Original Article

The Comparative Study of Fracture Strength between Celtra™ Duo and IPS e.max® CAD

Nantawan Krajangta[1], Chayanit Angkananuwat[2] and Lertrit Sarinnaphakorn[2]

[1]Department of Operative Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani Thailand

[2]Department of Prosthodontic, Faculty of Dentistry, Thammasat University, Pathumthani Thailand

Abstract

This study aims to measure the fracture strength in molar region of new zirconia-reinforced lithium silicate (Celtra™ Duo, Dentsply) in comparison to lithium disilicate (IPS e.max CAD, Ivoclar Vivadent) all ceramic crowns made with computer-aided design/computer-aided manufacturing. Thirty standardized crown resin models were prepared with the same dimensions and randomly assigned to either Celtra™ Duo or IPS e.max® CAD group, fifteen each. Fractural load values were measured by a universal testing machine (Instron model 4464, USA) with a static load applied along the long axis of the specimen at a crosshead speed of 1 mm/min at room temperature until fracture. Fracture load values were recorded for each specimen and statistically analyzed by using unpaired t-test. The mean ± SD for the fracture load values were 1,696.67 ± 230.31 N and 1,569.87 ± 154.71 N for Celtra™ Duo and IPS e.max® CAD, respectively. There was no statistically differences of fracture strength between Celtra™ Duo and IPS e.max® CAD ($p < 0.05$).

Keywords: All-Ceramic restoration, CAD/CAM, Fractural strength, Zirconia-reinforced lithium silicate

Received Date: Mar 16, 2016 Accepted Date: May 18, 2016

doi: 10.14456/jdat.2016.19

Correspondence to:

Nantawan Krajangta. Faculty of Dentistry, Thammasat University, 99 M.18 Khlong Nueng, Khlong Loung, Patumthani 12121 Thailand

Tel: 02-9869213, 084-4383040 Fax: 02-9869205 E-mail: knantawa@gmail.com

Introduction

Esthetic, adhesive restorations are increasingly becoming the restoration of choice for many clinical situations. In contrast to metallic restorations, all-ceramic restorations exhibit advantages such as realistic appearance, biocompatibility, wear resistance and color stability. However, they also show susceptibility to fracture and their ability to withstand occlusal forces is quite low. Among the clinical complications of all-ceramic crowns, crown fractures are reported most commonly.[1-4] Meanwhile, computer aided design/computed aided manufacturing (CAD/CAM) technologies were introduced to dentistry in the 1980s. Access to standardized manufacturing processes, uniform material quality, reproducibility of restorations and reduction of production costs have been achieved in CAD/CAM technologies.

As CAD/CAM production of dental restorations has become more common, a new innovation in lithium disilicate glass ceramic was developed in 2005 under the name of IPS e.max® CAD (Ivoclar Vivadent, Schaan, Liechtenstein) for milling techniques. The IPS e.max® CAD block is a partially crystallized block consisting of 40 % lithium meta-silicate crystals, allowing the material to be easily milled. After processing the blue block into the desired dental restoration, a re-crystallization process takes place at 850°C for 10 minutes, through which the lithium meta-silicate is transformed into lithium disilicate crystals. This transformation provides the restoration with its final mechanical and esthetic properties. According to the manufacturer's data, the flexural strength of fully crystallized IPS e.max® CAD is about 360 MPa.

Most recently, Zirconia-reinforced ceramic is a new class of materials for high strength glass ceramics with zirconia-reinforced lithium silicate (ZLS). This new ceramic system has been developed in an attempt to improve the strength of lithium disilicate ceramic. A new products based upon this approach is Celtra™ Duo (Dentsply Caulk, Milford, USA) for CAD/CAM processing. According to the manufacturer's information, Celtra™ Duo has a flexural strength of 210 MPa after milling, and additional 19 stains and glaze firing can increase the material's flexural strength to 370 MPa.

