

Aging Effect on Marginal Gap Distance and Cyclic Loading of Two Different Ceramic Crowns

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Abstract: This study was carried out to evaluate and compare the vertical marginal gap distance, and cyclic loading of all-ceramic crowns Vita suprinity and IPs e.max CAD (CAD/CAM milling, Cerec MCXL), using two types of finish lines (deep chamfer and radial shoulder). Specially designed stainless steel dies were constructed and a total number of 40 samples were constructed representing two equal groups (20 samples), according to the type of materials (VITA Suprinity and IPs E.max CAD “CAD/CAM milling technique Cerec MCXL) The twenty samples were further divided into two divisions (10 each) according to the type of the finish line used (deep chamfer and radial shoulder). Each division was then divided into two classes (5 each) (one class was constructed as a crown coping and then veneered, the second one was constructed as a full contoured crowns). Vita suprinity and IPs e.max CAD crowns were fabricated following a standard procedure and standard dimensions as controlled by the Cerec MCXL software. As regard the vertical marginal gap test, the results showed that IPs e.max CAD crowns regardless to finish line type and veneering, recorded a higher vertical marginal gap mean value ($42.59 \pm 2.38 \mu\text{m}$) than obtained with Vita Suprinity crowns ($36.11 \pm 1.76 \mu\text{m}$). Regardless to the production techniques and veneering, deep chamfer finish line recorded a lower vertical marginal gap mean value ($37.94 \pm 2.11 \mu\text{m}$) than obtained with radial shoulder finish line ($40.77 \pm 2.33 \mu\text{m}$). Regardless to production techniques and finish lines, full contoured crowns recorded a lower vertical marginal gap mean value ($38.34 \pm 2.36 \mu\text{m}$) than obtained veneering ($40.36 \pm 2.10 \mu\text{m}$). The cyclic loading test data revealed that IPs e.max CAD crowns recorded a higher fracture resistance mean value ($1013 \pm 53.84\text{N}$) than the load cycled crowns ($888.1 \pm 104.4\text{N}$). Vita suprinity crowns recorded a higher fracture resistance mean value ($803.7 \pm 66.45\text{N}$) than the load cycled crowns ($703.8 \pm 34.26\text{N}$), regardless to finish line type and veneering. The cyclic loading test data revealed that IPs e.max CAD crowns recorded a higher fracture resistance mean value ($1013 \pm 53.84\text{N}$) than the load cycled crowns ($888.1 \pm 104.4\text{N}$). Vita suprinity crowns recorded a higher fracture resistance mean value ($803.7 \pm 66.45\text{N}$) than the load cycled crowns ($703.8 \pm 34.26\text{N}$), regardless to finish line type and veneering.

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1. Introduction

Several modern all ceramic systems are developed to achieve the most challenging requirements in restorative dentistry, ease of fabrication, good esthetics with adequate strength and fracture toughness. Recently IPs e.max Cad is an innovative all-ceramic system which covers the entire all-ceramics indication range from thin veneers to 5 units bridges⁽¹⁾. Vita Suprinity, a new glass ceramic, features a special fine –grained and homogeneous structure which assures excellent material quality and consistent high load capacity, as well as long-term reliability⁽²⁾. Marginal accuracy is one of the most important and critical link in success of fixed prosthodontics⁽³⁾. The purpose of this study is to evaluate the CAD/CAM technology in construction of all-ceramic crowns and to study some of their mechanical properties by two different materials and different laboratory investigations.

An overview of all ceramic systems.

CEREC (Sirona) was the first computer-aided design/ manufacturing (CAD / CAM) method in restorative dentistry allowing production of inlays and crowns directly at the chair side from industrially sintered, homogenous ceramic block. The system consists of a laser –imaging probe, a monitor for viewing the image, and an electronic milling machine. This system has been available since 1985⁽⁴⁾.

Problems and complaints with early systems were mainly dependent on the machining accuracy of the particular system and not on the materials used with the system. Initial CAD/CAM systems produced restorations that had poor marginal fidelity with a general lack of internal adaptation to the die resulting from low resolution scanning devices and inadequate computing power whereby, technological advances in new systems and software development have minimized or eliminated these problems so that marginal integrity can be excellent⁽⁵⁾.

