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COMPARISON OF ACCURACY OF SINGLE CROWNS FABRICATED FROM MRI BASED DIGITAL IMPRESSIONS WITH THOSE OBTAINED BY OPTICAL SCANNERS-AN INVITRO STUDY

Prosthodontics

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ABSTRACT

MRI based scanning can record hard tissue behind soft tissue with a clear demarcation between them. Hence, this type of scanning may be considered a potential alternative for making digital impressions of tooth structure, particularly in the case of sub-gingival tooth preparations. This study aimed to analyze the accuracy of MRI based impressions made from teeth with sub-gingival preparation compared with impressions obtained through digital optical scanning. Twelve extracted human teeth (Maxillary pre-molars) were prepared for crowns with a chamfer finish line. These samples were divided into four groups with three samples each. Samples under group 1 and group 2 were devoid of gingival coverage. whereas, samples under group 3 and group 4 were covered with porcine gingiva (thickness ranged between 2mm and 4mm). Samples under groups 1 and 3 were subjected to optical scanning using CS2 extra-oral scanner (STRAUMANN), while samples under group 2 and 4 were subjected to MRI based scanning (SIEMENS). The dataset obtained from both scanners were converted to STL files. These STL files were utilized to 3D print twelve all-ceramic crowns. The accuracy of crowns was compared to evaluate the marginal and internal fit. The values were statistically analyzed using the student t-test. The digital impression of sub-gingivally prepared teeth was achievable using MRI scanners. They were able to scan teeth with accuracy better than that of optical scanners when samples were covered with gingiva.

KEYWORDS

INTRODUCTION:

An accurate and precise impression, especially of the tooth margins, is related to the survival of crowns and bridges because large marginal gaps between teeth and restorations may lead to secondary caries and periodontal disease [1,2,3]. Impression of sub-gingival margins could be made possible only with adequate gingival retraction. This procedure can be performed employing retraction cords or electro-surgery, which are usually painful for patients, in addition to requiring local anaesthesia and being time-consuming [4]. Moreover, for better results during tooth impression making, either with conventional impression materials or by digital scanning, the surface has to be dry. Oral fluids such as saliva and sulcus bleeding may jeopardize and delay the obtainment of a successful and accurate tooth impression. Although the techniques for taking conventional impressions are well known and have advantages such as the need for simple equipment and relatively low cost [5] they present potential disadvantages because all abutment teeth must be completely recorded in only one impression[6]. Hence for arches with multiple abutments, 50%-64% of the impressions made are clinically unsatisfactory. Due to various advancements in digital dentistry, there is also the chance of making digital impressions with intra-oral scanners. This is a time-saving technique with some remarkable resources, such as an all-time display, immediate control of dental preparation shape and impression quality. The digital workflow also eliminates the disinfection and storage of impressions, and the physical model can be bypassed in most cases. Despite the significant advantages of digital impressions, all currently commercially available scanners are optical systems unable to copy dental preparations through the gingiva and thus in the same way as conventional impressions, require gingival displacement to take a correct sub-gingival impression [6]. Hence, in this study, MRI based impressions were used to capture the tooth structure beneath the gingiva. This would eliminate all the disadvantages associated with conventional and digital impression techniques.

Material and Methods:

A total of 12 recently extracted caries-free maxillary premolars of approximately the same size and anatomy were selected. Patients' informed consent was obtained following which teeth were collected and preserved.

Preparation of samples: The teeth were prepared with chamfer finish lines using round end tapering diamond (TR 11-MANI DIAMOND BUR). The prepared teeth were then embedded in a centralized position in a sample holder made of plastic using a cold-polymerizing acrylic resin (DPI-RR COLD CURE DENTURE REPAIR MATERIAL)

Preparation of groups:

The prepared samples were divided into four groups with three samples each. Samples under group 1 and group 2 were not covered with porcine gingiva. Samples under group 3 and group 4 were covered with porcine gingiva near the margins of the prepared teeth.

