AJDS ALAZHAR
Al-Azhar Journal of Dental Science
Vol. 26- No. 3- 317:323- July 2023
Print ISSN 1110-6751 | online ISSN 2682 - 3314
https://ajdsm.journals.ekb.eg
Restorative Dentistry Issue *(Dental Biomaterials, Operative Dentistry, Endodontics, Removable & Fixed Prosthodontics)*

EVALUATION OF THE VERTICAL MARGINAL GAP OF THREE CAD/CAM CERAMIC SYSTEM AFTER CYCLIC LOADING

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ABSTRACT

Objective: The objective of this in vitro study was to evaluate the marginal accuracy of different CAD/CAM ceramic crowns after thermo-mechanical cyclic loading. **Material and methods:** The marginal accuracy of a polymer-infiltrated ceramic network (PICN) material (Vita Enamic [VE]) was compared to two machinable glass ceramics; Zirconia-reinforced lithium silicate (Vita Suprinity [VS]) and a lithium disilicate glass ceramic (IPS e.max. CAD, IPS). 30 natural premolar teeth of average size were prepared (n=10 each group) by computer numerical control (CNC) to fulfill the criteria of all ceramic crown design. Optical impressions were taken for each tooth preparation using the CAD/CAM scanner. 30 crowns were milled from ceramic blocks based on the optical data. A total of 30 crowns were fabricated using CAD/CAM system, and divided into three groups (IPS e.max, VE and VS). The vertical marginal gap was measured using stereomicroscope before, after cementation and after thermo mechanical cyclic loading. **Results:** No statistically significant difference in vertical marginal gap within or between groups of three tested materials before, after cementation and after thermo mechanical cyclic loading. **Conclusions:** Vertical marginal adaptation of all tested ceramics was within the clinically acceptable values.

KEYWORDS: Marginal accuracy, nanoceramics, hybrid ceramics, cyclic loading.

INTRODUCTION

To satisfy the aesthetic expectations of patients as well as mechanical requirements, various dental ceramics has been proposed and recommended. The advancements scored in material development has helped clinicians do more conservative tooth preparations, with less tooth structure removed during the procedure. Metal ceramic restorations have been considered the gold standard for fixed dental restorations. Although they have adequate fracture resistance, metal ceramic restorations demand invasive tooth preparations to give adequate space for the restoration. More recent ceramics developed don't necessarily require this invasive type of tooth preparation.

Among these newly developed ceramics are hybrid ceramics. This type of ceramic combines a ceramic network and a polymer infiltrating this network [(1)]. This hybrid structure has an elastic modulus of 30 GPa, which falls between the elastic modulus of enamel which is <94 GPa and the elastic modulus of human dentin which is <25 GPa [(2,3)]. Due to their polymer/resin component, these hybrids do not require and thermal post processing after their

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DOI: *10.21608/AJDSM.2022.117476.1292*

CAD/CAM fabrication, which makes them ideal for single visit fixed dental restorations [(4-6)]. PICN ceramics have also been proposed as an excellent choice for single-tooth replacement fixed to a dental implant due to their resilience, which may have a protective effect to supporting bone around a dental implant [(3)].

Success of a fixed dental restoration or a crown is influenced by several factors. Adaptation and accurate fit of the crown is among the most important of these factors [(7-11)]. Adaptation at the restorative margin is paramount to adequate clinical longevity. A maximum marginal discrepancy (MD) values between 100 mm and 150 mm have been reported to be the limit for clinical success of a fixed restoration [(12)]. Holmes et al [(13)] defined various measurements between the intaglio of the restoration and an underlying preparation. This ensures a standardized measurement of the marginal gab of a fixed dental restoration. Absolute Marginal Discrepancy can be defined as “the angular combination of MD and extension errors [(14)]. Adverse effects of increased marginal discrepancy of dental restorations have been reported, including plaque accumulation and all associating periodontal complications. In addition, microleakage and recurrent carious lesions are among the most typical complications of inadequate restorative margins [(15-17)].

