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Evaluation of the modern dental scanners on marginal fidelity of CAD/CAM processed zirconia crowns; light or laser scanner.

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ABSTRACT: The marginal fidelity of zirconia copings fabricated by CAD/CAM technology using two types of dental scanners (light and laser scanner) and the same milling machine were evaluated in vitro hypothesizing that there is no statistical significant difference between the tested groups and the marginal fidelity value for both type of dental scanner were within an acceptable clinical value.

Twenty four zirconia copings were fabricated and divided according to the dental scanner used into two groups; (Group 1 (G1): light scanner [n=12]), (Group 2 (G2): laser scanner [n=12]) and measured by stereomicroscope (12.5X magnification). The mean value of G1 (74.61µm ± SD 6.43), while the mean value of G2 (41.49µm ± SD 6.22); the independent t-test showed that there was statistically highly significant difference ($p<0.01$) between the tested groups and the results of both groups were within an acceptable clinical value.

Within the limitation of this experimental study, marginal fidelity of zirconia based restoration produced by laser scanner is more precise than marginal fidelity of zirconia based restoration produced by light scanner with statistically high significant difference and both groups were within clinical acceptable value. Also, these results indicated that scanning type did affect the marginal fidelity of CAD/CAM ceramic restorations.

KEYWORDS: Dental imaging; Dental scanner; Dental laser scanner; 3D analysis; Dental digital device.

1. INTRODUCTION

New CAD/CAM systems and technologies are increasingly spread in the dental market that lead to most dental companies that are involved with restorative dentistry are already in the market or are in the process of developing a system or material for the CAD/CAM market[1], and because of superior esthetics, durability, biocompatibility with oral tissue and highly improved physical properties all ceramic restorations fabricated by computer-assisted design/ computer assisted manufacturing or machining (CAD/CAM) technology are increasingly accepted by patients and clinicians due to in comparison with existing all ceramic systems used in fabrication fixed partial denture (FPDs). Another advantages accompanied with CAD/CAM generated dental restorations include: the access to new, almost defect-free, industrially prefabricated and controlled materials; an increase in goodness and reproducibility and also data storage balance with a standardized chain of production; an improvement in precision and planning, as well as an increase in efficiency. As a result of concurrent developments in computer hardware and software, new methods of production and new treatment concepts are to be expected, which will enable an additional reduction in costs[2].

All data relating to the dental cast or the oral tissue input into the CAD/CAM machine via dental scanner. Fundamentally, a 3D scanner consists of a light source; one or more cameras and a motion system supporting several axes for installing the scanned object towards the light source and cameras[3], there are two types of light source used in dental scanner its either white light or laser source. White light is a combination of all colors while a laser is single color light sources[4].

The basic principles used in laser and white light scanners are the same but it's impossible to say white light scanner is more precise than laser scanner or visa-versa[3].

Many requirements must be involved for proper function and durability of FPDs, among them the precision of FPDs which is one of the most important factors for successful FPDs. One of the most common reasons for failure of FPDs is inappropriate gap or imprecise restorations and one of the basic problems which may be affecting in the precision of the dental scanner is type of scanner; some type of light scanner required a powder painting for scanning to reduce the amount of reflected light from a high reflective material which led to lose of the data acquired at the same time the precision of dental scanner may be affected by the thickness of the powder layer or the distribution it. The presence of marginal discrepancies in a restoration exposes the adhering agent to the oral environment. The larger marginal discrepancy lead to more rapid rate of cement dissolution due to subsequent exposure of the dental luting agent to oral fluids[5]. In vivo studies have provided evidence that a large marginal discrepancy in a fixed restoration accompanies with a higher plaque index and reduced periodontal conditions [6,7]. Many studies have focused investigating the marginal gap of zirconia crowns fabricated with the different CAD/CAM systems currently available in the market, one of these studies reported that, achieving a gap width below

