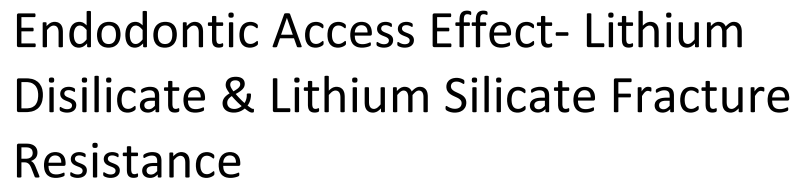

Endodontic Access Effect- Lithium Disilicate & Lithium Silicate Fracture Resistance

GREG A. SPILSBURY, Capt, USAF, DC
81 DS, KEESLER AFB, UNITED STATES AIR FORCE

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Table of Contents

Abstract ... iv

List of Tables ... v

List of Figures ... v

Manuscript ... 1

Introduction ... 1

Materials and Methods ... 3

Results ... 6

Discussion ... 9

Conclusion ... 13

Disclaimer ... 14

Bibliography ... 14

Endodontic Access Effects on Lithium Silicate and Disilicate Fracture Resistance Cemented to Human Teeth

Captain Greg A. Spilsbury

APPROVED:

Lt Col John A. Brewster
AEGD 24 Month Residency Research Director

Col Michael N. Wajdowicz
AEGD 24 Month Residency Director

Lt Col James J. Renda
AEGD 24 Month Residency Deputy Director

7 June 2019
Date

APPROVED:

Col Jay D. Graver
Dean, Air Force Postgraduate Dental School

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
AIR FORCE POSTGRADUATE DENTAL SCHOOL
301 Fisher Street, Room 1F505
Keesler Air Force Base, Mississippi 39534
www.usuhs.mil

7 June 2019

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Signature

Greg A. Spilsbury, DDS

Printed Name

AEGD 24 Month Residency Program
Air Force Postgraduate Dental School
Uniformed Services University of the Health Sciences

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Abstract

Objectives: To evaluate endodontic access (EA) effect on the fracture resistance (FR) of lithium silicate (LS-- CeltraDuo CAD) and lithium disilicate (LD-- e.max CAD) full contour crowns. Ho is there will be no difference in FR between CAD materials with or without EA.

Methods: 40 human mandibular molars were randomly assigned to 4 groups (n = 10); LD, LD with EA and LS, LS without EA. All specimens were prepared using a lathe device, following guidelines for full-contour LD/LS CAD restorations. Crowns were fabricated with a chairside CAD/CAM system (CEREC Omnicam, SW4.5, MCXL). Crystallization for LD and firing-cycle for LS accomplished (Programat P700). Crowns were adhesively luted (4.5% HF/silane/RelyX Unicem2). EA Groups: EA and instrumentation was performed by a board certified endodontist. Chamber restoration (Clearfil SE2/Gradia Core) and EA crown repair (9%HF/silane/Filtek Supreme Ultra) accomplished by a general dentist. Manufacturer recommendations were followed for all materials. After 24h storage (37°C/98% RH) specimens were fatigued in a dynamic cyclic loading machine (Sabri Dental); 100 N, 100,000 cycles at 2 Hz in 21°C distilled water. Specimens were then tested 45° until failure on a universal testing machine (0.5mm/min). Failure loads were analyzed using Kruskal-Wallis/Dunn's post hoc (p=0.05).

Results: No statistical differences were found in FR between the 4 groups; therefore we failed to reject our Ho. Failure modes were similar across all 4 groups.

Conclusions: Under the conditions of this study, there are no difference in FR between LD and LS crowns. It may not be necessary to replace LD/LS crowns which have EA repair.

List of Tables

Table 1. Mean Force to Fracture Data..5

Table 2. Minimum Values of Force to Fracture Data.....................................8

List of Figures

Figure 1. Mean Force to Fracture Chart 7

Figure 2. Box & Whiskers Chart 8

Figure 3. Sample Fracture Pictures 9

Manuscript

Introduction

Over the last decade, there has been an enormous demand for all ceramic restorations. A large part of this progression is a result of the population's demand for higher esthetics. A survey done by the American Academy of Cosmetic Dentistry in 2012 discovered that most respondents felt they would improve their smile by having whiter and brighter teeth[1]. This continuing trend is driving the market to innovate and develop new esthetically driven restorative options. A survey conducted by Glidewell Laboratories in 2013 revealed that only 10% of their crown fabrications were PFMs, down from 65% in 2007, yet they also reported that the number of LD crowns was steadily increasing, making up nearly half of all their anterior restorations[2].

