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Micro- Computed Tomographic Evaluation of Marginal Fit of Different Monolithic all Ceramic Crowns Fabricated Using Two CAD/CAM Systems.

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ABSTRACT

Purpose: the objective of the present in vitro study was to evaluate the effect of two different CAD/CAM systems on the marginal fit of three commercially available dental ceramics using micro-computed tomography. **Materials and Methods:** one human natural premolar was selected, received a standardized all ceramic preparation and duplicated using two types of die materials. PMMA dies were used for construction of E.max CAD and Vita Enamic monolithic crowns while zirconia dies were used for zirconia crowns. A total of thirty monolithic all-ceramic crowns (N=30) were constructed on the fabricated working dies. These were equally divided into 2 groups (n=15) according to the CAD/CAM system used as follows: group (I): Everest system and group (II): Zircon Zhan system. Each group was further subdivided into 3 subgroups (n=5) according to the ceramic material used into subgroup (E): E.max CAD glass ceramic, subgroup (Z): ice prettau zirconia and subgroup (V): Vita Enamic hybrid ceramic. Each sample was scanned for fit analysis using a quantitative micro-computed tomography scanner then were analyzed. **Results:** Everest CAD/CAM system showed statistically significantly lower mean marginal gap distance than ZirconZahn. Either with Everest or ZirconZahn; E.max CAD showed the statistically significantly highest mean vertical marginal gap distance followed by Zirconia while Vita Enamic showed the statistically significantly lowest mean vertical marginal gap distance. **Conclusions:** Micro-CT technology presents a reliable tool for evaluation of the dental restorations fit. Also, superior marginal fit is achievable with monolithic CAD/CAM hybrid ceramic compared to both zirconia based and glass ceramics.

KEYWORDS

Marginal fit,
micro CT, Hybrid ceramics,
monolithic crowns, E.max CAD.

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INTRODUCTION

In recent years the field of fixed dental prostheses had witnessed the introduction of new materials and procedures for esthetic reconstructions in a wide range of indications. The longevity of these restorations was extensively assessed in different researches attempting to relate clinical failure to their different causes. The importance of precise marginal accuracy and its implications of marginal discrepancies, including micro-leakage, caries and periodontal inflammation, have been emphasized in many studies [1-3].

Measuring methods of marginal accuracy are different, usually there are two main techniques; invasive and noninvasive technique. Experimental set-ups of marginal fit also can differ according to many factors such as sample size, number of measurements per specimen and the stage of testing as before and/or after cementation. Also, construction techniques of ceramic materials can affect the restoration fitting accuracy [4-6]. It has been documented that all ceramic crowns have marginal discrepancies ranging from 19–160 µm[4,7] .

Software restrictions as well as precision of milling machines can affect the marginal accuracy of CAD/CAM fabricated restorations [8]. In CAD/CAM systems it is conceivable to program the software to provide more space for cement accommodation that potentially has an impact on the internal and marginal accuracy of restorations.[9] Dental CAD/CAM technology is gaining celebrity because of its benefits in terms of manufacturing time, standardization of the fabrication process, and predictability of the restorations [10].

Lithium disilicate is one of the most widely used all ceramic materials in dentistry nowadays, with the most studies among all-ceramic restorations. It has a great combination of strength, beauty and the ability to bond at higher strengths [11]. Vita Enamic is a Hybrid ceramic material possessing a dual network structure. It has modulus of elasticity of 30 GPa, which is near the same range of human dentin[12] . Owing to absence of porcelain layering, monolithic zirconia has the potential to outlast layered restorations such as the PFM as there is no porcelain laminate, chipping, or fracture. Zirconia restorations has become very widely used in the recent years owing to its durability, precise fit, and enhanced esthetics [13,14].

MATERIALS AND METHODS

Preparation of Master Die

One human natural premolar was selected, received a standardized all ceramic preparation with following preparation properties [15] :1mm heavy chamfer finish line, 1.5 mm axial reduction, 1.5 mm occlusal reduction and of 6°occlusal convergence. Roundation of all line and point angles was done. High-speed hand piece attached to CNC milling machine (Centroid CNC, milling machine, USA) was used to prepare the tooth using diamond stone with a rounded end. Prepared premolar was duplicated using two types of die materials. PMMA dies were used for construction of E.max CAD and Vita Enamic monolithic crowns while zirconia dies were used for zirconia crowns.

