPa flexural strength),[10] feldspathic monolithic restorations exhibit resistances comparable to those of lithium disilicate crowns after being cemented with an adhesive luting agent.[11]

Figure 1 Apparatus for mechanical cycling. The loading device was positioned on the center of the occlusal surface.

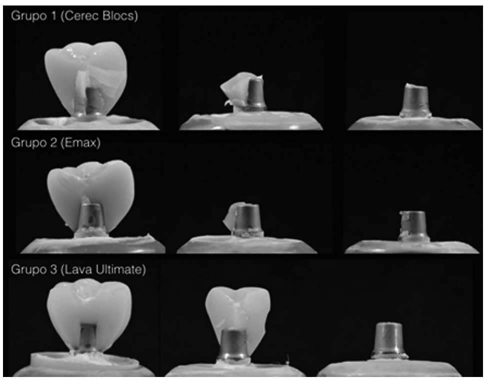

Figure 2 All groups exhibited similar failure patterns.

In addition, a resin block modified with nanoceramic particles is available for chairside CAD/CAM systems[12,13] and presents high flexural strength (300 MPa flexural strength).[10] Its relatively low elastic modulus is intended to prevent biomechanical complications during occlusal loading by mimicking the resilience of the periodontal ligament.[14] Although this is a popular material and is theoretically advantageous compared to ceramic materials,[15] the performance of resin-modified crowns has not been compared to ceramic crowns for dental implants in the posterior regions of the jaw.

Cemented crowns are increasingly being used in dental implants instead of screw-retained prostheses because the reliability of the Morse taper implant-abutment connection prevents screw-loosening issues.[16] One common abutment for a

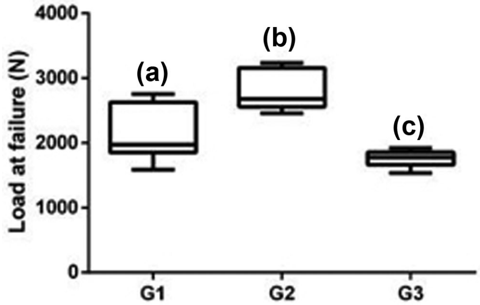

Figure 3 Data dispersion of the feldsphatic (G1), lithium disilicate (G2), and resin-modified (G3) groups. Different letters indicate significant difference between the groups (ANOVA, $p < 0.05$).

cemented prosthesis is the universal post, for which only a few components are necessary to restore single, edentulous spaces in the anterior and posterior regions.[17] However, CAD/CAM monolithic crowns cemented onto universal post abutments are subjected to cyclic occlusal loading under wet conditions that can lead to fractures and debonding.[18] It is important to investigate the performance of these implants because all CAD/CAM materials used for monolithic restorations have the potential for brittle catastrophic fractures[19] and because water absorption causes interfacial stress that can contribute to debonding failures.[15]

Therefore, the purpose of the present study was to evaluate the fatigue behavior, after thermal and mechanical cycling, of feldspathic, lithium disilicate and resin-modified CAD/CAM monolithic crowns designed for the second mandibular molar region and cemented onto a universal post abutment.

Materials and methods

A replica of a universal post abutment was centralized in a polyvinyl chloride tube with a 0.5-inch diameter (Tigre NBR 5648, Joinville, Brazil), using a dental parallelometer, and fixed with acrylic resin (Dencor; Clássico, São Paulo, Brazil). From this master model, 30 specimens were manufactured.

The universal post abutment was scanned (InEos Blue; Sirona, Bensheim, Germany) and imported into the CAD/CAM software (InLab version 4.0; Sirona). A right mandibular second molar was designed, and 30 crowns were machined using three different materials ($n = 10$): G1 – feldspathic ceramic (Cerec Blocs; Sirona), finished only with a glaze cycle; G2 – lithium disilicate (e.max CAD; Ivoclar Vivadent, Schaan, Liechtenstein), sintered and finished with a glaze cycle (Programat P300; Ivoclar Vivadent); and G3 – resin modified by nanoceramic (Lava Ultimate 14L; 3M ESPE, St. Paul, MN) and finished with rubber (Eve America; Naples, FL).

All universal posts were sand blasted by 50-μm aluminum oxide particles (Renfert, Hilzingen, Germany) at a distance of 10 cm and steam cleaned (Steamer X3; AmannGirrbach, Charlotte, NC). G1 and G2 crowns were treated with 10% hydrofluoric acid, (Condac, FGM, Joinville, Brazil) for 40 seconds (G1) and 20 seconds (G2), cleaned with isopropanol in an ultrasonic bath for 5 minutes, and silane treated (Monobond-S; Ivoclar Vivadent). For G3, the crowns were cleaned with

