Marginal and Internal Fitness of Full Contour CAD/CAM Fabricated Zirconia Crowns using Different Digital Intra-oral Scanners (An *In vitro* Study)

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The objective of this *in vitro* study was to evaluate and compare the marginal and internal gaps of full contour zirconia crowns using three different digital intra-oral scanners with different software design. Samples were distributed into five groups eight for each according to the type of scanner and software design used during milling procedure as follows: Group A: CEREC Omnicom + InLab SW 16.1. Group B: TRIOS3 + software of 3Shape dental system. Group C: TRIOS3 + InLab SW 16.1. Group D: CS3600 + software of exocad program. Group E: CS3600 + InLab SW 16.1. The crowns of all groups were milled with the same milling machine inLab MCX5. The marginal and internal fitness of crown was evaluated by direct measurement of cement thickness through sectioning procedure. The data were then analyzed using One-way ANOVA test and Tukey's (HSD) test. The results of this study showed that the least marginal gap was recorded in Group C (59.038, ±9.667) followed by Group D (63.405, ±6.038), Group E (64.674, ±6.478), Group B (70.112, ±4.954) and Group A (81.703, ±7.428) respectively. While for the internal gap, the least internal gap was recorded at Group C and Group B (119.691, ±4.107), (119.192, ±4.068) respectively followed by Group A (123.254, ±6.777), Group D (123.485, ±5.353) and Group E (130.816, ±3.926). As a conclusion, the intra-oral scanner that provides more accurate seating of monolithic crown restoration was TRIOS3.

Keywords: Intraoral scanner, Digital impression, STL datasets, CAD/CAM, All ceramic restoration, marginal fitness, internal fitness.

The Marginal and internal fitness play an important role in the longevity of crown restoration. A number of factors might affect this fitness such as: preparation design, location of the margin (supra or subgingival), quality of milling device, milling bur, cement spacer and image capturing system[1, 2, 3]. In the fabrication of a prosthesis using a CAD-CAM workflow, long term success depends on the system involved in scanning the tooth surface and in prosthesis design which determine the marginal and internal fit of the restoration to the abutment tooth[4].

The scanning of the recommended area for reconstruction is done with intra-oral scanner instead of conventional impression that enormously contributes to easier workflow and assists in preparation and cementation of crown in one session[2, 5]. The advancement of intra-oral cameras for high precision scanning, sophisticated software and milling standardization has reduced the marginal and internal discrepancy of crowns fabricated by CAD-CAM systems[2]. Modeling and milling depends mainly on the data acquired from the optical impression, so the use of most precise intra-oral scanners would be favorable to improve the quality of internal and marginal adaptation of restorations[6].

Digital work helps in better restoration fitness because the scanned teeth can be magnified

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greatly and allows better restoration design besides that any area look to be insufficiently reproduced can be re-examined and rescanned[2, 5].

MATERIALS AND METHODS

Forty sound human maxillary first premolar teeth of comparable size and shape extracted for orthodontic purpose from patient age (18-24) years were selected and collected in this study. Only sound teeth which are free from caries, cracks and enamel defects were selected[7]. The teeth were stored in deionized distilled water to keep them hydrated during all stages of the study[8]. All teeth were embedded in cold cure acrylic resin (Fig.1) 2mm below cemento-enamel junction according to the level of supporting alveolar bone[7].

All teeth were prepared to receive monolithic zirconia crown, the preparation was done by one operator to avoid inter-examiner differences[9]. Tooth preparation was done with aid of modified dental surveyor to which high speed

Fig. 1. Tooth sample

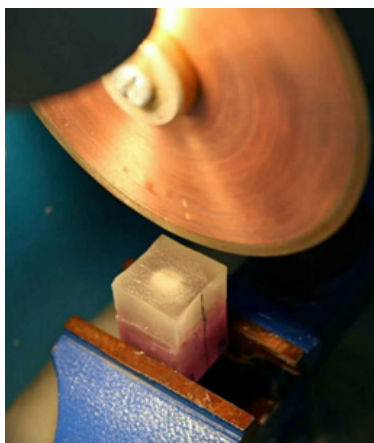**Fig. 2.** The beginning of sectioning procedure

hand-piece with water/air coolant was adapted to its' horizontal arm in such away so that bur will be kept parallel to the long axis of the tooth during axial wall preparation. A horizontal table (movable) was used to secure the acrylic block to ensure that long axis of tooth will be parallel to the bure and maintain the same convergence angle of preparation[10]. Teeth were then prepared for all ceramic restoration following the guidelines recommended for inCoris TZI C with the following features: (planner occlusal reduction, axial reduction 1mm-1.5mm, deep chamfer finishing line 0.8mm in depth, 6^0 convergence angle, and 4mm occluso-gingival height), these preparations were made by rugby ball bur (NO. 804647), round end tapered fissure bur (NO. 903319) for preparation and (NO. 931749) for finishing.

