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Research Article

THE EFFECT OF MATERIAL THICKNESS ON FRACTURE RESISTANCE OF CAD/CAM CROWNS FABRICATED FROM DIFFERENT ZIRCONIA-REINFORCED CERAMIC MATERIALS

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A B S T R A C T

Objective: The aim of this study was to assess the fracture resistance of zirconia-reinforcedceramic crowns depending on different ceramic thicknesses.
Material and Methods: Mandibular first molars were used for crown restorations in a typodont model with CEREC system. Samples (n=12 each) were fabricated by using two zirconia-reinforced lithium silicate (ZLS) ceramic materials (VITA Suprinity, Celtra Duo) and zirconia reinforced alumina ceramic (ZLA) (In-Ceram Zirconia) with thicknesses 1.0 and 1.5 mm. Fractural and thermomechanical loading tests were performed. One-way variance analysis test (ANOVA) and post-hoc Scheffé tests were used for analyzing the results.
Results: Fracture strength values were statistically significantly influenced by material thickness ($p<.001$), but not material type. Strength values were significantly higher for 1.5 mm thickness materials than 1.0 mm samples ($p<.001$).
Conclusions: CAD/CAM crowns showed acceptable fracture strength values which were above clinically expected loadings. Zirconia-reinforced ceramic materials with1.5 mm thickness may be a good choice for crown restorations in daily clinical practice.

INTRODUCTION

Increasing patient demand for esthetic restorations has played an important role in the development of new materials and fabrication methods, such as CAD/CAM systems, in today's dentistry (1).Metal-free restorations have become popular due to their biomechanical and esthetic properties superior than metal-fused restorations (2). These 'all-ceramic' materials has a wide family that includes several types of polycrystallineglass ceramic materials like zirconia-reinforced ceramics (3). Havingtetragonal structure crystallization, zirconia prevents material from cracks and a transformation occurs at the core of the material with increased durability (4, 5). Although being strengtened and having good properties, stabilized zirconia material has opaque effect in restoration limiting their use in posterior region predominantly (6). For this reason, the need for both esthetic and durable material has been arised in dentistry.

In the fabrication of all ceramic CAD/CAM restorations, the most popular material being used is lithium disilicate glass ceramic. This glass ceramic after being treated with heat turns into crystalline form and gains mechanical properties (7). This group of materials show good eshetic effect superior than those high strength polycrystalline materials (8). However, their mechanical and physical properties are not enough to use for the restorations in the posterior region (9,10). During chewing function, it is detected that the occlusal force in posterior teeth is about 100 N higher than anterior teeth (11). As it has been in chewing, functional or parafunctional loadings bring about the accumulation effect of forces, and these forces weaken the restoration causing cracks and clinical failures (12). Primer reason for that critical behaviour is the brittle characterization of ceramic material in which atomic bonds do not let the planes of atoms to dislocate during forces. This mechanical and chemical properties can cause fractural deformations, especially in posterior regions where the occlusal forces take place for function. The other factors that affect the failure mode of ceramic materials are geometrical properties and size of prosthesis (13). For this reason, there is a need for more durability and fracture resistance to expand the use of these kind of materials.

New ceramic systems were developed to evolve the resistance to crack propagation by making the use of crystalline structures into ceramic materials. A recent material type, zirconia reinforced lithium silicate glassceramic (ZLS), has been intoduced to dental market for use of inlay, onlay, crown, partial crown, and single tooth restorations for both anterior and posterior regions. The majority of the material consists of lithium-metasilicate glass ceramic (Li_2SiO_3) ceramic and about 10% is zirconium dioxide (ZrO_2), providing the microstructure with fine grains as Li_2O-ZrO_2-SiO_2. This new generation CAD/CAM material combines the advantages of the glass-ceramic and the zirconia. Moreover, adhesive systems can be

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used for cementing procedures as ZLS can be etched, unlike zirconia (4). This positive feature makes it possible to benefit from the advantage of fracture resistance of adhesive cement systems (5). In that regard, ZLS could influence the degree of fracture resistance with its mechanical properties.

