

Original Research Article

Comparative Evaluation of Flexural Strength of 2 Nanoceramic Composite Resin CAD/CAM Blocks (Lava Ultimate and Vita Enamic) and a Lithium Disilicate Glass Ceramic (IPS e.max CAD)

Fariborz Vafae¹, Farnaz Firooz², Bijan Heidari², Masoumeh khoshhal³, Farnoush fotovat⁴, Hanif Allahbakhshi^{4*}

¹Associate Professor, Dental Research Center, Department of Prosthodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

²Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

³Assistant Professor, Department of Periodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

⁴Resident of Prosthodontics, Department of Prosthodontics, Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran

*Corresponding author

Hanif Allahbakhshi

Email: h.allahbakhshi@yahoo.com

Abstract: Recently, new generations of nanoceramic composite resin CAD/CAM blocks, have been introduced to dentistry, which are claimed to have higher flexural strength, fracture, fatigue and wear resistance, and beside natural looking appearances can be polished easily. Therefore, the aim of this study was to compare flexural strength of 2 nanoceramic composite resin CAD/CAM blocks (Lava Ultimate and Vita Enamic) and a lithium disilicate glass ceramic (IPS e.max CAD) material. In this experimental study, resin nanoceramic blocks, Lava Ultimate (3M, ESPE, USA), Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany) and a lithium disilicate glass ceramic, IPS e.max CAD (Ivoclar Vivadent, Schann, Liechtenstein) prepared for flexural strength test on the basis of ISO 6872:2008. For 3 point bending test, 30 rectangular specimens (10 for each group) with the dimensions of ~14mm×4 mm×1.2 mm were prepared and loaded on a 10 mm span with crosshead speed of 1 mm/min by a universal testing machine (Zwick/Roell). Differences between the means of the 3 groups were analyzed with one way ANOVA followed by multiple comparison Tukey HSD test. Also the normality of the tested groups evaluated with kolmogorov Smirnov test. The mean flexural strength and standard deviation was 139.9±21.2MPa for Lava Ultimate, 273.8±56.03MPa for IPS e.max CAD and 127.7±11.9 MPa for Vita Enamic. Significant differences were found between the groups (P<0.001). The Tukey HSD test showed that flexural strength of IPS e.max CAD is significantly higher than two other ceramics (p<0.05). IPS e.max CAD exhibited higher values in flexural strength between the 3 groups. The others respectively were Lava Ultimate and Vita Enamic. The flexural modulus of Lava Ultimate and Enamic was greatly improved to levels not seen before in dental resin composites. However, their consideration and clinical use in patients with high muscular and masticatory forces especially patients with bruxism and clenching, better to be similar to that of conventional dental CAD/CAM resin composites and be limited to inlay, onlay and veneer restorations.

Keywords: Ceramics, CAD/CAM, Flexural strength, composite resins

INTRODUCTION

For decades, full coverage restorations have been used as the most common fixed prosthetic treatment to restore the function and appearance of the destroyed natural teeth [1]. Metal ceramic crowns have been considered the gold standard for full coverage restorations, due to their high strength, excellent fit and marginal integrity and long term survival rate [2, 3]. However, biologic complications such as periodontitis [2, 4], chipping and ceramic debonding [5] and lack of natural appearances are considered to be the problems

of these restorations [6]. Therefore, the interest and demand from patient and clinician for biocompatible metal free restorations, has encouraged researcher to seek alternatives [1, 7]. To fulfill these requirements, all-ceramic restorations with the advantages of soft tissue biocompatibility [8], color stability, improved wear resistance and excellent light transmitting properties [9] have been developed.

In 1965, McLean [10] introduced an alumina reinforced core ceramic, which was used for anterior

teeth restorations. Meanwhile, CAD/CAM technology (computer aided design/computer aided) was introduced to dentistry in the 1980s [11, 12]. In principle, this technology has been developed for fully sintered ceramic blocks (hard machining), it has now been expanded to partially sintered ceramics (soft machining), that are later fully heat treated to ensure adequate sintering [13]. As a result, new generations of ceramic and composite materials for bi-layered and monolithic applications were developed. However, chipping of the bi-layered all-ceramic restorations [2,14] and bulk fracture of monolithic all-ceramic restorations, still demonstrate the most commonly reported laboratory and clinical complications [15-17]. All ceramic crowns have been used widely as a superstructure of dental implants in recent years [18,19]. There are two types of inherent flaws that compromise the ability of all-ceramic restorations to withstand occlusal forces: fabrication defects (internal voids, porosities, or microstructural features that arise during processing) and surface cracks (defects on the surface as a result of machining and grinding process) [20, 21]. Lithium disilicate glass ceramic (IPS e.max CAD) which investigated in this study is a CAD/CAM generated restoration [7]. Reparability of conventional ceramics in oral environment is often problematic. In comparison, composites can be repaired simply but they have poor mechanical characteristics and biocompatibility [22]. Therefore some authors are