A rectangular base was fabricated for each working die by adjusting it on a resin pattern to facilitate handling of the die. A total of thirty monolithic all-ceramic crowns (N=30) were constructed on the fabricated working dies then equally divided into 2 groups (n=15) according to the CAD/CAM system used as follows: group (I): Monolithic crowns constructed using Everest system and group (II): Monolithic crowns constructed using Zircon Zhan system.

Each group was then subdivided into 3 subgroups (n=5) according to the type of ceramic material used into subgroup (E): all-ceramic crowns constructed from E.max CAD glass ceramic, subgroup (Z): all-ceramic crowns constructed from ice prettau zirconia and subgroup (V): all-ceramic crowns constructed from Vita Enamic hybrid ceramic.

Construction of monolithic all-ceramic restorations:

a: Construction of monolithic crowns using Everest CAD/CAM system, group (1) samples:

All samples of group (I) were constructed using Everest CAD/CAM milling machine. Previously constructed resin dies were used to fabricate E.max CAD (subgroup IE) and Vita Enamic (subgroup IV) samples, while zirconia dies were used to fabricate Ice Prettau zirconia (subgroup IZ) samples. The die spacer was set at 50μm for all subgroup's samples.

A new set of milling tools was used to mill each sample. Manufacturers' instructions were followed for every type of restoration. Kavo Everest Scan Pro scanner (Noncontact 3D strip-light projection scanner) was used for dies scanning. After each crown designing with the Everest software (KaVo multiCAD Software), the information was sent electronically as STL file to the CAM computer to transfer the crown design into the ceramic block.

Partially sintered zirconia monolithic crowns (subgroup IZ samples) were sintered at 1500°C for 10 hours in Everest HTC furnace (High – Temperature Furnace with program control unit) Crystallization of E.max CAD crowns (subgroup IE samples) took place after milling.

b: Construction of monolithic crowns using Zircon Zhan CAD/CAM system, group (II) samples:

All samples of group (II) were constructed using Zircon Zhan CAD/CAM milling machine (Milling Unit M2 Zirkonzahn GmbH, Bruneck, Italy). Previously constructed resin dies were used to fabricate E.max CAD (subgroup IIE) and Vita Enamic (subgroup IIV) samples, while zirconia dies were used to fabricate Ice Prettau zirconia (subgroup IIZ) samples. The die spacer was set at 50μm for all subgroup samples. New set of milling tools was used to mill each sample.

Manufacturers' instructions were followed for every type of restoration. The respective working dies was secured on the tray of the scanner (optical strip-light SCANNER S600 ARTI) for taking optical impression. The digital data were used by Zircon Zahn CAD/CAM software to design the crowns similar to those for group (I) samples using Zircon Zahn Modellier (Zirkonzahn GmbH, Bruneck, Italy). After tracing of the margins on the virtual model, fabrication of IPS e-max CAD, Ice Prettau zirconia and Vita Enamic samples used in this study were done.

Lithium disilicate crown manufactured with the Everest CAD CAD system (subgroup IM) was used during scanning process of the Zirconzhan system to produce specimens of exact dimensions and occlusal anatomy of group I for the purpose of standardization. The crowns were milled by the 5 axes Zircon Zahn milling system.

Partially sintered zirconia monolithic crowns (subgroup IZ samples) were sintered at 1500°C for 10 hours in Everest HTC furnace (High – Temperature Furnace with program control unit) Crystallization of E.max CAD crowns (subgroup IE samples) took place after milling as in case of first group.

Measurement of marginal gaps using micro-CT:

Each sample was scanned for fit analysis using a quantitative micro-computed tomography scanner then were analyzed. The analysis protocol consisted of 26 images per sample within the 360-degree perimeter. Thus, 13 images per perspective (sagittal and trans- axial) were evenly distributed around the cervical margin. Vertical marginal gaps were measured from the most external point of the margin of the tooth to the crown margin.

