Comparison of the Marginal Fitness of the Ceramic Crowns Fabricated with Different CAD/CAM Systems (An *In Vitro* Study)

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ABSTRACT

Background: The marginal fit is the most characteristic that closely related to the longevity or success of a restoration, which is absolutely affected by the fabrication technique. The objective of present *in vitro* study was to evaluate the effect of four different CAD/CAM systems on the marginal fit of lithiμm disilicate all ceramic crowns.

Materials and Methods: Adentoform tooth of a right mandibular first molar was prepared to receive all ceramic crown restoration with deep chamfer finishing line (1mm) and axial reduction convergence angle of 6 degree, dentoform model duplicated to have Nickel-Chromiμm master die. Thirty two stone dies produce from master die and distributed randomly in to four groups (8 dies for each group) according to the type of CAD/CAM system that used: Group A: fabricated with CERAMILL motion2 (Amann Girrbach); Group B:fabricated with CEREC in lab MCXL (Sirona);Group C: fabricated with CORiTEC 250i (imes-icore); Group D: fabricated with ZIRKONZAHN M5 (Zirkonzahn). Marginal discrepancy was measured at four points at each tooth surface. Sixteen points per tooth were measured using digital stereomicroscope at (140X) magnification.

Results: ANOVA and LSD post Hoc tests were used to identify and localize the source of difference among the groups. It was found that there is a highly significant difference in the marginal gap mean values between group C and group D, and highly significant differences between group A and group D.

Conclusions: From the above result we can conclude that better marginal fit values were may be exhibited by CORiTEC 250i CAD/CAM system.

Key words: marginal fitness, CAD/CAM system, ceramic crown. **(J Bagh Coll Dentistry 2016; 28(4):28-33)**

INTRODUCTION

Although marginal discrepancy alone does not directly correlate with microleakage, the accuracy of marginal adaptation is valued as one of the most important parameters for the clinical quality, success, and longevity of fixed dental restorations [(1)].

The importance of precise marginal fit and the subsequent implications of marginal misfit, including microleakage, caries, and periodontal inflammation, have been confirmed in many studies [(2)].

Generally, marginal fit proposed as clear terminology by Holmes *et al.* through the measuring the marginal gap or the absolute marginal discrepancy [(3-5)]. The vertical distance from the finishing line of the preparation to the cervical margin of the restoration was obvious definition of the marginal gap [(6)].

An overall review of the data collected for the vertical marginal gap presented that 94.9% of the values measured were less than or equal to120 μm, The widest marginal gap measured was 174 μm, and the smallest was 3.7 μm [(7)]. All-ceramic restorations are vastly used in dental field to attain the superior esthetics demanded by patients.

They show better light transmission than other restorative material, which improved reproduction of the color and translucency of natural teeth [(8)]. Many commercially in office and laboratory CAD/CAM systems are available today [(9,10)]. Marginal adaptation of CAD/CAM restorations is relying on different parameters that include finishing line configuration, die space, type of cement used, and the cementation technique [(11,12)].

Studies were suggested that scanning, software, and milling process have a detrimental effect on the marginal adaptation of CAD/CAM restorations [(13,14)]. Recent studies have reported average marginal discrepancies for CAD/CAM restoration that range from 24-110 μm [(15)], and clinical studies with scanning electron microscopy data have equivalent values about 35-71μm [(16)].

Several studies have been investigated the effect of scanning and milling process of CAD/CAM and its related to the marginal adaptation [(14,17,18)]. Following on from these studies, it was of interest to investigate whether or not the CAD/CAM system used could influence the marginal accuracy of the CAD/CAM crowns when fabricated with lithiμm disilicate glass ceramic material. It was also of interest to evaluate whether the use of a different CAD/CAM system would produce a different marginal integrity of the ceramic restoration.

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MATERIALS AND METHODS

Preparation of Master Die:

A dentoform tooth of a mandibular right first molar (Dentoform, Nissin, Kyoto, Japan) was prepared to receive all-ceramic crown restoration with following preparation properties: deep chamfer finish line (1mm), flat occlusal reduction to the depth of central occlusal pit, 1 to 1.5 mm of axial reduction with 6 degree convergence angle (Fig.1) [19,20].The prepared dentoform tooth was used as a pattern for the construction of the metal master die (Fig. 2). The dentoform tooth was sprued, invested, burn out and casting using non-precious-dental cast alloy for ceramics on nickel base, type 3, hard.