For the CERECI system a single image was made using a laser camera. The system was not

designed to accept more than one image or to incorporate multiple images and was not adaptable for fabrication of crowns⁽⁴⁾.

The introduction of the CERECII unit with enlargement of the grinding unit from three to six axes and upgrading of the software for the occlusion and the complex machining of the floor parts, the previous limitations were eliminated.

IPs e.max CAD is a lithium disilicate glass-ceramic block for the CAD/CAM technique. It is fabricated using an innovative process which provides an impressive homogeneity of the material. The block can be processed very easily in a CAD / CAM unit in this crystalline intermediate stage. The typical and striking color of IPs e.max CAD ranges from whitish to blue and bluish-grey microstructure of the glass-ceramic.⁽⁶⁾

Marginal adaptation of ceramic restorations

Marginal and internal fit to the underlying tooth structure are essential criteria which predetermine the longevity of a ceramic restoration.⁽⁷⁾ Since poor adaption might lead to marginal discoloration, exposure of luting resin, dissolution of cement, microleakage, increased plaque retention and secondary decay^(8,9)

Mously HA. (2014): evaluate marginal and internal fit of IPS. emax CAD and pressed crowns using CAD/CAM and pressed techniques and he concluded that best marginal and internal crown adaptation results come with heat pressed group.⁽¹⁰⁾

Anadioti E. (2015): evaluated marginal fit of all ceramic crowns made from digital and conventional impressions using IPS.emaxCAD and IPS.emax Press and he found a significant interaction between impression techniques and crown fabrication method and concluded that combination between conventional impression method and press fabrication technique produced the most accurate marginal fit.⁽¹¹⁾

Anadioto E. (2015): evaluate the internal fit of pressed ceramic crowns made from conventional impression using polyvinyl siloxane impression, crowns were pressed in lithium disilicate (IPS e.max press) and crowns milled from lithium disilicate blocks (IPS e.max CAD) with E4D scanner by direct and indirect techniques then crowns were milled using E4D engine, and he found that the internal gap obtained from indirect press group was significantly greater than that obtained from the other group and he concluded that the combination of the conventional and digital techniques produced the least accurate internal fit.⁽¹²⁾

Load cycling effect on ceramic

Cyclic fatigue of dental restorative material is a crucial aspect for evaluation of invivo performance. Individual loading cycles subject the restorative material to a stress well below its ultimate strength.

Heintze S. et al, (2008)⁽¹³⁾, compared the frequency of failures (complete fractures or partial cracks) of molar crowns made of two different all-ceramic materials (IPs Empress or an experimental e.max Press material) during dynamic loading in a chewing simulator, as well as the fracture load when subjected to static loading, in relation to different dynamic loading and luting protocols. They concluded that, the luting protocol used had the most significant effect on the fracture load of both materials. In conjunction with Empress, however, the luting material influenced the variability twice as much as in e.max Press. There was no statistically significant difference in the fracture load of glass ionomer cement GIC-luted e.max Press Exp crowns and that of the Variolink luted Empress crowns.

Borges et al, (2009)⁽¹⁴⁾, studied the hypothesis that fracture loads of fatigued dental ceramic crowns are affected by testing environment and luting cement by constructing ceramic crowns from three types of ceramics: an alumina-infiltrated ceramic, lithia-disilicate glass ceramic and a leucite-reinforced ceramic. Crowns were cemented with a composite resin and resin-modified glass ionomer cements. For each ceramic system a group was loaded to fracture without fatiguing. A second group was subjected to cyclic fatigue and fracture tested in a dry environment and a third group was fatigued and fractured in distilled water. They concluded that the fracture load of the three ceramic systems was found to be influenced by ceramic composition. Moreover, cement and fatigue condition influenced the fracture loads of the crown specimens.