100μm is desirable and considered clinically acceptable [8], while McLean and von Fraunhofer found that 120μm was the maximum tolerable marginal opening [9, 10]. In contrast, marginal gaps of 17-118 μm have been reported for CAD/CAM fabricated ceramic crowns [11, 12, 13, 14]; however, there is no consensus on what considers a clinically acceptable maximum marginal gap width. The values reported in the literature have a wide range (50-200μm) [15, 16]. Moreover, there is no standardization in the methodology used, which makes data comparison on difficult [17, 18, 19]. In general, it is very difficult to make comparison in the results of different all-ceramic systems; and the chances of producing errors that affect in the precision of fit are greater in an in vivo study than in an in vitro study. For example, the heights and taper values of abutment are always different between the two types of studies. Also, it is very difficult to compare the marginal gaps among different studies when the manufacturing procedures are different. Although many researchers have reported on the marginal gaps all-ceramic crowns [20, 21], whereas a survey of the literature shows that no articles were found that address the precision of marginal gaps of light and laser scanner. Therefore, the purpose of this investigation was to measure the marginal fidelity of zirconia based restorations to the working dies fabricated using two different types of dental scanner (light and laser scanners). The working hypothesis states that; both dental scanners produce marginal fidelity below than 120μm and, there is no significant difference between both dental scanners.

2. METHODS:

2.1. Die preparation:

Single standard master abutment was designed and prepared by CNC milling machine (imes-icore/ competence in CNC and Dental solutions, 450i, Germany). It should be mentioned that, the master die must be designed to has anti-rotational groove which was extended from the occlusal surface and directed toward the finish line and ended away from the finish line about 2mm and the depth of this groove was 2mm to prevent coping rotating on the master die, Fig (1). This model was made from poly ethyl ethyl ketone (PEEK) blank (20mm height, mm diameter- breCAM. BioHPP blank/ the new material class for prosthetic bredent/ Germany). The prepared model was seen under stereomicroscope with a magnification 12.5 X for final observation before coping construction.

Fig. 1: Master die with anti-rotation groove.

2.2. Samples grouping:

Two CAD/CAM systems were used to produce zirconia copings, each system composed from:-

a- **Dental scanner:** The marginal fidelity of zirconia copings produced by two types of dental surface digitizer or scanner (light and laser scanner) under evaluation in this study.

2.3. Light scanner (Maestro 3D, Italy):

The PEEK master die was placed on the special movable base inside the scanner unit. A 3D data acquired by passing rays of light through a set of ruled lines and a lens system. The light was reflected back to the scan head where it was sensed by a 2 CCD sensors which was act a receptor.

2.4.Laser scanner (D18/ 3 Shape, Denmark):

The same PEEK master die was placed on the special movable base inside the scanner machine to obtain a 3D data. The die was rotated with a movable base while the signal created by a laser light reflected by the die was picked up by the 2CCD arrays.

The reflected light and laser rays converted to a digital signal and relayed to the computer.

There was special CAD software for each type of dental CAD/CAM system which was used for processing the digital data to produce a virtual model.

- ExoCAD software was used with Maestro 3D CAD/CAM machine (Maestro 3D, Italy).
- 3 Shape dental Manger Software was used with 3 Shape CAD/CAM machines (3Shape, Denmark).

The same design was programmed for both type of CAD/CAM system. The simulated die or cement spacer was fixed at 0.05 mm; no cement spacer was included for the margin, starting 1mm away from the margin. The coping thickness was 0.7 mm.

In this study, twenty-four zirconia samples were prepared, twelve samples for each group, the same CAM machine (imes-icore/ competence in CNC and Dental solutions, 450i, Germany) was used for both CAD/CAM systems. Designed copings were milled with diamond burs from raw stage zirconia blanks of partially stabilized zircon powder Zirconia blanks (98mm height X 14mm diameter), (partial sintering blank, VITA InCeram ®YZ Disc), (VITA Zahnfabrik, Spitalgasse 3.D- 79713 Bad Säckingen/ Germany).

Prior to dense sintering, the copings were freed from dust caused by grinding. The copings milled approximately 25% greater in size, were shrunk to their original size by dense sintering furnace (MiHM-VOGT, HT, Germany) (start point: room temperature, heating rate: 8˚C/min, final temperature: 1480˚C). The coping obtained the desired physical properties through sinter firing. The marginal fidelity of the copings was measured in this study without veneering. The copings fabrication process for both CAD/CAM groups was performed by the same operator.