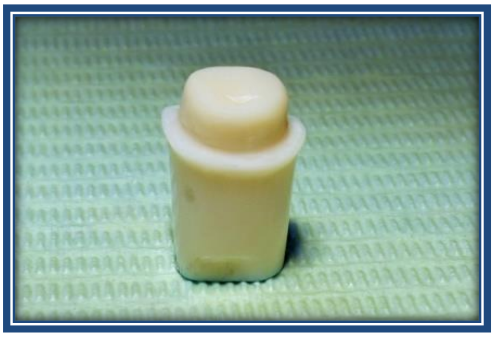

Figure 1: A dentoform tooth prepared with deep chamfer finish line

Figure 2: Master Metal die fixed to acrylic base

Impression procedures

A special tray was fabricated to be used during impression procedure. prior to fabrication of special tray, A two layer of modeling wax were adapted all around the metal die, this will provide a space about (2-2.5mm) for the impression material, the traditional method was followed to fabricate the special tray using translucent cold cure acrylic resin [21].

To ensure that there is a single path of insertion and removal of the impressions, a dental surveyor was used during impression procedure. In order for the special tray to be attached on the dental surveyor, some modifications were carried out; one end of the analysis rod was fixed to the most upper part of special tray while the other end connected to the vertical suspending arm of surveyor.

In addition, the lower part of the special tray that opposing the horizontal surface of the acrylic base of master die was designed so that it contained three pines to engage three holes on the acrylic base, this will serve as a guide and stopper for the special tray during impression procedure [22,23].

A thin layer of tray adhesive was brushed onto the tray 24 hours after the tray fabrication. Two-step impression technique was selected as technique for impression making. Auto mix heavy and light viscosity polyvinylesiloxanes (PVS) (Ivoclar vivadent AG, Liechtenstein, Italy) was used as impression materials (Fig. 3). This procedure was continued thirty two times to get thirty two impression. Impressions were then poured using type IV dental die stone; all the procedure was done with manufacturer's instructions.

Figure 3: Impression making with dental surveyor.

Crown Construction Using CAD/CAM System

Thirty two stone dies were used to produce 32 crowns by using 4 different CAD/CAM systems. To ensure standardization the same CAD programs parameters was detected for all CAD/CAM system, so the parameters were selected as follows:

Full anatomical tooth 46#; Wet milling; Spacer, 50µm; Marginal adhesive gap, 0; Starting or begin, 50µm; proximal contact, Non; Minimal thickness (Radial), No; Minimal thickness (occlusal), No; Margin thickness, 0; Consider instrument Geometry, No; Remove undercuts, yes [18]. In addition, one type of lithium disilicate glass ceramics material blocks, IPS e.max–CAD (Ivoclar Vivadent, Schaan, Liechtenstein), for CEREC and Inlab, LT A2, C14were used for the fabrication of the all-crowns and new set of milling burs were used for each group.

CERAMILL motion 2

CERAMILL Map 400 scanner and Ceramill^{R} mind software (Amann Girrbach GMbH, Durrenweg 40, Pforzheim, Germany) were used for scanning and designing of the group A restorations. Data were sent to the Ceramill Motion 2 milling engine, 5-axis milling device, Wet grinding, three steps milling with diamond burs: 2.5mm, 1.0mm and 0.6mm (Fig :4).

Figure 4: Final crown design before milling

CEREC in Lab MCXL

InEos Blue scanner and In Lab 4.2 software (Sirona Dental Systems GmbH, Bensheim, Germany) were used for scanning and designing of the group B restorations. CEREC In Lab MCXL milling engine, 4-axis milling device, Wetgrinding, Two step milling with diamond burs: Step bur 12S (1.2 mm) and Step bur 12 (1.0 mm) has been used to produce eight glass ceramic crowns by milling the IPS emax CAD blocks.

CORiTEC 250i

I3D scan scanner and the exocad software were used for the scanning and designing of the group C restoration, which was milled with CORITEC 250i milling engine (Imes-Icore GmbH, Leibozgraben, Germany) , 5-axis milling device, Wet grinding, Three steps milling with diamond grinding pins: 2.5/6.0 mm, 1.0/6.0 mm and 0.6/6.0 mm.

ZIRKONZAHN M5

S600 ARTI Scanner and ZirkonZahn software package were used for the scanning and designing of the group D restoration. IPS emax CAD block has been milled with M5 milling engine (ZirkonZahn GMbH, Italy), 5+1 axis milling device, Wet grinding, Three steps milling with diamond burs: 2.5 mm for rough milling, 1.0 mm for precise milling and 0.6 mm for very precise milling. This procedure was repeated for each die stone with his group following the manufacturer's instructions.