This increased expectation for oral esthetics even in areas where visibility is low, has been a challenge in dentistry. Although strength and esthetics are not mutually exclusive, they are commonly gained at the others expense. This paradox seems to have become more possible through the introduction of all ceramics and CAD/CAM technology. Monolithic blocks that offer multiple shades and differing levels of opacity can be milled, stained, and delivered in a single appointment. Providers and patients have seen these advantages, and consequently, have unlocked an expansive market where the trio of strength, esthetics, and simplicity of use drive innovation. Ivoclar first introduced IPS e.max as Empress 2. After improving processing methods, they rebranded it as IPS e.max. LD is a monolithic lithium disilicate ceramic that can be pressed or milled. It comes in a partially crystalized CAD block composed primarily of metasilicate. After milling, it is often stained, glazed, and then crystalized, completing the full crystallization process to lithium disilicate. This state accounts for about 70% of its content. It

has a flexural strength of 360–500 MPa[3,4], making it the ideal high-strength solution for single-unit anterior or posterior crowns.

Other companies have seen the success of LD and have introduced their own lithium silicate materials. Glidewell has Obsidian, Vita has Suprinity, and now Dentsply Sirona has Celtra Duo. Celtra Duo was introduced in 2016. It's available in pressed ingots and fully crystalized CAD blocks. These CAD blocks are milled, polished, and bonded possessing a flexural strength of 210 MPa; or milled, polished, stained/glazed, and fired with an increase in flexural strength[5]. Its lithium silicate particles are about 4x smaller than LD[6]. This is made possible by a small number of well dispersed zirconium oxide particles that influence the crystallization process creating an increase in smaller crystalites[5]. It's common for materials with smaller crystals and high glass content to have some favorable physical properties as well as esthetic properties[5,7]. It has been shown to perform similar in strength, and depending on the study, fares slightly better or worse when compared to LD with reported flexural strengths around 370 MPa[3,4,8].

With each new product development, there will always be marketers making claims, but it is the dentist's ultimate responsibility to verify those claims and know how they relate to a material's indications and limitations. One question that is becoming more and more relevant with the increasing use of all ceramic restorations is if a patient should have their all ceramic crown remade after an endodontic access for root canal therapy. It is not an uncommon practice that when endodontic access is performed through a full metal or PFM restoration, the crown is repaired with a core, barring the crown margins and form were intact. In fact, a survey of dental providers in 2000 highlighted that 20-50% of all respondents stated their endodontic therapy was

associated with a full coverage restoration[9]. Ceramic unlike metal, is a brittle material prone to failure through the introduction of flaws whether that be by the fabrication process, milling, adjustments, or function[8]. Accessing through an all ceramic crown will certainly introduce fractures in the restoration. At what level is this significant, and are some of the all ceramic materials like LD and LS, that possess improved physical properties (higher flexural strengths and fracture toughness) able to withstand the insult of an endodontic access while still maintaining functional longevity? The answers to these questions are valuable and important to patients so they can be informed on different treatment options. There is a growing body of laboratory studies evaluating the effect an endodontic access has on an all ceramic crown, but unlike this study, few have used natural teeth and cyclic fatiguing before testing for failure. Although most tested the effects of an endodontic access through bonded restorations, almost all were bonded to resin dies that do not exhibit the same bonding strength as natural teeth. To this date, there are no published studies that have investigated the effect an endodontic access would have on Celtra Duo. LD has been extensively evaluated in laboratory and clinical studies. The purpose of this study was to compare the strengths two CAD materials, LD and LS, before and after being endodontically accessed. Our null hypothesis was that there will be no difference in FR between CAD materials with or without EA.