Computer - aided design / computer - aided manufacturing:

Machinable ceramics are available as prefabricated glass-ceramic ingots. They are cut by tools that are controlled by the computer. After the tooth is prepared, an optical impression is taken for the preparation by a special scanner. The image is then transferred to the system's software. Then the software designs the restoration and sends the data to the computer controlled milling machine that grinds the ceramic block according to the desired shape.⁽¹⁵⁾

2. Material and Methods

A total of 40 samples were constructed representing two groups (20 samples each) according to the type of materials (VITA Suprinity and IPs E.max CAD "CAD/CAM milling technique"). The twenty samples were further divided into two divisions (10 each), deep chamfer and radial shoulder). Each division was then divided into two classes (5 each), (one class was constructed as a crown coping and then veneered, the second one was constructed as a full contoured crowns).

Working dies construction

Two specially designed stainless steel dies were fabricated using a lathe cutting machine, with two different margins designs (deep chamfer and radial shoulder “120”). They provided a total axial taper of 6 degrees, 7mm. axial height and 1mm. finish line thickness, with a central groove for perfect reorientation of the crowns.

Construction of IPs e.max CAD and Vita Suprinity crown copings and full contoured crowns:

Silicon duplicates were performed for the metal models (dies) of the two subgroups by using siloxane rubber base impression material. An extra hard, type four, stone material "Dentona", which is recommended for CAD/CAM models. After complete setting of the stone models, they were trimmed and were ready for scanning.

Scanning technique:

Cerec Omnicam, a new camera, a new workflow used for scanning the model by moving the camera smoothly over the top of the sample, and tilt and roll it 90 degree toward buccal and then lingual in order to capture the sides of the sample.

Designing the crown coping and the fully contoured crowns:

First design modes and restoration type were selected. Defining the margins is best accomplished manually. build the margins in small increments using the manual margination tool.

Using the scale, position and rotate tools allowed adjustment of the crown coping and fully contoured crowns dimensions according to the manufacturers recommended wall thickness which were 0.8mm for the coping and 1.2mm for the full contoured crown. the finished restoration was displayed in the milling simulation. The selected ceramic block of the required size (I12) was inserted in the spindle of the milling chamber of the CEREC MCXL system. This was followed by closure of the milling chamber door. The milling process run fully automated without any interference with the two diamond stones acting together simultaneously in the shaping process. The same process was repeated 20 times for each group to end with 40 milled restorations (20 crown copings and 20 fully contoured crowns).



Tracing of the preparation model margin Fitting of the crown copings:

At this stage, the material exhibited an unusual bluish color after milling. The milled samples were handled with care to avoid damage to their margins or

initiation of microscopic cracks leading to subsequent failure of the restoration.

Crystallization of the samples:

The samples were subjected to a short (approximately 22 minutes) crystallization process in the furnace.

Veneering of IPs e.max ceramic copings:

Dentin material was mixed with IPs e.max ceramic build-up liquid. The mix was then applied in a thin coat on the entire crown coping and fired according to manufacturer's instructions.

Glaze firing:

Glaze firing was conducted using IPs e.max ceramic glaze powder and liquid. The firing cycle was then conducted according to manufacturers instruction. After fabrication, All restoration were examined for deformity, debris and steam cleaned.

Vertical Marginal Gap Measurement:

Vertical marginal gap distance was examined using a stereomicroscope. Crowns were held in place over their corresponding dies using a specially designed and fabricated holding device to seat the crowns completely during microscopic measurements.

Cyclic loading test:-

All samples were individually mounted in the lower fixed compartment of a computer-controlled materials testing machine with a load cell of (5KN) and data were recorded using computer software.

The samples underwent cyclic loading, by means of a metallic sphere of (6.8 mm) diameter which was attached to the upper movable compartment of the machine and the load was applied at the center of occlusal surface, with a double layer of rubber sheet in-between for even load distribution. Cyclic compressive fatigue test at (10,000) load cycles. In this method tests were conducted sequentially, with the maximum applied load in each succeeding test being increased by a fixed amount, according to whether the previous load resulted in a failure or no failure.