The aim of this study was to assess and compare the fracture resistance of zirconia-reinforced ceramic crowns depending on different ceramic thicknesses. The null hypothesis under test considered any difference in fracture resistance with different material thicknesses between two ZLS and azirconia reinforced alumina ceramic materials.

MATERIALS AND METHODS

Mandibulary first molar on a typodont model (Frasaco ANA-VCER; Frasaco GmbH, Seefeld, Germany) was used to obtain crown restorations. Teeth were divided into three groups at random (http://www. randomizer.org), according to the type of used ceramic material (n=12):ZLS ceramic (groups V and C), and ZLA ceramic (group I).Two different types and three brands of ceramic CAD/CAM material were investigated in this in-vitro study. The compositions and manufacturers of the used ceramic materials are shown in Table-1.

Table 1 Materials used for fabrication of crowns in this study.

Group	Material	Label	Chemical structure	Manufacturer
V	ZLS ceramic	VITA Suprinity	Zirconiareinforcedlithiumsilicate glass-ceramic	VitaZahnfabrick, BadSäckingen, Germany
C	ZLS ceramic	Celtra Duo	Zirconia reinforced lithium silicate glass-ceramic	Dentsply Sirona, NY, USA
I	ZLA ceramic	In-Ceram Zirconia	Zirconia reinforced alumina ceramic	VitaZahnfabrick, BadSäckingen, Germany

For sample preparation, used acrylic phantom teeth (Frasaco ANA 4-ZP; Frasaco GmbH, Seefeld, Germany) were in pre-prepared form for crown restoration fabrication. Preparational properties of the teeth are as follows: 2.0 mmocclusal reduction,1.5 mmaxial reduction, shoulder ended margin level of 0.5 mm subgingivally, 6 degrees convergence angle, and had no sharpcorners or edges.

Restoration dies were obtained with stereolithography technique (SLA) (Mikro SLA 3D Drucker, Nanoscribe GmbH, Eggenstein-Leopoldshafen, Germany). System's methacrylate resin material (fractural strength 120-137 MPa, E-Modulus 2.7 GPa, shore hardness 83-88 Shore D) was used for SLA procedures. Anatomical designs of the dies were made by using a CAD Software (MeshLab, Visual Computing Lab, Pisa, Italy) with the guidelines for all-ceramic crown fabrication for all groups.

Crown restorations with the thicknesses of 1.0 and 1.5 mm were produced from each type of material by using CAD/CAM system (CEREC MCXL milling unit, Sirona Dental Systems, NY, USA). Firstly, 1.0 mm crown design was performed on a 1.0 mm SLA die using the system's software (InLab SW15.0 software, Sirona Dental Systems, NY, USA) indvidually. The setting for die spacer was adjusted for 40 µm for all groups, and the other parameters were accepted as 0 µm. The same fabrication protocol was followed for 1.5 mm crown designs. Fabrication of the samples was performed with the system's own milling unit (CEREC MCXL). Mode for milling procedure was adjusted to 'standard mode' and milling instruments were changed with new ones for every group. After milling process, glaze procedure was required for crowns according to the instructions from related manufacturers. Crowns were embedded in acrylic resin blocks (Acrylic VLXB, Kemet International, Kent, UK) for fatigue testing and fractural loading. Fatigue loading process was performed by using a chewing simulator equipment (CS-4.2 SD Mechatronik GmbH, Germany).

For thermomechanical loading, these parameters were followed: thermal cycling degrees of 5-55°, 120 s dwelling time,12,000 cycles, occlusal load of 49±0.7 N,1.2 million cycles,1.7 Hz, water change time 10 s) (14). Loading was performed by antagonistic cusp of an extracted natural molar to the central fissure of the sample to mimic the natural chewing process. After fatigue testing, the crowns were evaluated under a stereomicroscope (M-80, Leica, Wetzlar, Germany) with the magnification factor of 50x. The samples which had visible failure types (cracks) were eliminated. Remaining non-fractured samples were subjected to fractural loading procedure in auniversal testing machine (Instron 3300, Norwood, USA). Maximum load values were recorded for the samples' failure modes.