Materials and Methods

Forty caries free human mandibular molars were mounted in auto polymerizing methacrylate resin (Diamond D, Keystone Industries, Cherry Hill, NJ, USA) and then prepared to receive a full coverage LD or LS crown. All preparations were prepared according to manufacturer guidelines for their respective restorative material. Each tooth was prepared using a

high-speed electric dental handpiece (NSK Presto Aqua II High Speed Lab System, Brassler USA, Savannah, GA, USA) with a diamond bur (8847KR.31.025, Brassler USA, Savannah, GA, USA). A total occlusal convergence (TOC) of 12° taper was standardized by using the handpiece in a fixed lathe arrangement. Each preparation was measured for standardization of 4 millimeter axial wall height.

The specimens were then randomly divided into 2 groups. The first group (n = 20) was designated as the LS crown group, while the second group (n = 20) served as the LD group. Each of the respective groups were then further subdivided into two groups of 10 that would receive endodontic access, (LS-EA, LD-EA) and groups (LS, LD) that would remain intact and serve as a control. The prepared teeth were scanned and designed using a chairside CAD/CAM acquisition device (Omnicam® 4.5, Sirona Dental Systems, Charlotte, NC, USA) with the prepared teeth being mounted into a standardized occlusal template. All restorations were designed with a minimum 1.5 millimeter occlusal thickness and 1.0 millimeter axial wall thickness at their thinnest portion with subsequent milling (MCXL, Sirona Dental Systems, Charlotte, NC, USA).

After milling, each restoration received a pre-crystallization/firing polish. All restorations were then crystalized/fired according to manufactured instructions using a dental laboratory furnace (Programat P700, Ivoclar-Vivadent). No restorations required adjustment for final seating. All restorations were steam cleaned, intaglio surfaces etched with 4.5% hydrofluoric acid, ceramic primer applied, (Clearfil Ceramic primer, Kuraray America, New York, NY, USA, USA) and adhesively luted with a self-etching/self-adhesive resin cement (RelyX Unicem2, 3M ESPE, St. Paul, MN, USA) using finger pressure. Excess cement was removed, and then the

restoration was light cured for 20 seconds on the facial, occlusal, and lingual surfaces. All specimens were then stored under dark conditions at 37 ± 1 °C and 98 ± 1% humidity.

LS-EA, LD-EA groups then received endodontic access by a board certified endodontist using a ceramic endodontic access bur (Z801-018M, Prima Dental, Gloucester, UK) and two carbide burs (Endo-Z bur, Dentsply Mailleffer, Tulsa, OK, USA; 1958 bur, Integra-Miltex, Plainsboro, NJ, USA) to prepare and enlarge each access. The size of each endodontic access opening was accomplished to the point that the endodontist could gain straight line access as would be done clinically if canal instrumentation was to be done. The accessed groups, LS-EA, LD-EA were then restored in two parts. The chamber portion of the restoration was prepared using a self-etch, dual cure adhesive (Clearfil DC, Kuraray America, New York, NY, USA) and a dual cure, resin core material (Gradia Core, GC America, Alsip, IL, USA). The coronal-ceramic portion of restoration was repaired using 9% HF acid (Porcelain Etch, Ultradent, South Jordan, UT, USA), primer solution, (Clearfil Ceramic primer, Kuraray America, New York, NY, USA) and nano-filled composite (Filtek Supreme A2, 3M, Maplewood, MN, USA). All specimens were then returned to previous dark storage at 37 ± 1 °C and 98 ± 1% humidity.

After 24h storage (37°C/98% RH) specimens were fatigued in a dynamic cyclic loading machine (Sabri Dental, Downers Grove, IL); 100N, 100,000 cycles at 2 Hz in 21°C distilled water. Specimens were then placed into a fixture on a universal testing machine (Alliance RT/5, MTS Corporation, Eden Prairie, MN, USA) containing a hardened polished stainless steel piston with a 0.5-m radius of curvature with a three millimeter diameter. Specimens were loaded axially at a 45° angle at the mesial lingual cusp at a rate of 0.5 millimeter per minute until a load drop was recorded with confirmation of concurrent visualization of crack formation. Force to failure was recorded in newtons.