All fabrication procedures including model scanning, software designing, milling and sintering protocols were done according to the manufacturer instruction of zirconia (inCoris TZI C) and CAD-CAM milling system used. For the purpose of standardization a single scanning protocol was applied to all the three types of scanners, and a three dimensional digital model was produced and exported as STL file image.

The latest versions of intraoral scanners (CEREC Omnicam, Trios3, CS3600) were selected for this study, since in digital dentistry modeling and milling depend essentially on the data acquired through the optical impression. Sirona InLab software 16.1, 3Shape design software and exocad were used to designate crown restoration. In order to standardize the dimension and shape of final crown restoration for all specimens, one crown was
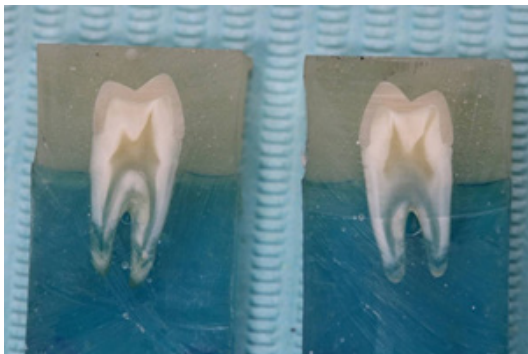

Fig. 3. Sectioning of tooth sample with efficient water coolant

considered as a reference for all the other groups and the fabricated crown was scanned and used to design the other monolithic crowns[11].

The crowns of all groups were milled by the same milling machine MCX5 (Sirona, Germany). The design of all groups was exported to CAM inLab SW16.1. The crowns after milling procedure were sintered into inFire HTC speed furnace (Sirona, Germany). Custom made holding and cementation device was used in this study to secure zirconia crown on natural tooth sample and to maintain seating force during cementation procedure[12]. A modification was added to this device, this modification allows more accurate seating of crown restoration for all specimens by allowing single standardized direction of applied load (5kg) that is perpendicular to the occlusal surface of crown restoration during cementation.

In this study, the fitness of crown was evaluated by direct measurement of cement thickness through sectioning procedure which is very beneficial tool that helps to reduce chance of software and repositioning error[13], and allow uninterrupted view of the gap[14]. This procedure require embedding of tooth sample in acrylic resin to reduce chance of sample destruction[15].

In order to make standardized cutting area through the specimen during sectioning procedure, a single seating position was chosen in sectioning machine for all specimens. A suctioning blade of 0.3mm thickness was used (Fig. 2, 3, 4). A digital microscope was used to measure the cement space between the zirconia crown and tooth at predetermined points. The magnification of 230X was used in this study because it was large enough to view the marginal and internal gap accurately. Eleven different predetermined measuring points were selected for each sample, these points indicate the four measuring different areas: (two marginal, two chamfer, four axial, three occlusal) (Fig. 5)

RESULTS

Descriptive statistics of the gap at the different areas of the five different groups measured in ¼m were listed in Table 1. The highest mean value of the gap was recorded at the occlusal area (170.652, ±8.579) of Group D, while the lowest mean value of the gap was recorded at the marginal area (59.038, ±9.667) of Group C. Table 2 the table also showed that in general, the lowest marginal and internal gaps (59.038, ±9.667) (119.691, ±4.107) was recorded at Group C while the highest marginal gap (81.703, ±7.428) was recorded in Group A and the highest internal gap (130.816, ±3.926) was recorded in Group E.

DISCUSSION

The quality of prosthetic restorations is ensured through the exactness of internal and marginal fit. CAD-CAM technology has allowed fabrication of more precise ceramic crowns than conventional methods. Marginal and internal fitness of CAD-CAM restoration will depend on the quality of 3-dimentional (3D) image. The important part in the planning of a prosthesis is making an accurate virtual cast of the prepared tooth[16].

Fig. 4. The two sections (mesial and distal) after completion of sectioning procedure

Fig. 5. Microscopical image at low magnification (30x) showing the measuring points of Bucco-palatal section

When comparing the marginal and internal fitness of monolithic zirconia crowns using three different intra-oral scanners and single design software the results revealed that the lowest marginal gap was recorded in Group C (Trios3) (59.038, ±9.667) followed by Group E (CS3600) (64.674, ±6.478) and Group A (Omnicam) (81.703, ±7.428). While the internal gap Group C (Trios3) recorded (119.691, ±4.107) followed by Group A (Omnicam) (123.254, ±6.777) and Group E (CS3600) (130.816, ±3.926). However when comparing the marginal and internal fitness of monolithic zirconia crowns using different software design (Sirona inLab SW16.1, 3shape dental system, exocad), the results revealed that the lowest marginal gap was recorded in Group D (CS3600) (63.405, ±6.038) followed by Group B (Trios3) (70.112, ±4.954) and Group A (Omnicam) (81.703, +-7.428). While the lowest internal gap was recorded in Group B (Trios3) (119.192, ±4.068) followed by Group A (Omnicam) (123.254,

