

## **A Comparative Study Of Flexural Strength And Fatigue Resistance Of 2 Nanoceramic Composite Resin Cad/Cam Blocks (Lava Ultimate And Vita Enamic) And A Lithium Disilicate Glass Ceramic (Ips E.Max Cad)**

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<http://dx.doi.org/10.13005/bpj/1080>

(Received: February 02, 2017; accepted: February 25, 2017)

### **ABSTRACT**

The aim of this study was to compare flexural strength and fatigue resistance of 2 nanoceramic composite resin CAD/CAM blocks and a glass ceramic material. In this experimental study, resin nanoceramic blocks, Lava Ultimate, Vita Enamic and a lithium disilicate glass ceramic, IPS e.max CAD prepared on the basis of ISO 6872:2008. For 3 point bending test, 30 rectangular specimens prepared and loaded on a 10 mm span with crosshead speed of 1 mm/min. In fatigue resistance test, full crowns for mandibular second premolar were prepared for chewing cycle dynamic loading (250000cycles, 2 Hz, 100 N). Specimens survived from fatigue cycles, were loaded to fracture with a cross head speed of 1 mm/min. Failures in terms of fracture, crack formation and chipping were macroscopically recorded. The results were analyzed with one way ANOVA followed by multiple comparison Tukey HSD test. Also we used Chi Square for quantitative comparison after fracture of the specimens. The mean flexural strength was 139.921.2MPa for Lava Ultimate, 273.856.03MPa for IPS e.max CAD and 127.711.9 MPa for Vita Enamic. Significant differences were found between the groups ( $P < 0.001$ ). Mean fracture load after static loading was 1009.392.1 N for Lava Ultimate, 1698.5237.5 N for IPS e.max CAD and 733.2261.5 for Vita Enamic, which showed significant differences between the groups ( $p < 0/001$ ). Regarding to the macroscopically results after fracture load, there were no significant differences between the groups ( $p > 0/05$ ). The application of these nanoceramic resin composite materials for tooth-implant supported crowns seems promising.

**Keywords:** Ceramics, Computer-Aided Design, Fatigue, 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<sup>1</sup>. 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<sup>2,3</sup>. However, biologic complications such as periodontitis<sup>2,4</sup>, chipping and ceramic debonding<sup>5</sup> and lack of natural appearances are considered to be the problems of these restorations<sup>6</sup>. Therefore, the interest and demand from patient and clinician for biocompatible metal free restorations, has encouraged researcher to seek alternatives<sup>1,7</sup>. To fulfill these requirements, all-ceramic restorations with the advantages of soft tissue biocompatibility<sup>8</sup>, color stability, improved wear resistance and excellent light transmitting properties<sup>9</sup> have been developed.

In 1965, McLean<sup>10</sup> introduced an alumina reinforced core ceramic, which was used for anterior teeth restorations. Meanwhile, CAD/CAM technology (computer aided design/computed aided) was introduced to dentistry in the 1980s<sup>11, 12</sup>. In principle, this technology have 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<sup>13</sup>. 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<sup>2,14</sup> and bulk fracture of monolithic all-ceramic restorations, still demonstrate the most commonly reported laboratory and clinical complications<sup>15-17</sup>. All ceramic crowns have been used widely as a superstructure of dental implants in recent years<sup>18,19</sup>. 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)<sup>20, 21</sup>. Lithium disilicate glass ceramic (IPS e.max CAD) which investigated in this study is a CAD/CAM generated

restoration<sup>7</sup>. 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<sup>22</sup>. Therefore some authors are following more optimal restorations on the basis of modulus elasticity of composites similar to dentin and esthetic of feldespatic ceramics similar to enamel<sup>23</sup>.

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<sup>24-26</sup>.

Therefore, the aim of this study was to compare flexural strength and fatigue resistance 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 of strength and fatigue resistance 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, Schann, Liechtenstein) as a control group were prepared for the flexural strength test according to the ISO 6872: 2008<sup>27</sup> (Fig 1).

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, Bad Sackingen, Germany). Then the specimens were loaded by a universal testing machine (Zwick/Roell, Z050, Ulm, Germany) with crosshead speed of 1 mm/min on a 10 mm span. The loading apparatus was 4 mm in diameter (Fig 2).