Results

Data was analyzed and did not meet the assumptions required to use a parametric test; therefore, the data was analyzed using Kruskal-Wallis with Dunn's post hoc analysis. A 95 percent level of confidence ($p = 0.05$) was used with all analysis. Table 1 shows similar averages in the mean force to fracture with LS being 1085.03N and LD 1057.93N. Likewise, mean force

Table 1

Force to Fracture Data		
Material	Non-Access	Accessed
LS	1085.03 (304)	985.90 (296)
LD	1057.93 (354)	873.19 (198)

Kruskal-Wallis Test (p=0.05) revealed no statistical differences between groups

to fracture between LS-EA was 985.90N and LD-EA was 873.19N.

Figure 1 and 2 demonstrate that the average mean force to fracture rates are higher in both LS and LD intact groups. LS intact had the highest force to fracture rate when compared to all groups including intact LD. Likewise, LS-EA had a higher force to fracture rate when compared to LD-EA.

Figures 1

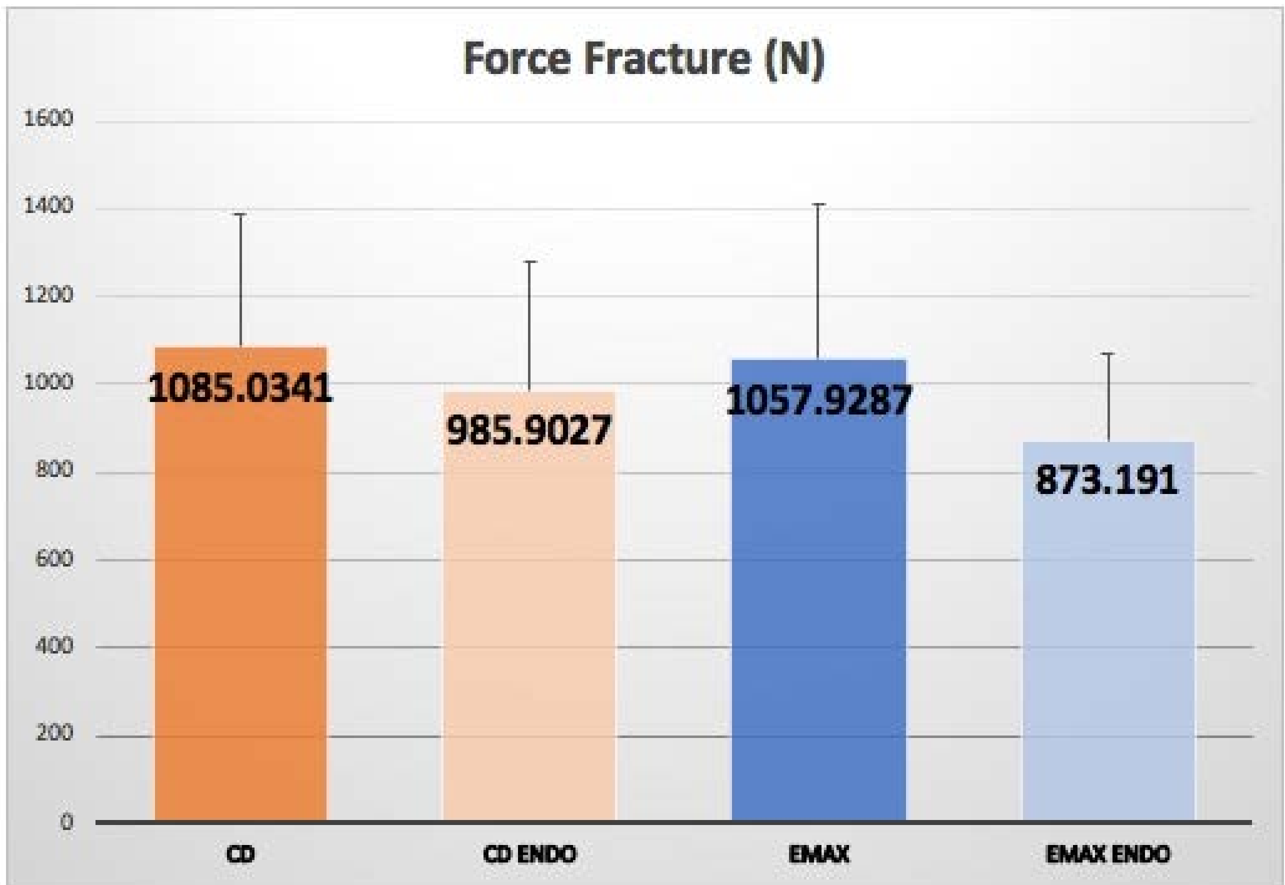
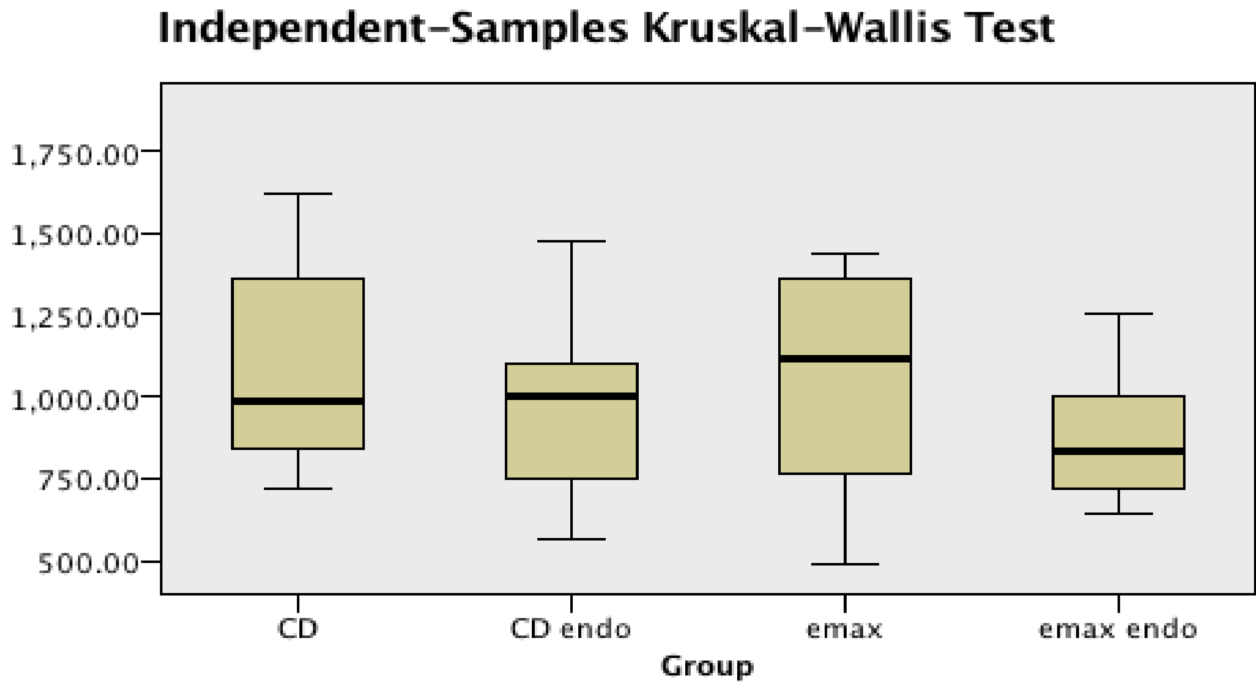