Traditionally, brittle dental ceramics were supported with a strong metal substructure. Today, with advances in CAD/CAM technologies, monolithic restorations have been introduced into dentistry.[5] However, there is no published evidence to validate the fractural strength of these new materials. Therefore, this study aims to compare fracture strength of new zirconia-reinforced lithium silicate and lithium disilicate all-ceramic crowns made with computer-aided design/computer-aided manufacturing (CAD/CAM).

Materials and Methods

1) Sample preparations

1.1 Epoxy resin die preparation

30 epoxy resin dies were prepared to simulate all ceramic crown prepared molar teeth (fig. 1). The dimension of die fabricated are as follow: 10 degree axial taper, 1 mm round shoulder finish line placed 0.5 mm occlusal to the cemento-enamel junction, 1.5 mm axial reduction, 2 mm occlusal reduction and 4 mm occluso-gingival height (fig. 2).

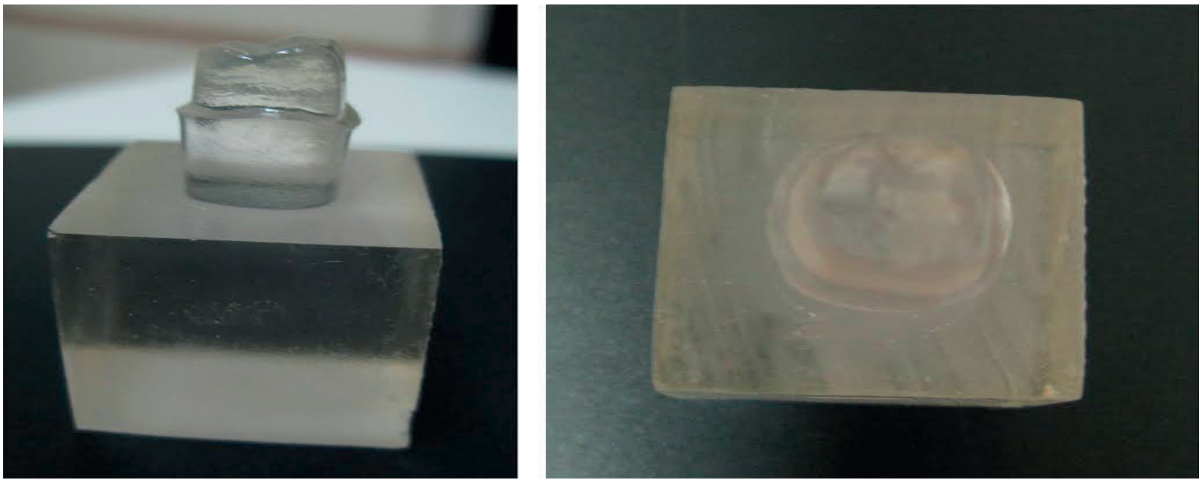

Figure 1 *Die fabrication using epoxy resin*

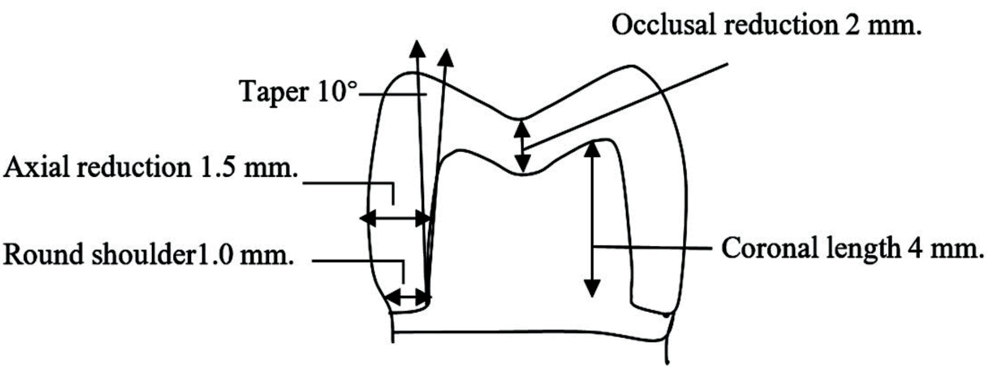

Figure 2 *The dimension of fabricated die*

1.2 CAD-CAM ceramic crown fabrication

All epoxy resin models were randomly divided into 2 groups (n = 15) for each of two CAD-CAM ceramic system (1) Zirconia-reinforced lithium silicate ceramic (Celtra™ Duo; Dentsply) and (2) Lithium disilicate ceramic (IPS e.max® CAD; Ivoclar Vivadent). One epoxy resin dies was scanned and designed using CEREC (Sirona dental system, Bensheim, Germany) system. Each identical monolithic CAD-CAM crown was fabricated with same design by one technician according to the manufacturer's instruction (fig. 3). The compositions of the ceramic used in this study are shown in table 1.