In fatigue resistance test, titanium abutments (Implantium, Seoul, Korea) were used as die structure for ceramic crowns. They had a platform diameter of 4.5 mm, a height of 5.5 mm and 1 mm circular shoulder width. Occlusal thickness was 1.5 mm which had the highest fracture strength regarding to other studies<sup>27,28</sup>.

Titanium fixture analogs (Implantium, Seoul, Korea) (12×4.3 mm<sup>2</sup>) were embedded into the borehole (13 mm depth, 4.5 mm diameter) prepared from self-cured poly methyl methacrylate blocks (Heraeus Kulzer, Dormagen, Germany). Then the abutments were screwed on the analogs with the torque of 30 NCM and spray coated with titanium dioxide powder (Vivadent; Vita Powder Scan Spray, Bad Sackingen, Germany) to produce a white opaque surface for 3D scanning (inEOS Blue, Sirona, Bensheim, Germany).

Full crowns for mandibular second premolar (10 each group) were machined by in-lab system (MCXL, Sirona, Germany). Before cementation the crowns were air abraded using alumina powder (110 μm) from a distance of 5 mm at 2 bar pressure<sup>27</sup>. Dynamic loading was performed by a universal machine (SD Mechatronik, Westerham, Germany). Internal surface of the crowns (except Lava ultimate) was first etched 60 seconds with 5% hydrofluoric acid, then rinsed, dried and silane (Monobond S, Ivoclar Vivadent, Bad Sackingen, Germany) was applied for 60 seconds. Crowns were cemented with resin based cement (Rely X U200, 3M ESPE, Minneapolis, USA) under 5-kg static load (Fig 3).

After careful removal of excess cement, load of 100 N was applied dynamically at 2 Hz for 100,000 cycles. Crowns received 1.5 mm laterally positioned axial loading from their buccal cusps.

Aluminum foil was placed between the loading tip and the buccal cups for appropriate load distribution. The loading apparatus was 4 mm in diameter and 8 mm in length (Fig 4).

Specimens survived from fatigue cycles, were loaded to fracture with a universal testing machine (Zwick/Roell, Z050, Ulm, Germany) at a cross head speed of 1 mm/min (Fig 5).

Failures in terms of fracture, crack formation and chipping were macroscopically recorded (Fig 6).

Differences between the means of the 3 groups were analyzed with one way ANOVA followed by multiple comparison Tukey HSD test. The normality of the groups evaluated with Kolmogorov Smirnov test, also we used Chi Square for quantitative comparison after fracture of the specimens.

## 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 139.921.2 MPa for Lava Ultimate, 273.856.03 MPa for IPS e.max CAD and 127.711.9 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].

In fatigue resistance test, none of the specimens fractured after cyclic loading. Excessive wear just created in Vita Enamic specimens at the sliding area without any crack formation.

For all 3 groups, the fracture strength values were calculated with the mean values, standard deviation, maximum, and minimum displayed in Table 3. The Kolmogorov Smirnov test showed the normality of the distribution ( $P > 0.05$ ).

The mean fracture strength value was 1009.392.1 N for Lava Ultimate, 1698.5237.5 N for IPS e.max CAD and 733.2261.5 for Vita Enamic. Significant differences were found between the groups ( $P < 0.001$ ) by one way ANOVA [Tab 3].

The Tukey HSD test showed that fracture strength of IPS e.max CAD is significantly higher than the two other ceramics ( $P < 0.05$ ) [Tab 4].

Regarding to the macroscopically results after fracture load, type of the ceramic didn't affect

the failure modes, bulk fracture and chipping, and there were no significant differences between the groups ( $p > 0/05$ ) [Tab 5].

**DISCUSSION**

Based on the results of the present study, the null hypothesis was refuted. Statistically significant differences in flexural and fracture strength ( $P < 0.001$ ) were observed between the 2 nanoceramic composite resin CAD/CAM blocks, Lava Ultimate and Vita Enamic, and a lithium



**Fig. 1 :**



**Fig. 2 :**



**Fig. 3 :**



**Fig. 4 :**



**Fig. 5 :**



**Fig. 6 :**

disilicate glass ceramic (IPS e.max CAD) material, meanwhile they showed similar fatigue resistance after dynamic loading (250,000 cycles, 100N) with the survival rate of 100%. This result could be due to the modulus elasticity and adhesive cementation of these materials.