2.5. Measuring procedure:

The marginal fidelity was established as the vertical marginal discrepancy according to the terminology reported by Holmes et al., [17] defining that as the distance from the edge of the crown to the edge of the finish line. The marginal gap was measured using a stereomicroscope at 12.5 X magnification (Leica, LEICA EZ4D, MEL SOBEL Microscopes LTD., Italy), each coping fitted on the master die and fixed in its position by special holder oriented to the microscope's plate during measuring procedure. The measurements were done via a personal computer, attached to a stereomicroscope by using Intervideo Software and a camera. The camera produced an image of the marginal gap on computer monitor. The marginal fidelity was measured by perpendicular moving a gap from one end to the other end of a measuring distance. The distance was counted in microns on a screen with the size of 640 X 480 pixels. Measurements of the marginal fidelity were made at five equidistant points on each of the four axial walls for a total of twenty marginal adaptation evaluation sites for each coping and the mean value was determined. Then, the mean value was determined for each group.

2.6. Statistical analysis:

An independent t-test was used to determine the differences in marginal fidelity between the light scanner and laser scanner techniques.

3. RESULTS

Table (1): represent the marginal fidelity of light and laser scanner which contain mean, Std. deviation and Std. error of mean.

Table (1): The marginal fidelity of light and laser scanner.

Groups		N	Mean	Std. Deviation	Std. Error Mean
Marginal fidelity (micron)	Light	12	74.6059	6.42714	1.85535
	Laser	12	41.4887	6.21598	1.79440

The result of this study shows that, the mean value of marginal fidelity test of the light scanner by micron is (74.61 ± SD 6.43), and the mean value of the marginal fidelity of the laser scanner by micron is (41.49 ± SD 6.22), while their mean difference is (33.12; SE= 2.58). The independent (t-test) shows that there is highly significant difference between the tested groups ($p<0.001$).

4. DISCUSSION

In dentistry, the attention in CAD/CAM system is growing increasingly because of these systems can cost-save associated with manpower and labor-intensive laboratory processes related to the ordinarily means of producing dental restorations. Also, these systems are used nowadays in the manipulating of high-strength ceramics, such as zirconia or alumina, include the ability to produce a precise fit and customized design, and time saving production process considers as a main advantages of this technology for dental restorations. In addition, the CAD/CAM components are excessively homogenous and biocompatible [22]

In this study, we focused on the marginal fidelity of the zirconia coping produced by two types of dental scanners. The two scanning systems follow a different approach; one of them is light scanner and other is laser scanner, both two scanning systems are optical scanner. The PEEK die was used as a master die to measure marginal fidelity; the advantages are namely standardized preparation and lack of wear during the manufacturing process and measurement. The margin designs of PEEK die included 1.0mm wide rounded shoulder around the entire circumference. This design is recommended for the preparation of all ceramic crowns [23] .

Also, impression material not used for duplicating the master die because of a distortion in dental impression materials is essential for restorative dentists. Some materials have a greater tendency to distortion [24, 25], and the manipulation of mixing materials can also affect their dimensional accuracy [26]. This information commonly originates for in vitro research where the standards for measurement accuracy are more precise than clinical. In vitro results should be careful viewed because in vitro testing, the clinical situation cannot be completely simulated. However, an in vitro study has the advantage of providing standardized conditions with consideration the design of preparation, fabrication techniques and experimental performance, resulting in more repeatable assessments [27]. The fit of the copings was measured without veneering because the coping mainly determines the overall fit of a veneered crown [28, 29] not the veneering itself.

In the current study, silicone impression material didn't used for the marginal measurement, because of silicone impression material famed as a high viscosity material affects to block even in the cement space created in the inner surface of coping, resulting in an increase in the gap [30], and the copings were seated on the PEEK die without cementation by a special device. The device was developed to position the coping and the PEEK model precisely to prevent the coping from rebounding as well as enabling the static force to be applied parallel to the long axis of the tooth and to maintain the force applied [13]. Measurements of marginal discrepancies were made by stereomicroscope at five equidistant points on each of the four axial walls for a total of twenty marginal adaptation evaluation sites for each coping. According to the terminology reported by Holmes et al. [17], Marginal gap (MG) was defined as the vertical marginal discrepancy in another word MG was defined as the perpendicular distance from the internal surface of the coping to the margin of the preparation.