Vetical Marginal Gap Results

Means and standard deviations of vertical marginal gap for e.max and suprinity ceramics as function of production techniques, finish line and surface finishing are summarized in table (1) and graphically drawn in figure (46).

Table (1): Vertical marginal gap results (Mean±SD) for e.max ceramic as function of production techniques, finish line and surface finishing

Group	Finish line	Fully anatomic	Veneering
e.max CAD	Deep chamfer	44.19 ± 2.682	42.38 ± 2.855
	Radial shoulder	43.81 ± 3.643	40.00 ± 3.036
Vita Suprinity	Deep chamfer	34.06 ± 1.598	31.13 ± 1.751
	Radial shoulder	41.50 ± 2.891	37.75 ± 2.656

Three-way ANOVA revealed significant ($p < 0.05$) influence of production technique (CAD recorded higher vertical marginal gap mean value than Suprinity) on vertical marginal gap mean values, a non-significant ($p > 0.05$) influence of veneering (Fully anatomic recorded higher vertical marginal gap mean value than veneering) on vertical marginal gap mean values. The effect of margin design (Radial shoulder recorded higher vertical marginal gap mean value than deep chamfer) was statistically non-significant ($p > 0.05$)

Cyclic Loading Results

E.max CAD

Regardless to finish line and veneering, non-cycled e.max CAD recorded a statistically non-significant higher fracture resistance mean value ($1013 \pm 53.84\text{N}$) than with load cycled ($888.1 \pm 104.5\text{N}$) as revealed with t-test ($t=2.004$, $p > 0.05$).

Vita Suprinity

Regardless to finish line and surface finishing, non-cycled Vita Suprinity recorded a statistically significant higher fracture resistance mean value ($803.7 \pm 66.45\text{N}$) than with load cycled ($703.8 \pm 34.26\text{N}$) as revealed with t-test ($t=2.7$, $p < 0.05$).

4. Discussion

All-ceramic restorations are characterized by enhanced esthetic properties, high biocompatibility, diminished plaque accumulation, low thermal conductivity, abrasion resistance and color stability. However, brittleness and low tensile strength are weak points of ceramic materials. new ceramic core materials were recently introduced. They were made either from pure alumina ceramic, glass-infiltrated alumina ceramic, leucite crystals embedded in ceramic, Zirconia based ceramics or lithium- disilicate based glass ceramic. The improvement in toughness and strength of dental ceramics have increased their clinical use.⁽¹⁶⁾

In the current study, Vita suprinity and IPs e.max CAD were selected as being recommended for use in posterior crowns because of the improved mechanical properties, with respect to two different margin designs (deep chamfer and radial shoulder).^(17,18)

IPs e.max CAD based on a lithium disilicate glass-ceramic system, and was introduced in 2007 by (Ivoclar, Schaan, Liechtenstein), but using machinable

Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) (Cerec in-lab) technique.

Since (1993), it has been possible to fabricate crowns and FPD frameworks from industrially prefabricated blocks using various machine milling methods: Precision copy milling and CAD/CAM milling as stated by **Wasserman et al, (2006)**⁽¹⁹⁾. The computer aided design – computer aided manufacturing (CAD/CAM) is included among the most recent advances in dental technology for direct fabrication of all-ceramic restorations.

Vita Suprinity, a new glass ceramic, features a special fine –grained and homogeneous structure which assures excellent material quality and consistent high load capacity, as well as long-term reliability.

The CEREC system is only one of the plethora's of CAD/CAM systems available today. Its advanced software allows for broad range of indications: crown copings, multi-unit bridge frameworks, inlays, onlays and fully contoured crowns out of single solid blocks. It also allows anatomically perfect results due to the bio-generic occlusal surface design of inlays and onlays. The bio-generic modeling function is based on data acquired from thousands of natural teeth.