After the completion of the glass ceramic crowns construction for all groups, all crowns were glazed and fired using IPS e-max CAD crystal/glaze (Ivoclar Vivadent, Italy) and fired with digital porcelain Furnace (Programat EP3000), (Ivoclar Vivadent AG, Schaan, Liechtenstein), IPS emax glazing program.

Measurement of the marginal gap

The marginal fit of the crown was calculated by measuring the vertical gap between the margin of the master die and that of the ceramic crown, all crowns were seated on master die to ensure standardization of study**.** Four indentations on the margin at the midpoint of mesial, distal, buccal and palatal surfaces of the master die were done. Four points in each surface were selected for vertical marginal gap measurement by using a stereo-microscope [17,22,24].

A screw loaded holding device (Essentials, china) was used during all measurement steps in order to maintain a seating pressure of(50 N) between all-ceramic crown and the master die [19, 25-27].To apply a uniform static load on the tested crown, a loading cell sensor (SF-400, china) was fixed to the metal die base during measurement procedure.

The measurement were performed on four points on each surface (two on each side of the indentation), first point was determined on the edge of the indentation whereas the second one was (1mm) away from the first point [28]. This was achieved by using a stereo microscope with a digital camera in the eye lens connected with the computer. The digital images were captured and measurements were done using IMAGE J software (Image J 1.32, U.S. NIH, Bethesda, MA, USA) which calculated the values in pixels, mark by drawing a line between the finishing line on the die and the crown margin line [29] (Fig. 5).

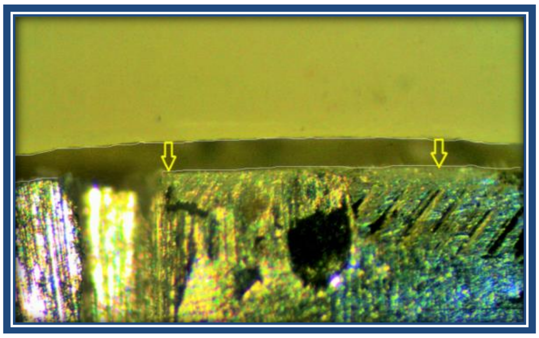

Figure 5: Two points for marginal gap measurement with Image J

The images were observed and captured at 140X magnification and calibrated using a photograph of a (1mm) increment taken at the same focal length and input into (IMAGE J) by the option of set scale, which converted all the calculated reading from pixels to (µm) [24]. Sixteen measurements were obtained from all the four surfaces (mesial, distal, palatal and buccal) of each sample. All measurements were done by the same investigator [17,28].

Statistical analyses

Data were collected and analyzed using SPSS (statistical package of social science) software version 15 for windows 8.1 Chicago, USA.

The following statistics were used:

A- Descriptive statistic: including mean, standard deviation, statistical tables and graphical presentation by bar charts.

B- Inferential statistics

1- One way analysis of variance test (ANOVA) was used to see if there were any significant differences among the means of groups.

2-LSD (least significant difference) test was carried out to examine the source of differences among the four groups.

RESULTS

Total of (512) measurements of vertical marginal gap from four groups were recorded, with 16 measurements for each crown.

Table (1) showed that the highest mean of vertical marginal gap was recorded in group D (39.12 µm ± 3.969) (manufactured with ZirkonZhan CAD/CAM system).While the lowest mean marginal gap was recorded in group C (29.00 µm ±4.761) (Manufactured with Imes-Icore CAD/CAM system).

Table (2) showed that there is a highly significant difference in vertical marginal gap among the four groups.

Table 1: Descriptive statistics of vertical marginal gap for the four groups in (µm)

Source of variation	N	Mean	S.D.	Min	Max
Group A Amann Girrbach system	8	29.3984	±5.569	21.63	37.75
Group B Sirona system	8	33.6484	±5.409	28.88	43.63
Group C Imes-Icore	8	29.0000	±4.761	22.63	35.94
Group D Zirkonzhan system	8	39.1250	±3.969	34.25	46.00
Total	32	32.7930	6.28571	21.63	46.00

Table 2: One way-ANOVA test among the four groups

ANOVA	Sμm of Squares	d.f.	Mean Square	F-test	Sig.
Between Groups	533.887	3	177.962	7.212	.001 (HS)
Within Groups	690.929	28	24.676		
Total	1224.816	31			