The minimization marginal gap of crown and fixed partial denture is an important object in prosthodontics. Smaller marginal gaps produce less gingival irritation [31, 31] and cement washout [33, 34], improving the clinical outcome and longevity of the restoration. The absolute value of the clinical acceptable vertical marginal gap has been discussed in the literature with proposed values ranging from 39 to 120µm [35]. An absolute value has not been appointed as the benchmark for clinical acceptability, because clinical identification an quantification of the gap can be difficult [36] depending on location [35] and instrumentation used [21,37]. Therefore, there are no clear standards to determine the acceptance range in clinical application. McLean et al., reported that a marginal gap of less than 120 µm achieved a favorable clinical results [38, 39]. This emphasizes the need for fabrication techniques that can produce restorations with minimal vertical marginal gaps in a repeatable fashion [40]. Several researchers have reported marginal gaps both in vitro and in vivo [5, 41, 42, 43]. McLean and von Fraunhofer reported that, the clinical acceptable marginal gap was within 120 µm [38]. Most authors agree that marginal opening or inaccuracies of less than 120 µm seem to be in the range of clinical acceptance with regard to longevity [29, 38, 44, 45]. While, other authors found that, marginal discrepancies in the range of 100 µm have been proposed as being clinically acceptable with regard to the longevity of restoration [19, 46]. For different all ceramic systems the marginal gap reported in several studies was within the range of 1-161 µm [28, 29, 47, 48]. For CAD/CAM restorations, the generally acceptable marginal gap discrepancies are between 50 and 100 µm [49, 50, 51, 52]. Nakamura et al., reported that a marginal gap of less than 100 µm does not affect the treatment results if there is little marginal leak, and resistant resin cement is used for crown placement [53]. The fit of zirconia copings varies according to the preparation angles [54, 55], finish line design [52, 56]. However; there is not enough evidence to decide which design of margin offers better marginal adaptation [57]. Therefore, achieving a gap width below 100µm is desirable and considered clinically acceptable [48]. These variations may be due to different measurement techniques, the type of restoration (crown [13, 58, 59], inlays [60] or onlays [13, 61]) and the restorative material (ceramic [58, 60, 61, 62] or resin [59]). These reports revealed that the clinical allowance range differs depending on researchers [63]. Restoration longevity is related to marginal fit, as defective margins have been reported as the cause of approximately 10 % of restoration failure [64].

The results of current study showed that the greatest marginal fidelity produced with the laser scanner with mean value (42 µm) compared with marginal fidelity produced with the light scanner with mean value (73 µm); also, t-test shown that there is high statistical differences between the tested groups, but the mean values for both groups considered clinically acceptance. Both groups were fabricated under identical condition but these finding may be due to the computer could not clearly read the image captured by light scanner, resulting in a rough surface and model distortion this result might be occurred due to White light is a combination of all colors, and not all these colors can be in perfect focus [65]. So that, white light scanners suffer from blur due to the fact that the different color components that exist in white light are refracted slightly differently [3].

This phenomenon is called chromatic aberration 1. Its effect can be minimized by careful design and assembly of a scanner's lens system, but it will limit the accuracy of a white light scanner. Lasers, in contrast, are single color light sources and hence don't suffer from chromatic aberration [4].

The result of this study in agreement with [14, 66, 67, 68] who found that cerec inLab laser scanning provided more accurate data than cerec intraoral 3D measuring camera under the conditions of these two different evaluations. The two scanning systems follow a different approach, and disagreed with [27] who found that the Everest CAD/CAM system's specimens showed significantly lower marginal gap mean values than those of cerec inLab system's specimens.

So that, the first branch of null hypothesis is proved because of both dental scanners produce marginal fidelity below than 120µm; while, the second condition of the null hypothesis is rejected because of the chance of null hypothesis will be small because of there is highly significant difference between the tested groups lead to reject the null hypothesis.

5.CONCLUSION

Within the limitation of this experimental study, marginal fidelity values of zirconia based restoration produced by laser scanner is more precise than marginal fidelity value of zirconia based restoration produced by light scanner with a highly significant differences and both values within clinical acceptable value. Also, these results indicated that scanning type did affect the marginal fidelity of CAD/CAM technology.

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