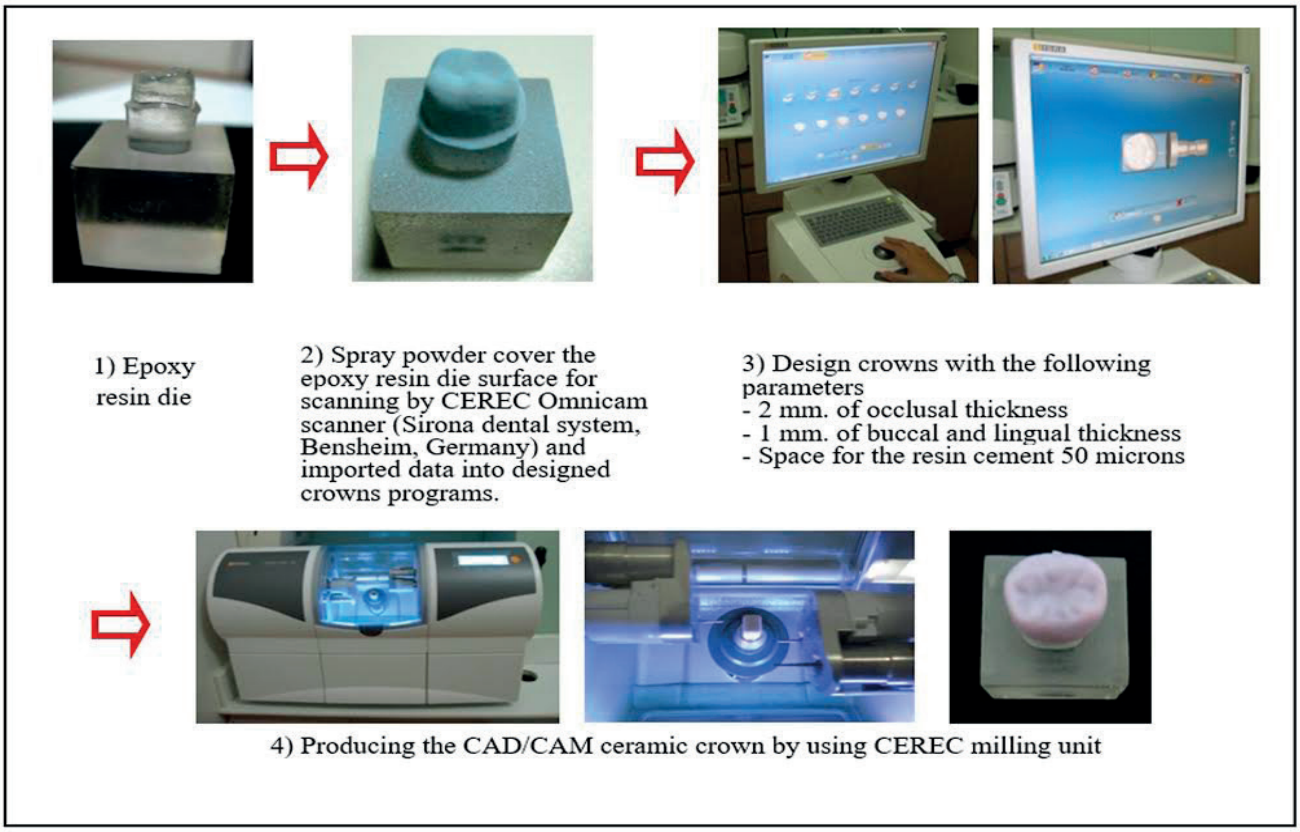

Figure 3 *The all ceramic crown production with CAD/CAM techniques*

Table 1 *The composition of the ceramic according to the manufacturer's instruction*

Ceramics	Composition
IPS e.max® CAD (lithium disilicate)	40 % volume lithium metasilicate crystals (Li_2SiO_3), which are embedded in a glassy phase Standard Composition: (in wt %) SiO_2 : 57.0 – 80.0 Li_2O : 11.0 – 19.0 K_2O : 0.0 – 13.0 P_2O_5 : 0.0 – 11.0 ZrO_2 : 0.0 – 8.0 ZnO : 0.0 – 8.0 Other and colouring oxides 0.0 – 12.0
Celtra™ Duo (Zirconia reinforced lithium silicate)	10 % dissolved zirconia reinforces the glass matrix

1.3 Cementation

All crowns were cemented with resin cement (Calibra® Automix, Dentsply) according to the manufacturer's instruction. Prior to cementation, each crown was seated on its respective epoxy model to ensure marginal fit. Internal surface of all crowns were acid etched with Phosphoric acid (Caulk® 34 % Tooth conditioner gel) for 30 seconds, rinsed with water, dried with air and then silanized (Calibra® Silane coupling agent). A microbrush was used to apply a thin layer of Prime and Bond NT dual cure mixture followed by application of Calibra® Automix. After initial seated crown with finger pressure, the excess cement was removed using dry brush. Light cure (Coltolux® LED, Coltene, Whaledent, Switzerland) all marginal areas for 20 seconds from the buccal, lingual, mesial and distal aspects. The cemented crowns were secured in place with finger pressure during light curing until cement setting for 10 minutes. Following cementation, all specimens were placed at room temperature for 24 hours.

2) Fractural strength test

The crowns were loaded centrally and axially to their central fossa at a crosshead speed of 1.0 mm/min by a universal testing machine (Instron model 4464, USA). A 4 mm diameter stainless steel indenter was used to transmit the force until fracture as shown in fig. 4. The appearance of failures was recorded. Fracture characteristic was define as type 1) complete fracture of both crown and resin block, type 2) crack line on both crown and resin block or type 3) crack line within crown (fig. 5).

Figure 4 *The load application in the central fossa with a 4 mm diameter stainless steel indenter*