Measuring marginal discrepancy in vivo can be done by several techniques, including but not limited to, optical microscope, stereomicroscope, electron microscopy, and microcomputed tomography (m-CT) [(4,14)]. On the other hand, measuring marginal discrepancy in vitro can be done using different techniques. These techniques include the use of replica made of silicone or resin, or by direct sectioning of a specimen [(19)]. A m-CT can be used to measure internal and marginal adaptation of restorations simultaneously [(5,7,19,20)]. This technique has the benefits of being noninvasive and does not cause damage to the specimen [(20)]. Furthermore, m-CT evaluation of adaptation of a restoration can provide either 2D or 3D images. Very thin sections can be made allowing safe examination of approximate structures [(8,22)].

The aim of this in vitro study was directed to evaluate the marginal adaptation of hybrid ceramic and a zirconia-reinforced lithium silicate ceramic crowns compared to lithium disilicate ceramic crowns before and after cementation, and after thermo-mechanical cyclic loading. The null hypothesis of this study was that there will be no difference between the three tested ceramic materials regarding the vertical marginal gap measurements before and after cementation, and after thermo-mechanical cyclic loading.

MATERIAL AND METHODS

Natural premolar teeth of average size were prepared by computer numerical control (CNC) to fulfill the criteria of all ceramic crown preparation design for use in the study and divided into 3 main groups: IPS. Emax CAD (EC), Vita Suprinity (VS) and Vita Enamic (VE), 10 crowns each.

The ethics committee at Al-Azhar University’s Faculty of Dental Medicine approved this study with approval number (758/2595). Thirty freshly extracted human maxillary first premolar teeth were collected from orthodontic department Al-Azhar University. Selection criteria were based on teeth condition and average size measured by digital caliber. The buccolingual diameter of the selected teeth equal 7.89±1ml and the mesiodistal width equal 6.98±1ml. Teeth were randomly distributed into 3 groups, 10 teeth in each one. A Parallometer (BEGO, Paraflex, Germany) was used to allow accurate orientation and vertical centralization of the tooth inside the plastic PVC mold.

Teeth were fixed in place with the aid of a hair pin until complete setting of the self-cure acrylic resin was ensured. To standardise the preparation dimensions, a Computerized Numerical Control (C.N.C Premium 4820, imes-icore, Eiterfeld, Germany) four axis milling machine was used on teeth preparation. Tooth reduction was done using a diamond endmill under oily water coolant. Reduction configuration was designed on a master cam software. The CNC machine was adjusted to reduce all teeth to fulfill the criteria of all ceramic crown design (1-mm rounded shoulder finish line, 2.0 mm occlusal surface reduction, and 6 degrees of axial convergence angle).

Optical impressions were taken by Scanning and digitization of the dies using the 3Shape D700 dental lab scanner (3Shape A/S, Holmens Kanal 7, 1060 Copenhagen K Denmark). Crown was selected as the restoration type with the design mode set to biogeneric individual. The tooth was also selected (maxillary first premolar). Restoration parameters were set, including the spacer thickness at (60) µm and all other parameters were kept according to the software default. Insertion axis was determined to avoid any undercuts, as the incorrect insertion axis may result in a thin or even a perforated wall. A total of 30 crown specimens (10 from each material) were fabricated from optical data using a 5-axis (CAD/CAM) milling machine (WIELAND Zenotec, Ivoclar Vivadent, Germany). specimens were placed on their corresponding prepared teeth and the seating of each crown were evaluated using a magnification loupe (5X) to perform an initial clinical evaluation. The IPS and VS specimens for the final crystallization cycle, were positioned in a ceramic furnace (The programat P310 furnace; Ivoclar Vivadent, Germany). No extra polishing or finishing was needed for the VE.

A Sample Positioning Device (SPD) was fabricated to overcome the challenges of repeating the measurements of the marginal fit at the same distance and at the same angle from microscope capturing unite. This SPD is a simple tool which consists of a calibrated gauge, fixable base, reading marks and coil spring to perform astatic load during measurements. The specimens were inserted in corresponding house created in the holding device till the guidance groove created previously in the sample coincide with the groove created in the holding device. The house holding the sample can rotate over the fixed base and fixed at each of the 12 points for accurate measurement (**Figure 1**).