following more optimal restorations on the basis of modulus elasticity of composites similar to dentin and esthetic of feldspathic ceramics similar to enamel [23]. Recently, new generations of nanoceramic composite resin CAD/CAM blocks, Lava Ultimate (3M, ESPE, USA) nano ceramic particles embedded in a highly cured resin matrix and Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany) polymer-infiltrated ceramic, have been introduced to dentistry, which are claimed to have higher flexural strength, fracture, fatigue and wear resistance, and beside natural looking appearances can be polished easily [24-26].

Therefore, the aim of this study was to compare flexural strength of 2 nanoceramic composite resin CAD/CAM blocks (Lava Ultimate and Vita Enamic) and a lithium disilicate glass ceramic (IPS e.max CAD) material. The null hypothesis was that there is no significant difference between the flexural strength of the three groups.

METHODS AND MATERIALS

In this experimental study, three CAD/CAM ceramic materials were compared. Resin nanoceramic blocks, Lava Ultimate (3M, ESPE, USA) and Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany) and a lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) as a control group were prepared for the flexural strength test according to the ISO 6872: 2008 [27] [Fig 1].



Fig-1: Samples prepared from Lava Ultimate, IPS e.max CAD and Vita Enamic blocks

For 3 point bending test, 30 rectangular specimens (10 for each group) with the dimensions of ~14mm×4 mm×1.2 mm were prepared using a cutting machine (Struers Minitom, Willich, Germany) at a rate of 250 rpm under water irrigation as instructed by the manufacturers [24]. Lava Ultimate and Vita Enamic just were polished with abrasive discs SiC paper 500, 1200 and 2400 # (LaboPol-1, Struers, Willich, Germany),

while IPS e.max CAD specimens were fully crystallized at 850°C for 10 minutes in a ceramic furnace (VITA Vacumat 6000, Zahnfabrik, Germany). Then the specimens were loaded by a universal testing machine (Zwick/Roell, Z050, Germany) with crosshead speed of 1 mm/min on a 10 mm span. The loading apparatus was 4 mm in diameter [Fig 2].



Fig-2: Universal testing machine for flexural strength test

Differences between the means of the 3 groups were analyzed with one way ANOVA followed by multiple comparison Tukey HSD test. Also the normality of the tested groups evaluated with kolmogorov Smirnov test.

RESULTS

For all the specimens, the flexural strength values were calculated with the mean values, standard deviation, maximum, and minimum displayed in Table 1.

The kolmogorov Smirnov test showed the normality of the distribution ($P>0.05$). The mean flexural strength value was 139.9 ± 21.2 MPa for Lava Ultimate, 273.8 ± 56.03 MPa for IPS e.max CAD and 127.7 ± 11.9 MPa for Vita Enamic. Significant differences were found between the groups ($P<0.001$) by one way ANOVA [Tab 1].

The Tukey HSD test showed that flexural strength of IPS e.max CAD is significantly higher than the two other ceramics ($P<0.05$) [Tab 2].

Table 1: Descriptive statistics of flexural strength (MPa) for all ceramic groups

Ceramic block		Minimum	Maximum	Mean \pm SD	ANOVA analysis
Lava Ultimate	10	112.65	175.47	139.9 ± 21.2	
IPS e.max CAD	10	158.27	352.96	273.8 ± 56.03	$F=52.751$ p-value<0.001
Vita Enamic	10	106.73	148.96	127.7 ± 11.9	

Table 2: Tukey HSD test for multiple comparison between the 3 groups.

Comparisons	Differences Mean	Std. Error	P-value
Lava Ultimate vs IPS e.max CAD	133.844	15.778	<0.001
IPS e.max CAD vs Vita Enamic	146.066	15.778	<0.001
Lava Ultimate vs Vita Enamic	12.222	15.778	0.722

DISCUSSION

Based on the results of the present study, the null hypothesis was refuted. A statistically significant difference in flexural strength ($P< 0.001$) was observed between the 2 nanoceramic composite resin CAD/CAM blocks, Lava Ultimate and Vita Enamic, and a lithium disilicate glass ceramic (IPS e.max CAD) material.

Although there are limitations with all these methods, the ISO standard test to determine the strength of polymer based restorative materials remains the three-point bend test. Accordingly, the utilization of this method to test these new materials allows for easy comparative analysis with other previously published results employing the same standard test methods.