Digital impressions:

Samples under group 1 and group 3 were scanned using a digital optical scanner (CS2 - STRAUMANN). Samples under group 2 and group 4 were scanned using MRI scanner (SIEMENS). Data set obtained from optical scanners were in STL format. whereas, data obtained from MRI scanners were in DICOM format. Files in DICOM format was converted to STL format using the software (3D SLICER, MESHLAB). All the STL files were utilized to 3 D print (SIRONA CEREC MC) all-ceramic crowns (AIDITE ZIRCONIA-ST MILLING BLANK).

Replica technique:

This technique was used to evaluate the marginal and internal fit values of crowns. To register marginal and internal spaces between the crown and tooth, crown cementation was simulated with low consistency polyvinylsiloxane (DENTSPLY REPROSIL VPS). The crowns filled with impression material were positioned on the respective teeth and an occlusal force of 20 N, controlled by a tension gauge (CORREX) was applied for30 s. After the material was set (6minutes), the crowns were separated from the prepared teeth leaving a thin layer of silicone attached to the teeth. The silicone layer was stabilized and captured by employing a customized tray filled with high consistency polyvinylsiloxane (DENTSPLY AQUASIL). These samples were sectioned and 8 slices were made from each replica. Thus a total of 96 slices were obtained for four groups.

Microscopic examination:
Ninety-six samples corresponding to 12 crowns/silicon replicas with 8 slices each were examined under a light microscope (OLYMPUS) at 100 X magnification for internal and marginal fit. Four points were used as standard reference points; Point1 along the occlusal surface, 500 µm distance from the center; Point 2: at the angle between occlusal and axial surfaces; Point 3: midpoint of the axial wall; and Point 4:at the margins. The thickness of the samples at all four points were measured.

Statistical analysis:
Data obtained were tabulated in an excel sheet. It was then analyzed using SPSS software (version 17). Data were assessed for normality and homogeneity of variances using the Kolmogorov-Smirnov test, Shapiro-Wilk test, and Levene's test. ANOVA test was performed to evaluate the statistical difference between groups. Games-Howell test was performed as a Post- Hoc test.

Result:
Data assessed for normality and homogeneity of variance using the Shapiro -Wilk test, Kolmogorov-Smirnov test and Levene's test were found to be normally distributed. ANOVA test and Post Hoc test revealed that group 1,2,3 and 4 were statistically significant from each other($p<0.05$) in all the parameters.

Table 1: Test of Homogeneity of Variances

		Levene statistics	Diff 1	Diff 2	Sig.
p1	Based on mean	5.929	3	44	.002
	Based on median	4.090	3	44	.012
	Based on mean and median adjusted with df	4.090	3	23.614	.018
	Based on trimmed mean	5.317	3	44	.003
p2	Based on mean	11.559	3	44	.003
	Based on median	6.188	3	44	.000
	Based on mean and median adjusted with df	6.188	3	44	.001
	Based on trimmed mean	11.530	3	24.112	.003
p3	Based on mean	26.141	3	44	.000
	Based on median	25.785	3	44	.000
	Based on mean and median adjusted with df	25.785	3	44	.000
	Based on trimmed mean	26.126	3	22.476	.000
p4	Based on mean	8.227	3	44	.000
	Based on median	7.210	3	44	.000
	Based on mean and median adjusted with df	7.210	3	25.650	.001
	Based on trimmed mean	8.141	3	44	.000

Table 2: ANOVA

		Sum of squares	df	Mean square	F	Sig.
p1	Between groups	3963214.118	3	1321071.373	65.688	.000
	Within groups	884894.499	44	20111.239		
	Total	4848108.617	47			
p2	Between groups	258535.892	3	86178.631	87.590	.000
	Within groups	43291.088	44	983.888		
	Total	301826.980	47			
p3	Between groups	830266.432	3	276755.477	246.198	.000
	Within groups	49461.125	44	1124.116		
	Total	879727.557	47			
p4	Between groups	207739.987	3	69246.662	142.165	.000
	Within groups	21431.766	44	487.086		
	Total	229171.753	47			