STATISTICAL ANALYSIS

Mann-Whitney U test was used for comparison between the two CAD/CAM systems. Kruskal-Wallis test was used for comparison between the three ceramic types. Dunn's test was used for pair-wise comparisons when Kruskal-Wallis test is significant.

RESULTS

For all tested ceramic material, Everest showed statistically significantly lower mean vertical marginal gap distance than Zircon Zahn. Either with Everest or Zircon Zahn; E.max CAD subgroup showed the statistically significantly highest mean vertical marginal gap distance. Zirconia subgroup showed statistically significantly lower mean marginal gap while Vita Enamic subgroup showed the statistically significantly lowest mean vertical marginal gap distance. There was no significant difference between Zirconia and Vita Enamic subgroups in case of Everest CAD/CAM system. Table (1), figure (1)

Table (1): *Descriptive statistics of overall vertical marginal gap distance (µm) for both CAD/CAM systems and all ceramic materials tested.*

CAD/CAM type (groups)	Ceramic type (sub-groups)	Mean	SD	Median	Minimum	Maximum	95% CI	
							Lower bound	Upper bound
Everest(groupI)	E.max CAD(IM)	25.1	2.6	25.3	20.4	29.1	23.5	26.7
	Zirconia(IZ)	15.1	3.4	14.8	10.8	22.0	13.1	17.2
	Vita Enamic(IV)	10.1	2.3	9.9	7.6	13.6	8.8	11.5
Zircon Zahn (group II)	E.max CAD(IIM)	54.7	4.8	54.7	45.9	61.5	51.8	57.7
	Zirconia(IIZ)	37.1	3.5	38.1	32.2	44.3	35.0	39.3
	Vita Enamic(IIV)	20.8	3.1	20.5	14.8	26.1	18.9	22.6

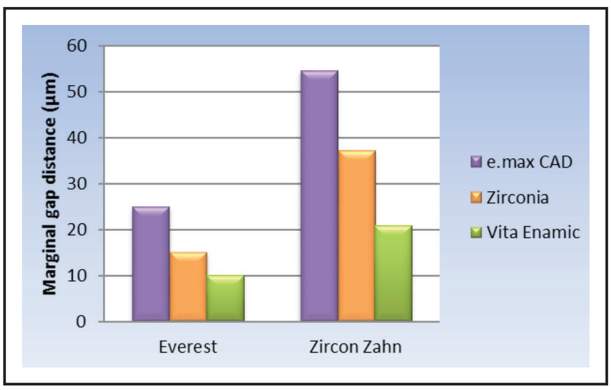

Figure (1): Bar chart representing mean overall vertical marginal gap distance of the three ceramic types.

DISCUSSION

The results of this study showed statistically significant differences between both assessed CAD/CAM groups (Everest and Zircon Zhan). Everest showed statistically significantly lower mean vertical marginal gap distance than Zirconzahn. This could be imputed to the digitization factors related to each system. Both systems used are subject to limitations related to the scanning finite resolution [16]. In comparison to Everest, the S600 ARTI scanner of zirconzhan system which uses the red laser technology to capture image from multiple angles for scanning, but with the higher wavelength of red laser, the accuracy of scanner may be reduced. These findings were in the agreement with that reported by previous study [17].

Within the two studied groups (Everest and ZirkonZahn), E.max CAD subgroup showed the highest mean marginal gap values. This was in the agreement with two previous studies [18,19], where E.max CAD produced inferior marginal fit among studied restorations. This was attributed to the dimensional changes that occur during firing procedure of E.max CAD. The authors suggested that as E.max CAD is not strong as zirconia (440Mpa compared with 900- 1400Mpa), it will be more vulnerable to dimensional changes occurring during firing and compromising the marginal accuracy of the restorations.