Figure 2



The minimum force to fracture rate is seen in table 2.

Table 2

Force to Fracture (Lowest minimum values)		
Material	Non-Accessed	Accessed
LS	717.30	564.01
LD	493.36	639.22

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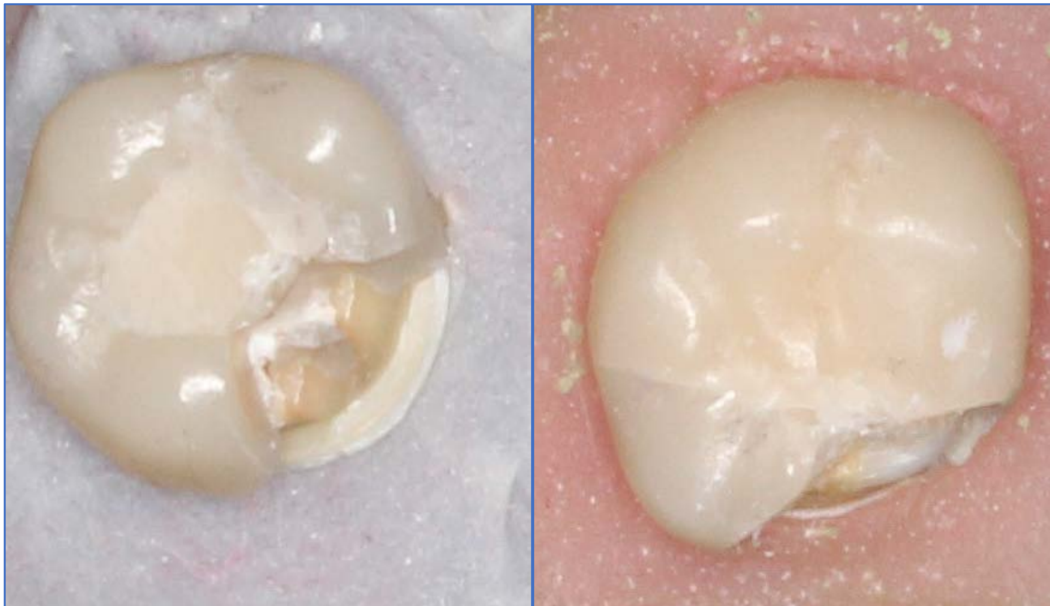
Although mean force to fracture rates are higher in the LS and LS-EA groups, these differences were not statistically significant from the LD and LD-EA. Visualization of fracture patterns were analyzed. Most fractures were mixed adhesive fractures between tooth and cement and crown to cement. Examples of fracture patterns are shown at figure 3

Figure 3



Fracture patterns consistently revealed bulk fractures that appear similar to clinical fracture patterns of all ceramic crowns[10]. All fracture patterns of EA all ceramic crowns showed an adhesive failure between core and crown with the core intact showing no sign of fracture.

Discussion

It's almost inevitable that providers will encounter teeth restored with an all ceramic crown needing endodontic therapy. Each provider should be able to evaluate the condition of that crown or fixed dental prosthesis and provide the patient an educated prognosis along with associated risks and benefits regarding its repair or replacement after endodontic therapy. No protocol or algorithm exists for such a decision. More literature is being published regarding this subject each year that may eventually lead to a guideline for best clinical practices but given the current state, there is insufficient evidence for creating such a protocol[11]. In this study, we were able to accept the null hypothesis that there will be no difference in FR between CAD materials

with or without EA. This is consistent with previous studies done[12,13,14,15,16]. The design of this study was to build on previous studies done with an amplified focus on replicating clinical conditions. We used human mandibular molar abutments that were prepared for anatomic restorations designed and milled according to manufacture guidelines. Endodontic accesses were made to mimic clinical access designs. A combination of medium grit diamond and carbide burs were used to access each crown to an appropriate size for a board certified endodontist to obtain straight line access. Cyclic fatiguing was done in a wet environment with loading to failure done at a 45° angle at the mesial lingual cusp so more clinically acceptable failure modes occurred. We repaired accesses in using a ceramic repair protocol that is commonly used clinically.

Almost all of the previous referenced studies were done on composite-resin dies and were loaded axially. At this given time, there is no ISO standard for loading all ceramic crowns until failure on a universal testing machine. The aim of our study was to test the strength of the all ceramic crown. That is why each specimen was loaded at a 45° angle along the mesial lingual and not in significant contact with core material. This manner created a common fracture pattern where radial bulk fractures occurred while regularly adhesively separating from an intact core material. This type of bulk fracture with all ceramic crowns is commonly seen in clinical situations. Similarly, lingual cusps of mandibular molars are the most common mode of fracture in the human dentition[10,17].

Lund et al compared the FR of LD and Lava Ultimate CAD crowns that were endodontically accessed after cementation to PMMA dies. They found that endodontic access through LD crowns did have a statistically significant effect on decreasing the FR of LD crowns[16]. Their result may differ due to crowns that were adhesively luted to a highly

polymerized PMMA die with an acidified primer/adhesive system which could have interfered with polymerization. This potential decrease in bonding has been shown to affect the FR of adhesively luted crowns. Qeblawi et al evaluated the effect of adhesively luting vs conventional luting LD CAD crowns. They found that adhesively luting significantly increased the FR of LD crowns that were endodontically accessed[14]. They also found that the introduction of a more course diamond for endodontic access had a decreasing effect on the FR of LD crowns. Haselton et al evaluated the differences in chipping found between an endodontic access performed by a carbide or a medium course diamond bur would have on leucite reinforced crowns. He found no difference between groups[18]. Both previous studies used a uniform endodontic access on resin dies. In this study, human molar abutments were prepared, and anatomic restorations were designed and milled according to manufacture guidelines. As stated previously, a combination of medium grit diamond and carbide burs were used to access each crown to an appropriate size for a board certified endodontist to obtain straight line access. Endodontic accesses were made to mimic clinical access designs which were not done in any previous studies.