Multiple comparisons
Games-Howell

Table 3: POST-HOC TEST

Dependent Variable	(I) groups	(J)groups	Mean difference (I – J)	Std.Error	Sig.	95% Confidence interval Lower bound	Upper bound
p1	Gr1	Gr2	37.88833	65.05694	.936	-142.9471	218.7238
		Gr3	156.44833	69.44864	.140	-36.4074	349.3040
		Gr4	714.85083*	48.57264	.000	568.7453	860.9563
	Gr2	Gr1	-37.88833	65.05694	.936	-218.7238	142.9471
		Gr3	118.56000	65.91240	.301	-64.7360	301.8560
		Gr4	676.96250*	43.36627	.000	546.5349	807.3901
	Gr3	Gr1	-156.44833	69.44864	.140	-349.3040	36.4074
		Gr2	-118.56000	65.91240	.301	-301.8560	64.7360
		Gr4	558.40250*	49.71259	.000	408.8645	707.9405
	Gr4	Gr1	-714.85083	48.57264	.000	-860.9563	-568.7453
		Gr2	*	43.36627	.000	-807.3901	-546.5349
		Gr3	-676.96250	49.71259	.000	-707.9405	-408.8645
p2	Gr1	Gr2	-26.54000	16.90187	.419	-74.3177	21.2377
		Gr3	-184.58667	10.39527	.000	-213.8057	-155.3677
		Gr4	*	9.19710	.089	-50.6145	2.9929
			-23.81083				
	Gr2	Gr1		16.90187	.419	-21.2377	74.3177
		Gr3	26.54000	15.60052	.000	-203.2488	-112.8445
		Gr4	-158.04667	14.82906	.998	-41.3071	46.7655
			*				
	Gr3	Gr1	2.72917	10.39527	.000	155.3677	213.8057
		Gr2		15.60052	.000	112.8445	203.2488
		Gr4	184.58667*	6.50304	.000	142.2698	179.2818
			158.04667				
	Gr4	Gr1	160.77583*	9.19710	.089	-2.9929	50.6145
		Gr2		14.82906	.998	-46.7655	41.3071
		Gr3	23.81083	6.50304	.000	-179.2818	-142.2698
			-2.72917				
			-160.77583				
			*				
p3	Gr1	Gr2	239.52500*	18.81503	.000	185.1814	293.8686
		Gr3	304.17417*	8.26046	.000	280.6888	327.6595
		Gr4	335.42333*	7.60634	.000	313.1291	357.7175
	Gr2	Gr1	-239.52500	18.81503	.000	-293.8686	-185.1814
		Gr3	*	17.80026	.015	11.8874	117.4110
		Gr4	64.64917*	17.50629	.001	43.4966	148.3000
			95.89833*				
	Gr3	Gr1		8.26046	.000	-327.6595	-280.6888
		Gr2	-304.17417	17.80026	.015	-117.4110	-11.8874
		Gr4	*	4.54972	.000	18.3604	44.1380
			-64.64917*				
	Gr4	Gr1	31.24917*	7.60634	.000	-357.7175	-313.1291
		Gr2		17.50629	.001	-148.3000	-43.4966
		Gr3	-335.42333	4.54972	.000	-148.3000	-18.3604
			*				
			-95.89833*				
			-31.24917*				
p4	Gr1	Gr2	-90.52667*	12.00069	.000	-124.0206	-57.0328
		Gr3	62.16500*	7.84034	.000	39.3951	84.9349
		Gr4	76.33833*	8.02492	.000	53.2432	99.4335
	Gr2	Gr1	90.52667*	12.00069	.000	57.0328	124.0206
		Gr3	152.69167*	9.89760	.000	123.5994	181.7839
		Gr4	166.86500*	10.04445	.000	137.5489	196.1811
	Gr3	Gr1	-62.16500*	7.84034	.000	-84.9349	-39.3951
		Gr2	-152.69167	9.89760	.000	-181.7839	-123.5994
		Gr4	*	4.28313	.016	2.2558	26.0909
			14.17333*				
	Gr4	Gr1		8.02492	.000	-99.4335	-53.2432
		Gr2	-76.33833*	10.04445	.000	-196.1811	-137.5489
		Gr3	-166.86500	4.28313	.016	-26.0909	-2.2558
			*				
			-14.17333*				

*. The mean difference is significant at the 0.05 level.