Statistical analyzes were madeby using the NCSS program (Number Cruncher Statistical System). The one-way analysis of variance (ANOVA) and post-hoc Scheffé tests were used in the comparison. Analysis results were shown as minimum, maximum, mean ± standard deviation (SD). The results were evaluated at $p < 0.05$ significance level.

RESULTS

The values of fatigue testing and fractural loading were presented for each group according to the thicknesses of materials in Table 2 and 3. For 1.0 mm thickness, six of group V,seven of group C, and five of group I could not survive for fatigue test process while 1.5 mm thickness crowns survived. Fractural loading values were within same range for the groups which had the same ceramic thickness and was not influenced from the type of material ($p>0.05$). However, different thicknesses presented different fractural loadings and significantly varied among the groups ($p<.001$). Fractural loading results were significantly higher for 1.5 mm thickness materials than 1.0 mm samples ($p<.001$).

DISCUSSION

This study evaluated the fracture resistance of zirconia-reinforced ceramic crowns depending on different ceramic thicknesses. The null hypothesis that any difference in fracture resistance with different material thicknesses between two ZLS and a zirconia reinforced alumina ceramic materials was rejected as the requirement of the results (Table 2 and 3).

Table 2 Maximum fractural loading values for the groupsof 1.0 mm crowns.

Group	Ceramic thickness(mm)	n	Minimum(N)	Maximum(N)	Mean(N)	SD	p
V	1.0	6	422.6a	825.4b	532.5c	142.2	0.13
C	1.0	5	378.2a	755.4b	476.2c	123.2	0.09
I	1.0	7	534.6a	932.4b	615.8c	134.6	0.12

n:Survived number of specimens after fatigue loading process.
a-c: There is no difference between groups with same letter for each surface.
N: Newton
p=0.05, significance level

Table 3 Maximum fractural loading values for the groupsof 1.5 mm crowns.

Group	Ceramic thickness(mm)	n	Minimum (N)	Maximum (N)	Mean (N)	SD	p
V	1.5	12	812.2d	1703.3e	916.6f	296.2	0.09
C	1.5	12	790.3d	1543.4e	860.4f	212.4	0.07
I	1.5	12	934.7d	1912.2e	1023.6f	342.3	0.10

n:Survived number of specimens after fatigue loading process.
d-f: There is no difference between groups with same letter for each surface
N: Newton
p=0.05, significance level

In this study, the mechanical testing results showed that 1.5 mm crowns obtained from ZLS or ZLA can be used for posterior region as a reliable option. This fractural resistance parameter has a clinical importance as it is accepted necessary to reduce the risk of failure (15). This novel ZLS material's mechanical properties were compared with the values of clinically accepted ZLA material and results were obtained in the style of in-vitro study. New materials must be assessed in laboratories before clinical use as well, but to express real clinical situation further in vivo studies are needed.

Fatigue testing and fractural loading were conducted without any cementation procedure as the cement agent may be play a supporting role for ceramic material (16). In the literature, studies have shown that the thickness of cement agent can affect the mechanical testing results (4,17). For this reason, cement layer parameter was set to 40 µm as a standard for all groups. In that respect, the values for fractural loading process may present lower values than the studies which had cementation procedure. Results may be obtained in higher degrees when resin cement agents are used for cementation of restoration due to having higher E-Modulus values. Further studies which included different cement agents are needed to clarify this clinical issue.

In the present study, to mimic the natural oral environment and chewing process, chewing simulator was used before fractural loading (14). It is reported in the literature that fatigue loading procedures, like using chewing simulator, cause stress concentration on the structure of ceramic and weaken material (18). Therefore, the studies without fatigue loading procedures may present higher values those found in the present study.

