Evaluation of marginal and internal adaptation of zirconia crowns constructed from traditional and digital impressions

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Background and objective: Recent advancement in restorative dentistry from impression to fabrication is toward digital workflow. There are very few studies, evaluating the internal and marginal fitness of full anatomic zirconia crowns fabricated with different impression techniques. The aim of this study was to determine whether improved technology of digital workflow results in better fitting crowns.
Methodology: The mandibular right first molar of a dentoform model was prepared for a full ceramic crown with deep shoulder finish line. Two impression techniques were used,for group one, ten traditional impressions with addition silicone were obtained, while in group two, ten digital intraoral impressions were captured.Twenty full anatomic zirconia crowns were designed and milled using dental CAD/CAM system . The internal and marginal gaps were measured for each crown on the master die with the aid of a stereomicroscope.
Results: The average (±SD) for the internal and marginal adaptation was: 145 µm (±39) and 85 µm (±17) for the digital impression group, 188 µm (±141) and 178 µm (±41) for the traditional impression group, respectively. The Kruskal-Wallis test showed no statistically significant difference between the two groups regarding marginal and internal adaptation.
Conclusion: Full anatomic zirconia crowns fabricated from intraoral digital impressions demonstrated comparable or even better marginal and internal fit than crowns fabricated with traditional silicone impressions.

Keywords: Digital impression, polyvinylsiloxane, stone model, virtual model, full anatomic ziconia.

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Introduction

The development of digital technology with computer-aided design/computer-aided manufacture (CAD/CAM) systems results in improved communication and restorative procedures,[1] by creating accurate indirect prosthesis while simplifying the entire fabrication process. Together with the progress in biomaterials such as high strength zirconia ceramics had led to serious advancement in education and patient care.[2]
Precision and accuracy of master impressions are essential for overall excellence and marginal fit of fixed dental prosthesis. Traditional impression with elastomeric impression material and die-stone model fabrication had been considered the gold standard in fixed prosthesis fabrication.[3,4]
The digital impression had gained access to dentistry to simplify the workflow and avoid inaccuracies related to the traditional workflow,[5] it includes direct digitalization using intraoral scanners to scan the dental arch and indirect digitalization using laboratory scanners to scan dental impressions and/or dental models and obtain digital data.[6]
The marginal fit is one of the important factors that is closely related to the structural durability of the restoration.[7,8] The marginal gap should be kept to a minimum since a significant

marginal gap would expose the dental cement to the oral environment causing destructive micro-leakage. A minimum marginal gap prohibits plaque accumulation, decrease cement dissolution and reduce the possibility of secondary caries development,[7,9] also enhance the mechanical features of restorations, in term of strength and retention.[10]
In addition to the marginal fit, the overall three-dimensional fit of restoration plays a significant rule to provide maximum mechanical support from the underlying tooth, in which a minimum and uniform cement film thickness are preferred.[11] Accurate information on marginal and internal fitness are prerequisite towards long-term clinical success.[12]
Zirconium dioxides material as esthetic and biocompatible ceramic is widely used for crown fabrication to restore badly broken down tooth structure. The marginal and internal fit of full anatomical zirconia crowns manufactured with traditional and digital impression techniques were evaluated since it is not clearly documented in the literature. The null hypothesis was that there is astatistical significant difference in the marginal and internal accuracy of the zirconia crowns fabricated with different impression techniques.

Materials and methods

Master die fabrication. The mandibular right first molar replica tooth number thirty (#30) of a dentaform was prepared for a full anatomic zirconia crown. High-speed dental hand-piece was used to prepare the replica according to standard tooth preparation criteria. The circumferential tooth reduction was carried out with diamond bur (DFS DiamonGmbh, Riedenburg, Germany), the margins were placed supra-gingival and finished to obtain a heavy shoulder finish line of 1mm. The occlusal reduction of 1.5 mm was performed, and the bevel then placed at the junction between occlusal and axial wall of the functional cusp. All point and line angles were rounded.
Impression making. Two impression techniques, traditionaland digital impression were used.
For the traditionl group, single step putty-wash technique using polyvinyl siloxane (Turboflex, R&S, Paris, France) was used. To increase the accuracy of the impressions,custom sectional trays were fabricated from light-curing resin. The impressions were then poured in extra hard high density die stone (KIMBERLIT, Protechno, Vilamalla, Spain) with the water/powder ratio of 20 ml/100 g. The stone casts were then stored 24 hours to complete the final setting. From ten PVS impressions, ten stone casts were fabricated. For indirect digitalization a laboratory scanner (S600 ARTI, Zirkonzahn GmbH, Gais, Italy) was used to obtain virtual model for crown fabrication. Each stone model was fixed to the model support base individually and scanned.
For the digital impression, the dentaform quadrant involving the prepared tooth (#30) was scanned with an intra-oral digital scanner (3Shape TRIOS® 3, Copenhagen,Denmark). The scanning process included all the surfaces of the master die to ensure that all the details of the preparation, the occlusal, facial, proximal, and lingual surfaces of the master die were captured and the margins were clearly visible. The quality of the scan was evaluated to confirm the precision of the impression for entire abutment visibility including the inter-proximal area. All the datasets were exported into Standard Tesselation Language (STL) format, and ten virtual models were obtained.
Zirconia crowns fabrication. All full anatomic zirconia crowns (n =20) were designed by the same CAD/CAM software (Modellier software, Zirkonzahn GmbH, Gais, Italy) using default cement space and margin settings (The cement thickness was set at 60μm, 1mm above the margin).
Before fabricating the restorations, the five-axis computerized numerically controlled milling machine (Zirkonzahn GmbH, Gais, Italy) was calibrated, and the restorations were milled using green-state zirconia block (ICE zircon, zirkonzahn GmbH, Gais, Italy). All samples were sintered in a special furnace (Zirkonofen 600/V2, Zirkonzahn GmbH, Gais, Italy) at 1500°C for two hours according to manufacturers' recommendation.
Measurement of crown adaptation. For the measurement of marginal gap, each of the fabricated crowns was seated separately on the master die and was examined for ver-