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<sup>24</sup>. Vita Enamic Launched onto the market in 2013 and has been called a "hybrid

ceramic" or a polymer-infiltrated-ceramic network (PICN)<sup>26</sup>.

The flexural strength of resin nanoceramic CAD/CAM blocks in our study was similar to the value reported by other researchers<sup>28-30</sup>. Although, our results showed that the mean value of just Vita Enamic met the claims of the manufacturer<sup>26</sup>. He and Swain<sup>31,32</sup> 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*<sup>33</sup> 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. However Vita Enamic had higher flexural strength than Lava Ultimate, but it was not significant. In accordance with the current study, Thornton I *et al* 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

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

Ceramic block	Minimum	Maximum	Mean ± SD	ANOVA analysis
Lava Ultimate	10	112.65	175.47	139.921.2
IPS e.max CAD	10	158.27	352.96	273.856.03
Vita Enamic	10	106.73	148.96	127.711.9

**Table 2: Tukey HSD test for multiple comparisons 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

**Table 3: Descriptive statistics of fracture strength (N) for all ceramic groups**

Ceramic block	Minimum	Maximum	Mean ± SD	ANOVA analysis
Lava Ultimate	10	854.69	1142.95	1009.392.1
IPS e.max CAD	10	1396.91	2163.7	1698.5237.5
Vita Enamic	10	476.8	1321.9	733.2261.5

**Table 4: Tukey HSD test for multiple comparisons between the 3 groups**

Comparisons	Differences Mean	Std. Error	P-value
Lava Ultimate vs IPS e.max CAD	689.223	94.278	<0.001
IPS e.max CAD vs Vita Enamic	965.258	94.278	<0.001
Lava Ultimate vs Vita Enamic	276.035	94.278	0.018

**Table 5: Descriptive statistics of specimen failure modes after static loading**

Failure Modes	Type of ceramics						P-value
	Vita Enamic		Lava Ultimate		IPS e.max CAD		
	N	%	N	%	N	%	
Chipping	6	60%	5	50%	3	30%	0.00116
Bulk Fracture	4	40%	5	50%	7	70%	p-value=0/534

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, Kopmann *et al.*<sup>60</sup> evaluated the comparison of filler morphology, mechanical strength and milling characteristics of 4 different CAD/CAM blocks for Sirona inLabMC XL milling system and showed that Coltene (Coltene AG) had the highest flexural strength, and Vita Enamic the Lowest one.

Titanium is a conventional material in posterior implant abutments due to its mechanical properties. Also in recent years, all ceramic crowns have been used as superstructures for posterior implants<sup>18, 19</sup>. Unilateral masticatory loads are variable between 216 to 847 N in posterior regions, but a maximum of 1031 N have been reported<sup>29</sup>. Aboushelib *et al.*<sup>64</sup> evaluated the influence of cyclic fatigue on two resin infiltrated ceramics and three all-ceramic crowns manufactured using CAD/CAM technology. They stated that dynamic fatigue resulted in significant reduction of the initial fracture strength of the tested specimens.

Bulk fracture was the only failure mode reported for all tested monolithic CAD/CAM crowns.

The differences in comparison to our study are probably due to the using of composite resin dies. Because when hybrid crowns are cemented to the dies with similar modulus elasticity, crown-die complex performs as an integrated unit, therefore they show higher fracture resistance. Fatigue behavior of IPS e.max CAD and core veneered zirconia evaluated in an invitro study<sup>7</sup> using step stress cycling fatigue test. This study reported that there were almost 90% of chipping in zirconia based ceramics (100,000 cycles , 200 N). In contrast, there was no fracture for IPS emax CAD after step stress fatigue (180,000 cycles , 900 N) similar to our study.

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.maxCAD, and actually behave as resin composites.

This invitro 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. Regarding to the mean fracture load of the 2 specimens that are

higher than the mean fracture load suggested for posterior regions, the application of these nanoceramic resin composite materials for tooth-implant supported crowns seems promising. 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.

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