Lava Ultimate was introduced into the dental market in 2012 and contains a blend of individually

bonded nano-particles and nano-particles agglomerated in clusters, all embedded in a highly cross-linked polymer matrix. It contains a total nanoceramic filler content of approximately 80 % by weight [24]. Vita Enamic Launched onto the market in 2013 and has been called a “hybrid ceramic” or a polymer-infiltrated-ceramic network (PICN) [26].

The flexural strength of resin nanoceramic CAD/CAM blocks in our study was similar to the value reported by other researchers [28-31]. Although, our results showed that the mean value of just Vita Enamic met the claims of the manufacturer [26]. He and Swain [32, 33] described the mechanical properties of these materials and found that they were very similar to natural dentin and enamel. Different results were found in the current study compared to other studies for flexural strength. Albero A *et al.* [34] evaluated the

characterization of a novel cad-cam polymer-infiltrated-ceramic-network. The results showed IPS e.max presented mechanical properties significantly better than other materials. Although, Vita Enamic had higher flexural strength than Lava Ultimate, but it was not significant. In accordance with the current study, Thornton I *et al.* [31] stated that in comparison to conventional resin composites, the presence of ceramic nano-particles in Lava Ultimate and Enamic did not greatly improve flexural strength of these materials. Their results showed that the flexural strength of Enamic was statistically significantly lower than that of Lava Ultimate, while the flexural modulus of Enamic was statistically significantly higher. Also, Kopfmann C *et al.* [30] evaluated the comparison of filler morphology, mechanical strength and milling characteristics of 4 different CAD/CAM blocks for Sirona inLab MC XL milling system and showed that Coltene (Coltene AG) had the highest flexural strength, and Vita Enamic the Lowest one.

When looking at the spectrum of resin composite-ceramic, it becomes clear that the new nanoceramic resin composite materials do not behave similarly to the tested control, a lithium disilicate ceramic, IPS e.max CAD, and actually behave as resin composites.

This *in vitro* study had some limitations such as difficult simulation of the oral environment. Further *in vitro* and *in vivo* investigations are necessary to evaluate surface roughness, marginal integrity, reparability and milling accuracy of these new materials.

CONCLUSION

IPS e.max CAD exhibited higher values in flexural strength between the 3 groups. The others respectively were Lava Ultimate and Vita Enamic. Clinically it is demonstrated that IPS e.max CAD can tolerate higher values of mechanical loads until fracture. The flexural strength of Lava Ultimate and Enamic was greatly improved to levels not seen before in dental resin composites. This characteristic similar to the tooth makes them an option to be considered as crown materials. However, their consideration and clinical use in patients with high muscular and masticatory forces especially patients with bruxism and clenching, better to be similar to that of conventional dental CAD/CAM resin composites and be limited to Inlay, Onlay and Veneer restorations.

REFERENCES

1. Dolan TA, Gilbert GH, Duncan RP, Foerster U; Risk indicators of edentulism, partial tooth loss and prosthetic status among black and white middle-aged and older adults. *Community Dent Oral Epidemiol.*, 2001; 29:329-340.
2. Pjetursson BE, Sailer I, Zwahlen M, Hämmerle CH; A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3years. Part I: Single crowns. *Clin Oral Implants Res.*, 2007; (18 suppl 3):73-85
3. Reitemeier B, Hansel K, Kastner C, Weber A, Walter MH; A prospective 10-year study of metal ceramic single crowns and fixed dental prosthesis retainers in private practice settings. *J Prosthet Dent.*, 2013; 109(3): 149-155.
4. Lucas LC, Lemons JE; Biodegradation of restorative metallic systems. *Adv Dent Res.*, 1992; 6: 32-37.
5. Marklund S, Bergman B, Hedlund SO, Nilson H; An intraindividual clinical comparison of two metal-ceramic systems: a 5-year prospective study. *Int J Prosthodont.*, 2003; 16(1): 70-73.
6. Anusavice KJ; Recent developments in restorative dental ceramics. *J Am Dent Assoc.*, 1993; 124(2): 72-74, 76-78, 80-84.
7. Guess PC, Zavanelli RA, Silva NR, Bonfante EA; Monolithic CAD/CAM lithium disilicate versus veneered Y-TZP crowns: comparison of failure modes and reliability after fatigue. *Int J Prosthodont.*, 2010; 23(5):434-42.
8. Sjogren G, Sletten G, Dahl JE; Cytotoxicity of dental alloys, metals, and ceramics assessed by millipore filter, agar overlay, and MTT tests. *J Prosthet Dent.*, 2000; 84(2): 229-236.
9. Gallucci GO, Guex P, Vinci D, Belser UC; Achieving natural-looking morphology and surface textures in anterior ceramic fixed rehabilitations. *Int J Periodontics Restorative Dent.*, 2007; 27(2): 117-125.
10. McLean JW, Hughes TH; The reinforcement of dental porcelain with ceramic oxides. *Br Dent J.*, 1965; 119(6): 251-267.
11. Manicone PF, Lommetti PR, Raffaelli L; An overview of zirconia ceramics: basic properties and clinical applications. *Journal of Dentistry*, 2007; 35(11):819-826.
12. Kelly JR, Denry I; Stabilized zirconia as a structural ceramic: an overview. *Dental Materials*, 2008; 24(3):289-298.
13. Denry I, Holloway JA; Ceramics for dental applications: A review. *Materials*, 2010; 3:351-368.
14. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY; Clinical complications in fixed prosthodontics. *J Prosthet Dent.*, 2003; 90:31-41.
15. Al-Amleh B., Lyons K., Swain M; Clinical trials in zirconia: a systematic review. *J Oral Rehabil.*, 2010; 37(8): 641-652.
16. Bindl A., Richter B., Mormann W.H; Survival of ceramic computer-aided design/manufacturing crowns bonded to preparations with reduced macroretention geometry." *Int J Prosthodont* 2005; 18(3): 219-224.
17. Coelho PG, Silva NR, Bonfante EA; Fatigue testing of two porcelain-zirconia all-ceramic crown systems. *Dent Mater.*, 2009; 25(9):1122-1127.