Marginal gap values obtained for subgroup (IM) (E.max CAD crowns constructed using Everest CAD/CAM system), (25.1±2.6 μm) were similar to values obtained with previous study [20] that measured the marginal gap of E.max CAD crowns using (CEREC In Lab and Kavo Everest) CAD/CAM systems. The specimens fabricated using Everest CAD/CAM system presented the statistically significantly lower mean marginal gap values than those of the Cerec In Lab system. The study correlated the difference between both groups to the different number of milling axis of both systems (3-axis milling unit of the Cerec In Lab and the 5-axis unit of the Everest system). For zirconia using Everest the results in current study were also similar to their study.

On the other hand, for of E.max CAD crowns and ZirkonZhan system (subgroup IIM), previous study [21] obtained lower marginal gap values (39.12 µm ±3.969) while investigating marginal adaptation of E.max CAD crowns constructed using ZirkonZhan CAD/CAM system) than current study (52.7±9.2 µm). This could be attributed to differences in working die used (Nickel-Chromium mandibular first molar master die was used as a working die while PMMA upper first premolar dies were used in current study). In addition, stereomicroscope was used for marginal gap evaluation at sixteen measuring points per each sample, while in this study marginal gap was evaluated at 52 points per sample using micro CT device.

For zirconia crowns using Zirkonzahn system (subgroup IIZ), the results in current study were coincide with another study (22) evaluated similar marginal gap for zirconia copings for Zirkonzahn system. Anyway, their study used zirconia copings instead of full crowns in this study, master Cr-Co model stump was used instead of zirconia and PMMA dies in this study and measurements were taken using a stereomicroscope instead of micro CT in current study.

Comparing marginal gap values obtained for E.max (M) and zirconia (Z) subgroups in both groups; significant decrease in marginal gap values were obtained for zirconia subgroup, table (1) and figure (1).

According to previous study, [19] marginal accuracy of CAD/CAM fabricated restorations could be affected by the scanning method, designing software and milling process. Carbide milling tools were used to mill zirconia blocks while diamond tools were used for E.max CAD blocks. Also, the milling process of zirconia blanks were done in a dry field while E.max CAD blocks were milled in a wet field. This difference in milling atmosphere account for the difference in marginal accuracy values produced.

However, other studies [23,24] compared marginal gap of CAD/CAM fabricated crowns by using different materials and found that superior adaptation is obtained with E.max CAD in comparison to zirconia, disagreeing with results of the current study and this may be attributed to the differences in fabrication process for the tested materials.

Many studies of marginal accuracy of CAD/CAM fabricated ceramic crowns have been conflicting in their findings. This conflict could be attributed to study design variations, scanning and milling machines, abutment design and materials and measuring system used [25,26].

In current study the mean marginal discrepancy of the hybrid vita Enamic was statistically significantly lower than that of E.max CAD subgroups in group I with Everest system but not significantly different from Zirconia subgroup. While with Zirconzahn, vita Enamic showed the statistically significantly lowest mean vertical marginal gap distance among subgroups. This difference could be due to the difference in materials' physical properties. Since vita Enamic blocks are softer than lithium disilicate CAD/CAM blocks. Thus, they can be milled faster producing less wear of the milling burs.

For vita Enamic, the values obtained in the current study were lower than those recorded by previous study [24] where vita Enamic group recorded mean marginal gap values (122.23 ±44.64 μm) and those recorded by another study [12] (47.91 ±6.45 μm). both studies used Silicone replica technique for evaluation of marginal gaps and CEREC CAD/CAM system to fabricated studied restorations.

The results of current study are in the agreement with a study [25], compared the marginal accuracy of full contour CAD/CAM crowns constructed from four different ceramic materials (zirconia, lithium disilicate, zirconia-reinforced lithium silicate and hybrid dental ceramic). The best marginal fit was shown by crowns fabricated from hybrid ceramic (vita Enamic), which were statistically highly significant when compared to other groups.

CONCLUSIONS

Within the limitations of the current study, the following could be concluded:

1. Micro-CT technology presents a reliable tool for evaluation of the dental restorations fit.
2. Both Everest and ZirconZhan systems produce restorations with clinically accepted marginal fitness. However, better marginal fit is expected in restorations constructed using Everest CAD/CAM system.
3. Superior marginal fit is achievable with monolithic CAD/CAM hybrid ceramic compared to both zirconia based and glass ceramics.

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