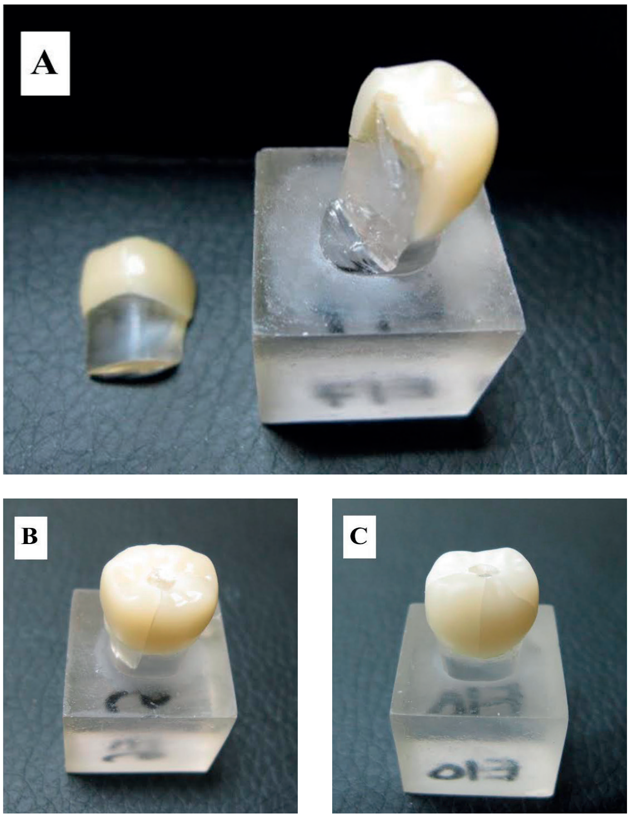

Figure 5 *The characteristics of fracture crown: A) Type 1 complete fracture of both crown and resin block, B) Type 2 crack line on both crown and resin block and C) Type 3 crack line within crown*

3) Statistic analysis

Results of fracture load were analyzed statistically using SPSS for Windows (Chicago, IL, USA). Normal distribution of fracture load data was determined using a Shapiro-Wilk test. The significance of difference in fracture load values between group was determined using unpaired *t*-test (α= 0.05).

Results

The fracture load values of Celtra™ Duo and IPS e.max® CAD crowns are shown in Table 2. The mean and standard deviation of the fracture strength of the Celtra™ Duo crown and IPS e.max® CAD crown were 1696.67 ± 230.31 N and 1569.87 ± 154.71 N, respectively. It was found that all tests were normally distributed according to The Shapiro-Wilk test. The unpair t-test revealed no statistically significant (p <0.05) of fracture load value between the Celtra ™ Duo and IPS e.max® CAD crown.

Table 2 *The fracture load value of each specimen (Newton; N)*

The fracture resistance test values (Newton; N)		
Sample	Celtra™ Duo	IPS e.max® CAD
1	1559	1382
2	1749	1697
3	1873	1778
4	1692	1424
5	1763	1600
6	1150	1561
7	1318	1711
8	1626	1547
9	1792	1450
10	1847	1404
11	1511	1651
12	1788	1430
13	1887	1370
14	1919	1836
15	1976	1707
Mean ±SD	1696.67 ± 230.31	1569.87 ±154.71

The contact diameter of all tested ceramic crowns were about 3 mm (fig. 6). The number and percentage of fracture characteristics of both type of ceramics demonstrated primarily type 1 (complete fracture of both crown and resin block) as shown in table 3.

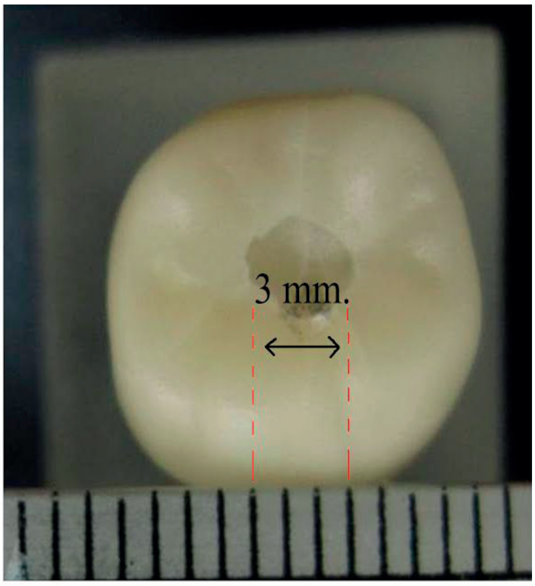

Figure 6 *Fracture load contact surface dimension with 3 mm diameter*

Table 3 *Number of Celtra™ Duo and IPS e.max® CAD crowns that were fractured in different* characteristics

Ceramic type	Number of specimens		
	Type 1 complete fracture of both crown and resin block (broken into pieces)	Type 2 crack line on both crown and resin block (Not broken into pieces)	Type 3 crack line within crown. (Not broken into pieces)
Celtra™ Duo	46.7 % (n=7)	20.0 % (n=3)	33.3% (n=5)
IPS e.max® CAD	73.3 % (n=11)	26.7 % (n=4)	-