Fatigue testing results revealed high fracture resistance according to obtained values from the study groups. It can be concluded from the study that ZLS and ZLA showed similar values for fractural loading. This situation can be attributed to the structural mechanism of the ceramic materials used as they contain zirconia inside the formulation of mentioned ceramic materials. Reinforced glass matrix with zirconia fillers give increased resistance to fatigue loading. New ceramic materials which have different proportions of zirconia filling can show different results.

The limitations of this study are as follows: (1) Phantom acrylic teeth were used for sample production which have different properties from natural tooth; (2) in-vitro study design which has not same clinical conditions with oral environment; (3) only one type of CAD/CAM system were used for the fabrication of the crowns, as different digital systems may have different settings and can influence the testing results. Future studies are needed to evaluate the effect of cementing procedures, type of cement agent, and adhesion variables of ZLS materials.

CONCLUSION

Within the limitations of this study, it may be concluded that:

1. CAD/CAM crowns which were fabricated from ZLS and ZLA ceramic materials showed acceptable fracture strength values which were above clinically expected loadings.
2. Zirconia-reinforced ceramic materials with 1.5 mm thickness may be a good choice for crown restorations in daily clinical practice.

References

1. Reiss B. Long-term clinical performance of CEREC restorations and the variables affecting treatment success. Compend Contin Educ Dent. 2001; 22:14-18.
2. Guess PC, Schultheis S, Bonfante EA, Coelho PG, Ferencz JL, Silva NR. All-ceramic systems: Laboratory and clinical performance. Dent Clin North Am 2011; 55: 333-352.
3. Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater 2015; 31: 603-623.
4. VITA SUPRINITY®, Technical and scientific documentation, Vita Zahnfabrik, Bad Säckingen, Germany, 2014.
5. Bindl A, Luthy H, Mormann WH. Strength and fracture pattern of monolithic CAD/CAM-generated posterior crowns. Dent Mater 2006; 22: 29-36.
6. Stevenson B, Ibbetson R. The effect of the substructure on the colour of samples/restorations veneered with ceramic: a literature review. *J Dent* 2010; 38: 361-368.
7. Ma L, Guess PC, Zhang Y. Load bearing properties of minimal-invasive monolithic lithium disilicate and zirconia occlusal onlays: Finite element and theoretical analyses. Dent Mater 2013; 29: 742-751.
8. Raptis NV, Michalakis KX, Hirayama H. Optical behavior of current ceramic systems. *Int J Periodontics Restorative Dent* 2006; 26: 31-41.
9. Silva NR, Bonfante EA, Martins LM, Valverde GB, Thompson VP, Ferencz JL, Coelho PG. Reliability of reduced-thickness and thinly veneered lithium disilicate crowns. J Dent Res 2012; 91: 305-310.
10. Carvalho AO, Bruzi G, Giannini M, Magne P. Fatigue resistance of CAD/CAM complete crowns with a simplified cementation process. *J Prosthet Dent* 2014; 111: 310-317.
11. Craig RG. Restorative dental materials. St Louis, Mo: CV Mosby; 1996.
12. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. *J Prosthet Dent*. 1999; 81:652-661.
13. McLean J. The nature of dental ceramics and their clinical use. In: The Science and Art of Dental Ceramics. Chicago, Ill: Quintessence Publishing Co, Inc; 1979:23.
14. Fasbinder DJ. Materials for chairside CAD/CAM restorations. Compend Contin Educ Dent. 2010; 31(9):702-4, 706, 708-9.
15. Ritter JE. Predicting lifetimes of materials and material structures. Dent Mater. 1995; 11(2):142-6.

16. Wiedhahn K. From blue to white: new high-strength material for Cerec--IPS e.max CAD LT. *Int J Comput Dent*. 2007; 10(1):79-91.
17. Pieger S, Salman A, Bidra AS. Clinical outcomes of lithium disilicate single crowns and partial fixed dental prostheses: a systematic review. *J Prosthet Dent*. 2014; 112(1):22-30. doi: 10.1016/j.prosdent.2014.01.005.
18. Fischer H, Waindich A, Telle R. Influence of preparation of ceramic SEVNB specimens on fracture toughness testing results. Dent Mater. 2008; 24(5):618-22.

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