DISCUSSION

The MRI scanner was able to record sub-gingival tooth preparation margins. However, higher deviation values were obtained between the MRI scanner and the optical scanner when the samples were not covered with gingiva. Measurements at the margin (Point 4) denote that the finish line of the prepared teeth beneath the porcine gingiva was recorded successfully by the MRI scanner. Two different ways of measuring the marginal fit was proposed by Neves et al[7] It includes horizontal and vertical misfits. They are measured in the parallel and perpendicular directions according to the path of insertion of the crowns. Replica technique is utilized to measure the marginal fit by observing the marginal gap, which denotes the perpendicular distance from the internal surface of the crown near the margin to the finish line of the preparation [8]

Only marginal and internal gaps can be recorded using the replica technique. Over or under extensions may occur even in restorations with minimal marginal gaps. This fact may also be explained by the inability of the MRI scanner to copy the preparation through probable air spaces in the study model. In situations where the gingiva adheres to the tooth structure, air blisters are less common, easily identifiable, and can be corrected by the dentist during the digital impressions.

However, the type of scanner used in this study had no role in the occurrence of overextended crown. All groups showed overextensions in about 85% of the surfaces examined. This could be deciphered as a negative result for both scanners, but it is entirely reasonable with the fabrication process of zirconia crowns and with the methodology followed in this study. A marginal augmentation of 0.2 mm is recommended to prevent fracture or chipping of the crown margins during the pre-sintering state of zirconia. This kind of augmentation could initiate overextensions that could be corrected chairside during restoration adjustment procedures. This is in agreement with the findings of Mostafa et al. [9], who conveyed that crowns manufactured with CAD/CAM technology, despite marginal augmentation reduced to 0.1 mm, showed more overextension than crowns that were manufactured conventionally.

In the present study, no adjustments were made to the crowns to avoid insertion of subjective factors that could distort the results [10,11]. This explains the higher occurrence rate of overextensions irrespective of the type of scanner used in this study. Micro-computed tomography has also been applied as a non-destructive technique to evaluate the marginal fit of crowns [12,13,14]. Although it is considered an innovative and promising method that provides a greater number of measurement points [15], it still presents limitations concerning reproducing the standardized position of the specimens and their respective measurement points [12,13,14]. Also, the role of zirconia artifacts [16] on crown misfit is yet to be determined. In this study, the replica technique permits the development of standard measurement points which gave a more precise record of the internal and marginal discrepancy because they intersect the interface between the prepared tooth and the crown in a more perpendicular direction at all measurement points.

Limitations of this study include recruitment of cases restricted to monolithic zirconia single crowns on posterior teeth; the use of a single cement spacing parameter; and the lack of ability to replicate a more realistic and natural clinical scenario with regards to the relationship between the tooth surface and surrounding soft tissue.

Further studies are necessary to test the MRI scanner under different conditions such as use for anterior teeth or multiple-unit fixed dental prostheses. Clinical studies are mandatory to confirm the accuracy of MRI based digital impression-taking and to demonstrate the clinical benefits of impression procedures without retraction cords and no influence of saliva or gingival bleeding.

Crowns produced from MRI based digital impressions presented accuracy of fit comparable with those from extra scanners used in this study.

CONCLUSION

Within the limits of the study, it may be concluded that optical scanners produced crowns with better marginal fit when the samples were not covered with gingiva. Whereas, MRI scanners produced crowns with better marginal fit when the samples were covered with gingiva.

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