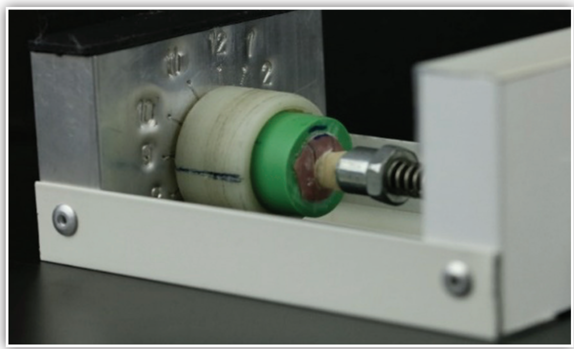

FIG (1) The Sample positioning device (SPD) under stereomicroscope.

The vertical Marginal gap was evaluated before cementation by measuring the vertical gap between crown margin and finish line by stereomicroscope device and integrated digital camera using a magnification of 35X and analysis software (Figures 2).

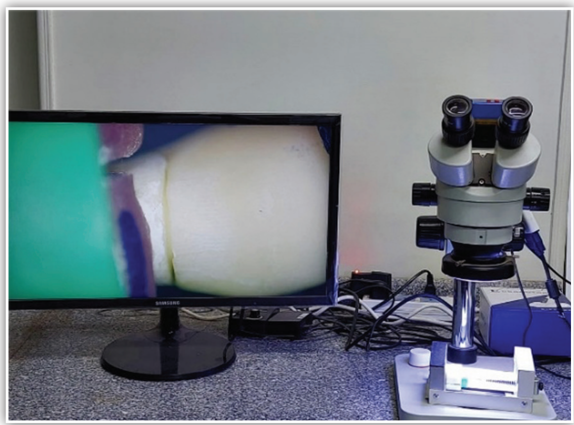

FIG (2) Stereomicroscope with integrated digital camera.

Measurements on each specimen were determined at a total of 12 points, with three points on each surface at a predetermined location[23]. The mean marginal fit value for each crown was computed from the mean values of cervical circumferential measuring points.

Digital images of specimens were taken through adjusted special holding device and the integrated software was used to measure evaluated gap by microns. The final data was collected, processed, and statistical analysis was performed**.**

Each set of ceramic crowns was surface treated according to their manufacturer's instructions. The intaglio of the crowns was etched with 9.5% Hydrofluoric acid for 20 seconds, except for crowns made of hybrid ceramic which were etched for 30 seconds, then rinsed off with forceful water spray for 60 seconds and dried with moisture-free oil-free air until the internal surface of the restoration showed frosted white appearance. A silane coupling agent (Porcelain Primer, Bisco, Inc. Schamburg, IL USA) was applied to the etched ceramic surface for 60 seconds then air-spray was applied for 5 second. This is the conventional surface treatment method for glass ceramics.

Teeth were washed with water and dried with air with care taken not to over dry the tooth surface. Prepared teeth were selectively etched with 37% phosphoric acid etch (Meta Etchant gel, Korea) for 30 secs for enamel only at the margin according to the manufacturer's instructions. Then the etchant was washed thoroughly with air-water stream for 15 secs, then air dried. Teeth to be bonded were treated by application of bonding agent, Tetric N-Bond Universal (Ivoclar Vivadent, Germany) applied to the axial dentine wall (using self-etching technique), scrubbing with micro-brush for 10 seconds, air-drying for 10 seconds to remove excess solvent, then curing with a LED curing light (Monitex Industrial Co, Ltd. Taiwan) for 10 seconds.

A dual-cure resin cement (Variolink Esthetic DC, Ivoclar Vivadent, Germany) was applied to the ceramic crowns. The bonding procedure was carried out using a static load, that produce a constant seating load of by 7 kg (approx. 70 N) [(23)], applied for 5 min while the crown was bonded to dentin surface. According to manufacturer's instructions, excess cement was gently removed with a sharp instrument after spot curing with a LED curing light for 2-3 seconds at a distance approximately 1-2 mm. After that, the specimens were light cured for 40 seconds per side with the LED curing light.