Discussion

The demand for esthetics restoration is not limited to the anterior zone. The increased patient's demand for esthetics has led to an increased shift towards the use of all ceramic crowns for large posterior restorations. For several years, lithium disilicate glass ceramic has been known for its high level of esthetics due to its mimicking natural tooth appearance. However, the glass ceramic crowns, which are beautiful, usually fracture under occlusal load, especially in the posterior teeth. Recently, a new dental CAD/CAM material for CEREC has been developed by Dentsply Company to improve fractural strength of lithium disilicate glass ceramic. It is a zirconia reinforced lithium silicate ceramic. In the present study, a new launched zirconia reinforced lithium silicate ceramic, (Celtra™ Duo, Dentsply Caulk, Milford, USA) was evaluated for its fracture load comparing that of lithium disilicate ceramic (IPS e.max® CAD , Ivoclar Vivadent, Schaan, Liechtenstein).

The fractural load of a material can be defined as the maximum load that a material can withstand before fracture.[6] Fractural load test of dental ceramic is one of the important mechanical properties which has a high influence to predict the occlusal load that the material can withstand without fracture of ceramic material.[7, 8] Since no standard method exists for testing the strength of a clinical ceramic and each test setups are individually designed, the data are not comparable to each other. Reviewed studies have tested the fracture load of dental ceramic using extracted natural tooth[9-12] metal dies[13,14] or epoxy resin materials.[15,16] Metal dies have a higher elastic modulus than natural teeth. Increasing the elastic modulus of the die material has been investigated to increase the fracture load of all-ceramic posterior crown restorations.[17] However, use of natural teeth might also have some disadvantages, including variation in shape, size and mechanical properties.[18] Die materials in fracture load testing should have an elastic modulus similar to that of dentin.[19]

In the present study, epoxy resin was used to fabricate standardized dies to obtain fracture load values.[7,20,21] In addition, the application of epoxy resin provided the advantages of facilitated fabrication of homogenous substrates in a highly standardized manner. Epoxy resin dies were prepared according to clinically established preparation criteria and also according to the manufacturer recommendations for the assessment of the new materials. Each identical monolithic CAD/CAM crown was designed and manufactured by one technician using CEREC (Sirona dental system, Bensheim, Germany) system for the purpose of standardization. All crowns were cemented using finger pressure by one operator for clinical relevant situation. In this study, a 4 mm diameter stainless steel indenter was used to transfer the force through the central fossa of tested ceramic crown on the resin block. The result showed the occlusal contact area of 4 mm diameter steel ball and specimen is approximately 3 mm^2 in size (fig. 6) related with the finding of Hidaka et.al 1999, which found that the maximum size of occlusal contact area in molar was 3.2 mm^2.[22]

In the present study, the fracture loads of the monolithic CAD/CAM single crowns made by Celtra™ Duo and IPS e.max® CAD were 1,150-1,976 N and 1,370-1,836 N, respectively. The large variation of fracture load values within the same experimental group can be observed. This may be affected from the differences in finger pressure applied during crown cementation. Moreover, the unknown nature of the bonding between luting cement and epoxy resin model. However, these two factors equally influenced to both crowns in this study therefore it is possible to make a comparison between two groups.