Significant at P≤ 0.05

DISCUSSION

Results obtained from the current study showed that the marginal gap of the 4 tested groups was within the clinically acceptable range and with acceptable range of the CAD/CAM fabricated restoration marginal gap, because the mean marginal gap with the range of 100 µm have been proposed as being clinically acceptable with regard to the longevity of restorations[30]. Furthermore, recent studies have reported that vertical marginal gap for CAD/CAM fabricated all ceramic restorations range from 24 to 110 µm [6,15,27]. This study revealed different values of vertical marginal gap among the four groups, which indicated that the type of the CAD/CAM system may affected the marginal adaptation of the all ceramic crown fabricated with CAD/CAM technology, these results were in agreement with other study reported the same result [14,17,18,31,32].

In present study there is a highly significant difference was reported between group D (Zirkonzhan M5) with group A (Ceramill motion 2) and C (CORiTECH 250i) respectively, in addition to the significant differences between group D and group B (CEREC in lab MCXL), the explanation that the various result for different CAD/CAM systems has been resulted during different steps in CAD/CAM processing, scanning, design and milling step. The first three systems (Ceramill motion 2, CEREC in lab MCXL, CORiTEC 250i) used the blue-light scanning technology, which use short wavelength that lead to high level of scanning accuracy as compared to the S600 ARTI scanner of zirkonzhan system which used 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 reduce, this findings were in agreement with that reported by Neves *et al.* [33]. But disagree with another opinion that the variability of cutting tool was another explanation of these differences. An additional to the problem that may associate with scanning device during ceramic restorations constructed with CAD/CAM, the design of the cutting tools may affect the marginal accuracy of all ceramic restoration because it may be larger in diameter than some small parts of the tooth preparation, such as the inner surface of the finish line causing misfits, resulting in inferior marginal adaptation, this will coincided with that reported by Reich *et al.* [34]. In current study, CEREC in lab MCXL system (group B) may provide less marginal fit as compared with group A and group C, these differences may attributed to that CEREC in lab MCXL system was used a 4-axis milling device, while the CORiTEC 250i and Ceramill motion 2 systems were used a 5-axis milling machine. The Five-axis milling machine have been found to improve accuracy and precision of the ceramic restorations by using the machines additional axes; these 2 additional orientation axes allow the machining and processing of complex parts, which cannot be machined with 3-axis and 4-axis orientation machines. The 5-axis machinery has superior cutting conditions to those of the 3-axis type or 4-axis type, which improves the efficiency of the milling by creating efficient tool paths and movement directions which improve the dimensional accuracy, texture, and surface finish of the milled products. This may explain the more accurate fit of restoration that fabricated with 5-axis milling machine [13,35].These findings were coincided with different studies reported that the 5-axis milling device of CAD/CAM system provided better marginal adaptation than 4-axis milling device [14,17,18]. However conflicted with another opinion that the quality or marginal accuracy of the ceramic restoration does not necessarily improve as the number of milling device axes increases, which reported with a study that done by Beuer *et al.* [36]. In this study, the result was revealed that the CORiTEC 250i (group C) may demonstrated smaller marginal gaps than the Ceramill motion 2 (group A) group. In spite of that the both CAD/CAM systems are similar to each other in fabricating steps of lithium disilicate restorations and the milling device movement axes, there is apriority for the CORiTEC system in the result obtained with each systems. These priority may attributed to the efficiency of CAD software and the constant quality of scanners, which may make the restoration fabricated with the CORiTEC 250i system more precise in marginal fit. These results were in agreement with that reported by Agarwal and Ram [37] that the type of the CAD/CAM scanner have been affected the marginal adaptation of the ceramic restoration. Also, software limitations in restorations design, could produce errors in the CAD/CAM technique especially during manual tracing of the finish line, this fact was coincided with other studies [38,39]. But disagree with another studies that reported, the shape of the cutting instrument is various and these differences may affect the final result of ceramic restoration [18,33]. For example, significant enlargement in internal gap would result when the internal cutting bur that used in milling device larger than small parts of the tooth preparation considering manufacturing techniques and tools, this will agree and parallel with that reported by Abduo *et al.* [40].

It can be concluded that better marginal fit values were exhibited by CORiTEC 250i CAD/CAM system. The present study was supported the good performance of CAD/CAM milling process of single- unite lithiμme disilicate FDP while also highlighting the possible effect of different CAD/CAM scanner and software on FDP fabrication.

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