±6.777) and Group D (CS3600) (123.485, ±5.353), these findings may be contributed to:

1.   The different working principles (technological aspect) used by various intra-oral scanners could lead to different scan precision[17]. Trios3 system works with concept of ultrafast optical sectioning and confocal microscopy, in which the variations in the focus plane are recognized by the system[16, 18, 19]. Carestream 3600 system works according to the principle of active 3D video, it is LED light scanner[6]. CEREC Omnicam works with active triangulation technique and emits white light of different wavelength that focused on the same point. If the surface presents an uneven light dispersion it might decrease the scanning accuracy[16, 18, 19].

2.   All scans were exported as STL files, in this file format a scanned surface is approximated using triangle from the point cloud generated by 3Dscanner. Scanners with high-definition sensors generated more points and a shorter point to point

Table 1. Descriptive statistics of the gap at the different
areas of the five different groups measured in μm

Groups	Areas	N	Mean	S.D.	Min.	Max.
Group A	Marginal	8	81.703	7.428	73.913	95.652
	Chamfer	8	136.299	8.501	121.957	147.570
	Axial	8	90.117	6.043	79.710	96.377
	Occlusal	8	143.347	10.408	134.198	156.521
	Internal	8	123.254	6.777	115.611	131.779
Group B	Marginal	8	70.112	4.954	62.319	75.362
	Chamfer	8	93.898	4.382	88.130	102.480
	Axial	8	100.274	6.221	90.580	107.250
	Occlusal	8	163.406	5.943	153.620	169.080
	Internal	8	119.192	4.068	112.826	124.336
Group C	Marginal	8	59.038	9.667	47.826	71.014
	Chamfer	8	113.178	5.624	102.479	120.925
	Axial	8	91.298	5.368	81.884	96.376
	Occlusal	8	154.597	7.386	144.927	165.217
	Internal	8	119.691	4.107	113.862	125.666
Group D	Marginal	8	63.405	6.038	50.724	69.565
	Chamfer	8	92.231	5.586	84.033	98.380
	Axial	8	107.572	5.515	100.000	115.942
	Occlusal	8	170.652	8.579	159.420	183.575
	Internal	8	123.485	5.353	115.772	130.099
Group E	Marginal	8	64.674	6.478	53.623	69.565
	Chamfer	8	149.363	6.239	141.421	157.818
	Axial	8	89.221	9.795	74.637	100.000
	Occlusal	8	153.864	9.392	143.961	168.115
	Internal	8	130.816	3.926	124.837	134.853

Table 2. One-way ANOVA test for comparison of the gap among the different areas of each group

Groups	ANOVA	Sum of Squares	d.f.	Mean Square	F-test	p-value
Group A	Between Groups	23734.687	3	7911.562	116.231	0.000(HS)
	Within Groups	1905.892	28	68.068		
	Total	25640.579	31			
Group B	Between Groups	38074.267	3	12691.422	431.094	0.000(HS)
	Within Groups	824.320	28	29.440		
	Total	38898.588	31			
Group C	Between Groups	38608.882	3	12869.627	246.946	0.000(HS)
	Within Groups	1459.227	28	52.115		
	Total	40068.109	31			
Group D	Between Groups	49295.309	3	16431.770	382.860	0.000(HS)
	Within Groups	1201.719	28	42.919		
	Total	50497.027	31			
Group E	Between Groups	47092.224	3	15697.408	236.898	0.000(HS)
	Within Groups	1855.343	28	66.262		
	Total	48947.567	31			

One-way ANOVA test was used for comparison of the gap among the different areas of each group as listed in Table2, in which there is a statistically highly significant difference of the gap among the different areas of each group (P Value <0.01).

distance thus producing more triangles for surface reconstruction that would result in a more detailed representation of the scanned body. The Trios3 had the lowest number of triangles[20].

3. The physical resolution of the scanning system and further the post processing of the data[21].

4. The fit of restoration was influenced by the quality of design program, by the translation of the design code into the numerically controlled milling process and by the quality of the milling device themselves (the use of small bur diameters and higher degree of freedom of milling axis lead to smaller gap) [22].

The above findings were in agreement with Gray D. and Sebastian B (2015), Bohner *et al.* (2017), Carbajal Mejia *et al.* (2017), kocaagaoglu *et al.* (2017), Nedelcu *et al.* (2018)[7, 16, 18, 20, 23].

CONCLUSION

As a conclusion, the intra-oral scanner that provides more accurate seating of monolithic crown restoration is TRIOS3.

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