No statistically significant of fracture load between Celtra™ Duo and IPS e.max® CAD was founded is in agreement with a previous study.[23] There are two hypothetical explanations for this result. The first explanation might be due to the composition of ceramics. Although Celtra™ Duo is reinforced by adding zirconia, it has only 10 % by weight of dissolved zirconia reinforces the glass matrix. The manufacturer has claimed that zirconia particles will reinforce the ceramic structure by crack interruption. However, the number of crystals filler in the material is other factor that greatly affected to the strength of ceramic.[11] According to manufacturer information, crystallized Celtra™ Duo has lower crystals filler volume (36 % volume of lithium disilicate and lithium silicate) when compared to that of crystallized IPS e.max® CAD (70 % volume of lithium disilicate). In addition, the second explanation might be due to the using of adhesive cementation can balanced the fracture resistance of higher strength ceramic to comparable that of lower strength ceramic crowns.[24]

Besides Celtra™ Duo, VITA® Suprinity (VITA Zahnfabrik, Bad Sackingen, Germany) is another zirconia-reinforced lithium silicate. Although, VITA® Suprinity contains the same composition with Celtra™ Duo (10 % Zirconia and 90 % lithium silicate), there were difference form (partially sintered block/fully sintered block) and difference manufacturer. There is a study has compared the fracture load between Celtra™ Duo and VITA® Suprinity on titanium implant abutments showed that VITA® Suprinity have higher fracture load than Celtra™ Duo maybe influenced from milling process of partially sintered VITA® Suprinity comparing to fully sintered Celtra™ Duo.[25] Currently, little is known about the mechanical properties between difference zirconia-reinforced lithium silicate ceramics. As the next step, it is interesting to investigated in further study.

Based on this study, it may be assumed that both Celtra™ Duo and IPS e.max® CAD are able to withstand intraoral masticatory forces in the mouth which is in the range of 216-890 Newton.[26,27] Therefore, both types of ceramic are strong enough to restore the posterior teeth and short-span fixed bridges. However, in this study, we tested the fractural strength of all ceramic crowns which are milled and sintered but not glazed so that may be effect the strength of material.[28]

From the result of fracture characteristic, although type I (complete fracture) and type II (crack line on both crown and resin block) fracture were found on both type of ceramic. There was crack line within crown (type 3) in only Celtra™ Duo group. It is probably cause by more fabrication flaws into ceramic from hard machining of fully sintered zirconia reinforced lithium silicate ceramic when comparing to soft machining of partially sintered lithium disilicate. However, this might be the advantage of Celtra™ Duo because the cracked crown could be removed and replaced with the new crown. This research could not determine the cause of the difference characteristics of ceramic crown fracture. Further investigations regarding the use of this material are required.

Conclusions

According to the limitations of this study, there was no statistically significant difference of the fracture load between Celtra™ Duo and IPS e.max® CAD ceramic crown. There loading forces are in the range that can withstand chewing force in a clinical setting.

Acknowledgments

This research was supported by the research foundation, Faculty of Dentistry, Thammasat University. We thank Stardent dental clinic who provided CEREC (Sirona dental system, Bensheim, Germany) system for fabricating CAD/CAM crown.

References

1. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications in fixed prosthodontics. ***J Prosthet Dent*** 2003;90:31-41.

2. Quinn GD, Giuseppetti AA, Hoffman KH. Chipping fracture resistance of dental CAD/CAM restorative materials: part 2. Phenomenological model and the effect of indenter type. ***Dent Mater*** 2014;30:e112-23.

3. Quinn GD, Giuseppetti AA, Hoffman KH. Chipping fracture resistance of dental CAD/CAM restorative materials: part I--procedures and results. ***Dent Mater*** 2014;30:e99-e111.

4. Wittneben JG, Wright RF, Weber HP, Gallucci GO. A systematic review of the clinical performance of CAD/CAM single-tooth restorations. ***Int J Prosthodont*** 2009;22:466-71.

5. Fischer H, Marx R. Fracture toughness of dental ceramics: comparison of bending and indentation method. ***Dent Mater*** 2002;18:12-9.

6. Sakaguchi RL, Powers JM. Craig's restorative dental materials: Elsevier/Mosby; 2011.

7. Heintze SD, Albrecht T, Cavalleri A, Steiner M. A new method to test the fracture probability of all-ceramic crowns with a dual-axis chewing simulator. ***Dent Mater*** 2011;27:e10-9.