After luting of the 30 ceramic crowns to teeth, vertical Marginal gap was evaluated by measuring the vertical gap between crown margin and finish line by stereomicroscope device and integrated digital camera using a fixed magnification of 35X and analysis software as done before cementation.

After marginal fit evaluation, all sample were subjected to mechanical cyclic loading for 75000 cycles, 50 N and range of frequency 1-1.6 Hz in wet condition which resemble approximately 6 months under function accompanied with thermal cycling at 5-55°C [(7)] by ***ROBOTA*** chewing simulator**.** The dwell time for thermal cycling was 60 s. The chewing simulator calculate about 456 thermal cycles during the chewing simulation. The antagonist metal stylus was designed in milling machine with tip diameter of 3mm**.** A programmable logic-controlled equipment was used to accomplish thermomechanical cyclic loading; the designed four-station multimodal ROBOTA chewing simulator (Model ACH-09075DC-T, Germany) with thermo-cycle protocol was operated on servomotors.

After cyclic loading was completed, vertical marginal gap for each crown was measured by stereomicroscope with the same magnification and at the same points by aids of the Sample positioning device (SPD) (**Figures 3**). The final data was collected, processed, and statistical analysis was performed.

Data were represented by mean, standard deviation (±SD), with 95% Confidence Interval (95% CI) values. One way ANOVA test, Tuckey's post hoc tests and descriptive statistics were used to compare between different materials. The significance level was set to $P \leq 0,05$. Statistical analysis was performed with IBM SPSS® Statistics version 20 at 95% confidence interval.

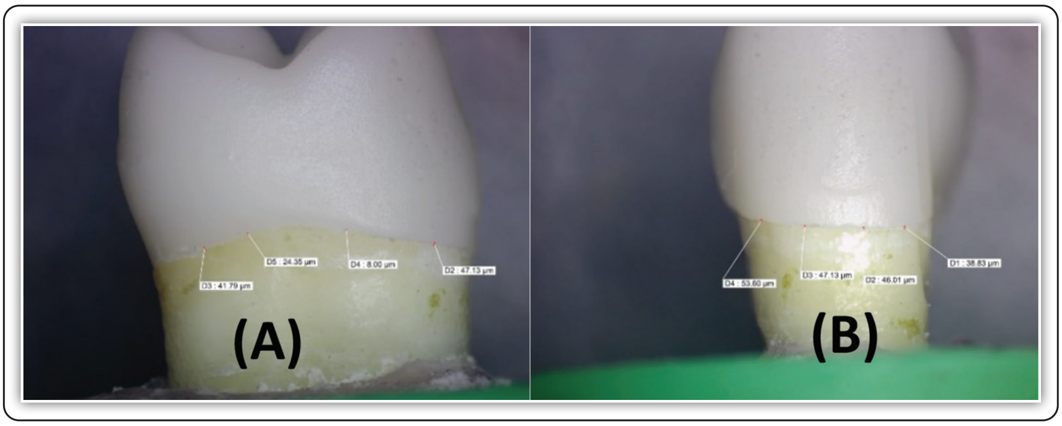

FIG (3) Vertical marginal gap measurements (A) on the proximal surface (B) on the buccal surface.

RESULTS

The total marginal fit value at each wall was measured by calculation of an average of all readings recorded of three points on a given wall; two points at the line angles, and one mid-wall point. There was no statistically significant difference of the marginal fit before cementation (BC), after cementation (AC), and after cyclic loading (ACL for the 3 groups (EC p=0.85, VS p=0.86, and VE p=0.87). The best marginal fit was recorded with e.max CAD, followed by Vita Enamic, then Vita Suprinity. All data are represented in table (1) and figure (4).