18. Andersson B, Ödman P, Lindvall AM, Brånemark PI; Cemented single crowns on osseointegrated implants after 5 Years: Results from a prospective study on Cera One. *Int J Prosthodont.*, 1998; 11:212–218.
19. Prestipino V, Ingber A, Kravitz J; Clinical and laboratory consideration in the use of a new all-ceramic restorative system. *Pract Periodontics Aesthet Dent.*, 1998; 10:567–575.
20. Rosenstiel SF, Land MF, Fujimoto J; *Contemporary Fixed Prosthodontics*. St. Louis, MO, Mosby, 2016; 774-804.
21. Beier US, Kapferer I, Dumfahrt H; Clinical long-term evaluation and failure characteristics of 1,335 all-ceramic restorations. *Int J Prosthodont.*, 2012; 25(1): 70–78.
22. Nguyen JF, Ruse D, Phan AC, Sadoun MJ; High-temperature-pressure polymerized resin-infiltrated ceramic networks. *J Dent Res.*, 2014; 93(1):62-67.
23. Della Bona A, Corazza PH, Zhang Y; Characterization of a polymer-infiltrated ceramic-network material. *Dental Materials*, 2014; 30(5):564-9.
24. 3M ESPE internal data; Lava Ultimate CAD/CAM restorative technical profile, 2012; 1-23 http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSufSevTsZxtUoYtUmY_ZevUqevTSevTSevTSeSSSSSS--&fn=Lava_Ult_TPP.pdf (accessed 11 July 2014)
25. Koller M, Arnetzl GV, Holly L, Arnetzl G; Lava ultimate resin nano ceramic for CAD/CAM: Customization case study. *Int J Comput Dent.*, 2012; 15(2):159-64.
26. VITA internal data; Vita Enamic: the concept, 2013. 1-16 http://vident.com/wp-content/uploads/2013/01/Enamic-Concept-Brochure-L-10024E.pdf-8_13.pdf (accessed 11 July 2014)
27. ISO 6872: 2008, Ceramic materials, International Organization for Standardization.
28. Awada A, Nathanson D; Mechanical properties of resin-ceramic CAD/CAM restorative materials. *J Prosthetic Dent.*, 2015; 114(4):587-593.
29. Stawarczyk B, Liebermann A, Eichberger M, Guth JF; Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. *J Mech Behav Biomed Mater.*, 2015; 55:1-11.
30. Kopfmann C, Zweifel D, Böhner R; Comparison of filler morphology, mechanical strength and milling characteristics of different CAD/CAM blocks for Sirona inLab MC XL milling system. www.coltene.com
31. Thornton I; Mechanical properties of dental resin composite CAD/CAM blocks. UBC Theses and Dissertations, 2014.
32. He L, Swain M; A novel polymer infiltrated ceramic dental material. *Dent Mater.*, 2011; 27(6):527-34.
33. He L, Purton D, Swain M; A novel polymer infiltrated ceramic for dental simulation. *J Mater Sci: Mater Med.*, 2011; 22:1639-1643.
34. Albero A, Pascual A, Camps I, Grau-Benitez M; Comparative characterization of a novel cad-cam polymer-infiltrated-ceramic-network. *J Clin Exp Dent.*, 2015; 7(4):e495-500.