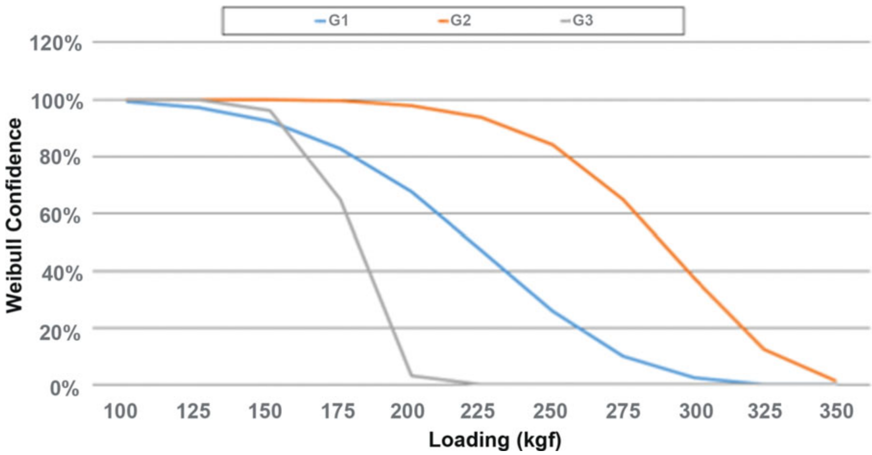

Figure 4 Weibull confidence for feldsphatic (G1), lithium disilicate (G2), and resin-modified (G3) groups.

isopropanol in an ultrasonic bath for 5 minutes, and an adhesive was applied (Scotchbond Universal; 3M ESPE). Next, all crowns were cemented (RelyX Ultimate; 3M ESPE) under a 50-N constant load using a universal test machine (EMIC DL2000; Instron, Norwood, MA).[16] The excess cement was removed, and crowns were light-cured for 30 seconds (Valo Cordless; Ultradent, South Jordan, UT). After 10 minutes, all crowns were immersed in deionized water for 7 days prior to thermal and mechanical cycling.

The thermal cycling consisted of varying the temperature from 2 to 50°C for 350,000 cycles (521-4D; Nova Ética, Brazil). This was used to simulate aging in buccal conditions, where stresses are generated at the interface due to the differing coefficients of linear thermal expansion of the materials.[20] Immediately after the thermal cycling, the specimens were submitted to mechanical cycling in a fatigue simulator (ER 11000; ERIOS, São Paulo, Brazil). Each specimen was fixed in the machine, submersed in a physiological saline solution at 23°C, and a load of 250 N was applied for 1,000,000 cycles at 2 Hz. The load was applied on the center of the occlusal surface (Fig 1).

The resistance of each crown was verified after cycling in a compression-to-failure test, at 1 mm/min in a universal test machine (DL 2000; EMIC, São José dos Pinhais, Brazil). The load at the moment of fracture was recorded by the machine software, and the mean was calculated for each group. After verifying the data with the Shapiro-Wilk test, the groups were compared using one-way ANOVA and Bonferroni post hoc test (SPSS 17; IBM, Armonk, NY), at a 5% level of significance. The cumulative probability of failure was calculated for each group using Weibull statistics.[21]

Results

All materials exhibited a similar pattern of fracture (Fig 2). The resin-modified group was the least-resistant group (1755 ± 124 N), followed by the feldspathic (2147 ± 412 N) and lithium disilicate groups (2804 ± 303 N) (Fig 3). The Weibull statistics demonstrated that lithium disilicate is the most reliable material and has the lowest fracture probability (Fig 4).

Discussion

This study evaluated three materials available in the CEREC system for use in monolithic implant-supported crowns using the mandibular second molar as a reference. The use of a monolithic structure reduces the vulnerability of a cover layer, and a much less complex structure is expected.[22,23] Because the average masticatory force at the molar region is 595 N,[4] all of the tested materials present enough strength to be used in the posterior region; however, lithium disilicate exhibited the highest fracture resistance and the lowest failure probability of the materials tested in the present study.

Other studies[8,22,23] have corroborated the present results and support the clinical performance of lithium disilicate as a restorative material.[5,19] However, lithium disilicate requires a sintering process in a specific oven, which demands more investment in equipment and requires more clinical time, contrary to the initial proposal of the CEREC system of patient care in a single session. In contrast, the feldspathic and resin-modified crowns can be finished and polished with brushes and rubber for a smooth surface,[24] which is much easier to handle.

The resin blocks require a shorter milling time, and the restorations can be more easily repaired than ceramic crowns. Although the incorporation of nanoceramic particles increases the hardness and wear resistance of resin, the material maintains its resiliency and capacity to absorb impact, which would favor its use in load-bearing restorations.[25,26] However, resin is more likely to fracture and face debonding issues after clinical use due to material degradation (e.g., hydrolysis, mechanical fatigue, wear) and a weak adhesive luting interface.[27] Therefore, it is important to evaluate materials after thermal and mechanical cycling.

The three materials used in the present study have different mechanical properties, but all can support the masticatory forces of the molar region, even after mechanical and thermal cycling. Therefore, a professional must consider the reduced clinical time, ease of handling, and lower investment in accessory equipment when choosing a material.

Conclusion

Despite having different resistances to fracture, the feldspathic, lithium disilicate and resin-modified CAD/CAM materials can all be used as implant-supported molar crowns.

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