Another difference is the use of cyclic fatiguing. Bompolaki et al is the only previous study to include cyclic fatiguing when testing the effect an endodontic access would have on an all ceramic crown was done[13]. Cyclic fatiguing was done in a dry environment. In regard to cyclic fatiguing all ceramic restorations, it was shown by Kelly et al, that cyclic fatiguing in the presence of water decreased overall failure loads[10]. This may be one reason the present study's mean force to fracture values were nearly 70% less than those seen in the Bompolaki study.

Qeblawi et al used a uniform access on identical maxillary molar crowns luted and adhesively luted to composite resin dies. They also loaded each all ceramic crown axially until

failure. No mention of how final force measurements were determined regarding the visualization of a fracture or bulk fracture. They did demonstrate that with adhesively luted crowns, 100% had a fracture mode involving both the all ceramic crown and die. They observed fracture to failure rates three times the ones seen in this study. This could be due to the way each specimen was loaded to failure. The indenter appeared to occupy the entire occlusal surface making it difficult to visualize crack formation and they did not define at what point failure was determined and recorded.

Due to the heterogeneity existing within each of the previous studies evaluation methods of testing the effects an endodontic access may have in the fracture resistance of an all ceramic crown, it is difficult to compare. In this study, we used human teeth that will naturally have anatomical and size disparities. These differences translate into different preparation sizes, restoration proposals, and all ceramic restoration morphology when fabricating a CAD all ceramic restoration. We took care to account for these discrepancies by using sample randomization, use the given proposal and making minimal adjustments in a standardized process of design, and including uniform parameters across all groups. Another challenge to uniformity is the variability between pulpal anatomy of teeth. This directly influences the extent of an endodontic access required to adequately perform an endodontic procedure. For standardization and to attempt to reduce variability, endodontic access was performed by a single board certified endodontist who utilized periprocedural digital radiographs and an endodontic microscope to achieve straight line access for each tooth. Although using human teeth introduces challenges to standardization, we feel that under a strict and well-designed study, any limitations present are outweighed by creating a in vitro study that better mimics the clinical environment.

Every patient will have these same differences and a provider needs to look at each variable and determine the influence they could have on the future prognosis.

Many previous studies referenced literature regarding the occlusal forces seen in human dentition with values of 585N to 900N and voluntary forces being reported[19,20,21]. Most studies evaluating the effect an endodontic access has on all ceramic crowns refer to their findings being greater than these occlusal forces. Although the mean failure to fracture values for all groups in this study exceed the 585N to 900N, there are specimens that fell below those ranges (Table 1 and 2) . Due to the many limitations that are present in laboratory studies, we cannot infer broad clinical recommendations regarding provider's decisions to recommend replacement or repair of all ceramic crowns that have been endodontically accessed. There are multiple factors that a provider should consider when making that recommendation. These are not meant to be all inclusive, but some of these factors should include the patient's occlusal scheme, whether margins are sealed and no recurrent caries are present, presence of working or nonworking interferences, parafunction, type of instrument used to make the access, condition of access margins and size of access, type of cement used, and the condition of abutment tooth. It is always important that a patient understands the risks involved, but it seems justifiable in certain clinical situations for a provider to recommend repair an all ceramic restoration following root canal therapy.

Conclusion

Within the limitations of this study, there are no difference in FR between LD and LS crowns. After evaluating multiple previously discussed factors, it may not be necessary for a patient to require replacement of their LD/LS crown after EA and repair.

Disclaimer

The authors report no conflicts of interest. The information and views expressed in this article are those of the authors and do not reflect the official policy or position of the US Air Force, the Department of Defense, or the US government.

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