8. Rekow D, Thompson VP. Engineering long term clinical success of advanced ceramic prostheses. ***J Mater Sci Mater Med*** 2007;18:47-56.

9. Attia A, Abdelaziz KM, Freitag S, Kern M. Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns. ***J Prosthet Dent*** 2006;95:117-23.

10. Kassem AS, Atta O, El-Mowafy O. Combined effects of thermocycling and load-cycling on microleakage of computer-aided design/computer-assisted manufacture molar crowns. ***Int J Prosthodont*** 2011;24:376-8.

11. Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. ***Aust Dent J*** 2011;56 Suppl 1:84-96.

12. Seydler B, Rues S, Muller D, Schmitter M. In vitro fracture load of monolithic lithium disilicate

ceramic molar crowns with different wall thicknesses. ***Clin Oral Investig*** 2014;18:1165-71.
13. AL-Makramani BM, Razak AA, Abu-Hassan MI. Evaluation of load at fracture of Procera AllCeram copings using different luting cements. ***J Prosthodont*** 2008;17:120-4.
14. Akesson J, Sundh A, Sjogren G. Fracture resistance of all-ceramic crowns placed on a preparation with a slice-formed finishing line. ***J Oral Rehabil*** 2009;36:516-23.
15. Zahran M, El-Mowafy O, Tam L, Watson PA, Finer Y. Fracture strength and fatigue resistance of all-ceramic molar crowns manufactured with CAD/CAM technology. ***J Prosthodont*** 2008;17:370-7.
16. Wood KC, Berzins DW, Luo Q, Thompson GA, Toth JM, Nagy WW. Resistance to fracture of two all-ceramic crown materials following endodontic access. ***J Prosthet Dent*** 2006;95:33-41.
17. Scherrer SS, de Rijk WG. The fracture resistance of all-ceramic crowns on supporting structures with different elastic moduli. ***Int J Prosthodont*** 1993;6:462-7.
18. Heintze SD, Cavalleri A, Zellweger G, Buchler A, Zappini G. Fracture frequency of all-ceramic crowns during dynamic loading in a chewing simulator using different loading and luting protocols. ***Dent Mater*** 2008;24:1352-61.
19. Kelly JR, Rungruanganunt P, Hunter B, Vailati F. Development of a clinically validated bulk failure test for ceramic crowns. ***J Prosthet Dent*** 2010;104:228-38.
20. 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.
21. Wakabayashi N, Anusavice KJ. Crack initiation modes in bilayered alumina/porcelain disks as a function of core/veneer thickness ratio and supporting substrate stiffness. ***J Dent Res*** 2000;79:1398-404.
22. Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. ***J Dent Res*** 1999;78:1336-44.
23. Preis V, Behr M, Hahnel S, Rosentrirr M. Influence of cementation on in vitro performance, marginal adaptation and fracture resistance of CAD/CAM-fabricated ZLS molar crowns. ***Dent Mater*** 2015; 31:1363-1369.
24. Bindl A, Luthy H, Mormann WH. Strength and fracture pattern of monolithic CAD/CAM-generated posterior crowns. ***Dent Mater*** 2006;22:29-36.
25. Weyhrauch M, Igiel C, Scheller H, Weibrich G, Lehmann KM. Fracture Strength of Monolithic All-Ceramic Crowns on Titanium Implant Abutments. ***J Oral Maxillofac Implants*** 2016;31:304-9.
26. Kohyama K, Hatakeyama E, Sasaki T, Azuma T, Karita K. Effect of sample thickness on bite force studied with a multiple-point sheet sensor. ***J Oral Rehabil*** 2004;31:327-34.
27. Kelly JR. Clinically relevant approach to failure testing of all-ceramic restorations. ***J Prosthet Dent*** 1999;81:652-61.
28. O'Brien WJ. Strengthening mechanisms of current dental porcelains. ***Compend Contin Educ Dent*** 2000;21:625-30.