TABLE (1) Showing comparisons of marginal fit within groups

Marginal fit within groups (µ)					
		BC	**AC**	**ACL**	**p value**
EC	Mean	0.088211	0.091211	0.093211	0.854821
	±SD	0.026726	0.032037	0.020035	
VS	Mean	0.098381	0.101381	0.103532	0.868107
	±SD	0.018126	0.025104	0.021539	
VE	Mean	0.093381	0.096381	0.098381	0.87552
	±SD	0.030696	0.027705	0.021773	

There was no statistically significant difference between tested groups before cementation (p=0.56), after cementation (p=0.50), or after cyclic loading (p=0.55).

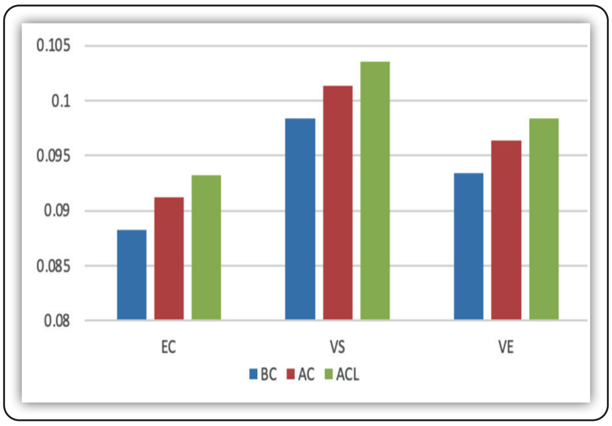

FIG (4) A column chart showing comparisons of the marginal fit within groups.

DISCUSSION

Minimal marginal and internal gab are essential for success of a fixed dental restoration. CAD/CAM technology was selected to control thickness, anatomy and ensure greater accuracy, standardization, and increased efficiency [1]. Plaque accumulation and bacterial colonization, which are well-known causes of periodontal disease, in addition to dental caries, irreversible pulpal inflammation, and eventually pulpal death and necrosis resulting in biologic failure are among the consequences of increased marginal discrepancy of a fixed dental restoration. Furthermore, Wolfart et al [25] stated that the marginal adaptation is the most relevant in crown evaluation and should be considered the most important. As a result, the vertical marginal gap measurement was chosen as the most utilized to assess the restoration's fit.

The tooth chosen to represent the die was a natural maxillary first premolar and prepared by aids of CNC device and special mold to give accurate mounting and preparation as well as elimination of the human errors as much as possible [26]. Before and after thermomechanical cycling, marginal gab was assessed by examining with external measurements using a stereo microscope at a fixed magnification of 35x. This technique has the benefit of providing noninvasive, accurate, and repeatable measurements, making it useful for detecting the precision of fit of the entire specimen margin [27].

However, repeatable measurement of marginal gap at the same identical angle is very difficult. So, to achieve standardization, a special Sample Positioning Device (SPD) was utilized during marginal gap measurement to hold the tested specimens in place. This has allowed standardizing the angle of measurement ensuring its alignment with the focal plane of the microscope [18].

Regarding thermomechanical cycling, it was found that no statistically significant effect on the marginal adaptation in all groups before and after loading. This result supported by Guess et al. [28] which report that the simulated five-year ageing of all ceramic partial coverage restorations (using indenter 6 mm width, and 98 N occlusal force) had no impact on the marginal fit.

Finally, controversy in the literature of the value of adequate marginal gap for ceramic crowns still exist. Several studies have found that for cemented restorations, the optimal marginal gap should be 25 to 40m. many additional studies judged a marginal gap of 100 to 200m acceptable. Recent investigations have determined that a marginal gap of less than 100 mm is clinically appropriate. As a result, the marginal gap results for both groups in this investigation are clinically acceptable [29].

The null hypothesis of this study was accepted as there is non-statistically significant deference between the three ceramic materials used in this study regarding the vertical marginal gap measurements; also, there is non-statistically significant deference between the vertical marginal gap measurements before, after cementation and after thermomechanical cycling.

CONCLUSIONS

The following conclusions were formed based on the findings of this in vitro study:

1. There were no significant differences in marginal gab values between Vita Enamic, Vita Suprinity, and Emax Cad.
2. IPS CAD-CAM have the best marginal fit followed by VE and VS.

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