The preparation margin is marked with just a few mouse clicks and the software does all the rest. In order to ensure the accuracy of the restoration, we should see what will be milled on the screen before it is sent to the milling machine. Milling performance and precision has been optimized to ± 25 microns.⁽²⁰⁾

Due to the aim of the study and the variability of measurements, moreover, variations of margin designs, and difficulty to standardize the designs to ensure realistic estimates of strength as a function of shape parameters, an in-vitro design was selected. The use of one single master metal die for each design made it possible to start the fabrication of all specimens from the same original situation. Metal dies with actual ceramic specimens fabricated to the anatomic configuration of teeth became a useful tool for the identification of their behavior. Accordingly, clinical variations and disturbing parameters not related to the manufacturing technique and may affect the recorded values were reduced or avoided as much as possible. Finally, the evaluation was performed on the unchanged base line, conditions of the master metal dies. This was found to be in agreement with **Kern et al, (1992)**⁽²¹⁾.

While, in contraindication with **Chitmongkolsuk et al (2002)**⁽²²⁾, **Kolbeck et al (2002)**⁽²³⁾, and **Rosentritt et al (2003)**⁽²⁴⁾, who recommended the use of extracted human teeth as abutments because their modulus of elasticity, bonding characteristics, thermal conductivity and strength are closer to the clinical situation than those of metal, plastic and animal teeth.

Vertical marginal gap

The vertical cervical marginal gap measurement was selected as the most frequently used method to quantify the accuracy of fit of a restoration (**Patteno et al, 2000**⁽²⁵⁾, and **Groten et al, 1997**⁽²⁶⁾). In spite of the presence of various testing methods and measuring tools, the direct view method using the digital measuring microscope is considered more convenient, accurate, easy, and rapid for determining the marginal gap distance. **Sorensen et al, 1990**⁽²⁷⁾.

The results of this study revealed the effect of the production technique on the vertical marginal gap measurements of the e.max specimens, as the e.max CAD specimens recorded a higher vertical marginal gap mean value (42.59) μm than that obtained with vita suprinity specimens (36.11) μm . There is a significant difference between e.max CAD vertical marginal gap mean value and that of vita suprinity. This may be attributed to geometrical design of the restoration and difficulties regarding scanning, digitization, and the milling process of brittle ceramic material. Moreover, the adaptation of restorations made out of milled ceramic blanks may be affected by the size of milling burs, and material conditions during the milling procedure. These measurements were in accordance with **Tinschert et al 2001**⁽²⁸⁾, **Guazzato et al 2004**⁽²⁹⁾, and **Fleming et al 2005**⁽³⁰⁾.

The accuracy of CAD / CAM restorations could be affected by surface roughness which may be related to the detachment of abrasive particles from the diamond burs or to forced vibration of the ceramic block at the finishing stage, as reported by **Yara et al 2004**⁽³¹⁾.

The results of this study revealed that the finish line geometry (deep chamfer and radial shoulder) had no statistically significant effect on the vertical marginal gap distance records for the e.max specimens using t-test analysis. These results concur with **Quintas et al**⁽³²⁾ and **Tsirou et al**⁽³³⁾ who reported that no significant difference was related to the finish line type.

Cyclic loading

To simulate conditions that are as close as possible to the clinical situation the cyclic compressive fatigue test at 10000 load cycles (most ceramics degraded significantly between 10000 to 100000)⁽³⁴⁾ were determined by testing according to the modified “staircase” method. The results of this study revealed that the cyclic loading had a significant effect on the fracture resistance values of the e.max cad crowns regardless to finish line design and veneering, as all the non-cycled e.max crowns recorded a statistically significant higher fracture resistance mean value (908.4) N. than load cycled one (796.0) N. as revealed with t-test. This was in agreement with (**Attia and Kern, 2004**)⁽³⁵⁾

5. Conclusions

Under the limitations of this study, several conclusions could be detected:

1- Regarding the recorded levels of the suggested acceptability for vertical marginal gap distance, the tested groups had acceptable marginal fit which lead to clinical success.

2- Posterior crowns made from Vita suprinity are more accurately fit than those made of IPs e.max CAD. While IPs e.max CAD are stronger than Vita suprinity crowns.

3- CAD / CAM milling, Cerec MCXL, is a recent technique that allows easy and rapid constructions of restorations, but still effort must be done to improve precision.

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