tical marginal fit in relation to the die and a constant load of 20N (2 Kg)[13] was placed over the crown with the aid of dental surveyor (DENTAURAM paraline, Germany). The marginal gap was measured using direct visualization method under the stereomicroscope. The master die was held in place in special alignment desk to allow reproducible rotational positions for all crown margin measurements. Circumferential vertical marginal gap measurements were made at 12 measurement locations. Three measurement locations were taken on each crown surface (mesial, distal, buccal, and lingual).

The measurement evaluation was performed using a computerized digital image analysis system.[14–17] This included an image gained throughout the stereomicroscope(MOTIC ST-39 C-N9GO, Hong Kong) at 20x magnification power using a digital camera (Canon, EOS 550D, Tokyo, Japan)

The internal adaptation of the crowns was measured using a replica technique.[18] A low viscosity polyvinyl siloxane impression material was used as the cement analog. The light body impression material was injected into the inner portion of the restorations and then was placed over the prepared tooth with finger pressure and was immediately placed under a constant load of 20N(2 Kg) [13] using a dental surveyor.

After the manufacture recommended setting time (5 min), the restorations were gently removed leaving fragile light body replica attached to the master die. A bite registration silicone of different color (R&S, Turbocclusion, Paris, France) was then placed over the fragile light body replica to achieve a steady structure with the aid of a specially designed box. Then, An additional layer of the same material was applied to the internal surface of the light body film to make the cutting of the replica easier without damage.[19,20]

The replicas were then cut in occlusal-cervical direction and in two paths: bucco-lingual and mesio-distal using a blade in four equal parts using the designed box as a cutting guide. All sections were examined under a stereomicroscope at 20x magnification power and recorded using a digital camera.

The cement analog thickness was measured using computer program in five regions of each section (marginal gap, shoulder area, the middle of the axial wall, axio-occlusal line angle, occlusal area)Those predetermined regions were measured in both halves of each section of the replica, then the measurements of both halves were averaged and five internal gap thickness measurements were obtained for each section with a total of twenty measurements of each sample to be subjected to statistical analysis.

Statistical analysis. Marginal and internal adaptation outcomes were not normally distributed (Shapiro-Wilk'sp value < 0.05) and did not satisfy the assumptions of two-way mixed ANOVA analysis. The Kruskal-Wallis test was used to compare marginal and internal adaptation between the study groups.

Data are presented as mean ± standard deviation. The IBM® SPSS® statistics 23.0 statistical package was used to carry out all statistical analyses.Statistical significance was set at 0.01 for the comparison of marginal fit between different surfaces to account for 5 repeated tests and at 0.017 for all other comparisons to account for 3 repeated tests (Bonferroni correction).

Results

Mean marginal adaptation values ranged between 67.3 ± 29.9 µm minimum for the cast-less group at the lingual surface and 213 ± 39 µm maximum for stone cast group at the mesial side. While the mean internal adaptation values ranged from 139.0 ± 33.4 µm minimum for cast-less group at the bucco-lingual site to 203± 175 µm maximum for stone cast group at the mesio-distal site. (Table 1).

There are no statistically significant differences in marginal adaptation between the 4 different tooth surfaces between the two groups ($p < 0.001$; Table 1, Fig. 1). The marginal gap for both cast-less and die stone groups were similar, although it was higher for the stone cast group however there was no statistically significant difference. (p value > 0.01)

When comparing the values of the stone cast group and cast-less group, no significant differences could be demonstrated regarding internal adaptation both for the bucco-

Table 1.Descriptive and comparative statistics of marginal and internal adaptation between the two groups at each surface (Buccal, Distal, Lingual, and Mesial).

	Groups				Group comparison		
	Cast-less (*n=10*)		Stone cast (*n=10*)		Kruskal-Wallis Test₸		Adjusted Post hoc
	Mean	SD	Mean	SD	F	*P*-value	
Marginal							
Buccal	108.683	56.123	156.867	75.262	20.782	<0.001*	0.535
Distal	89.838	84.929	159.758	42.151	23.280	<0.001*	0.143
Lingual	67.256	29.908	182.142	50.763	25.301	<0.001*	0.044
Mesial	73.275	36.541	212.667	39.509	25.806	<0.001*	0.033
Average	84.763	17.449	177.859	40.894	25.806	<0.001*	0.033
Internal							
Bucco-lingual	139.045	33.831	172.907	110.258	20.604	<0.001*	0.791
Mesio-distal	150.424	46.483	202.983	174.869	20.720	<0.001*	0.728
Average	144.734	39.465	187.945	141.968	20.841	<0.001*	0.668

SD: standard deviation; Critical p value set at $p < 0.01$ for marginal adaptation (Bonferroni correction for 5 tests); * Statistically significant at $p < 0.01$
Critical p value set at $p < 0.0167$ for internal adaptation (Bonferroni correction for 3 tests); * Statistically significant at $p < 0.0167$

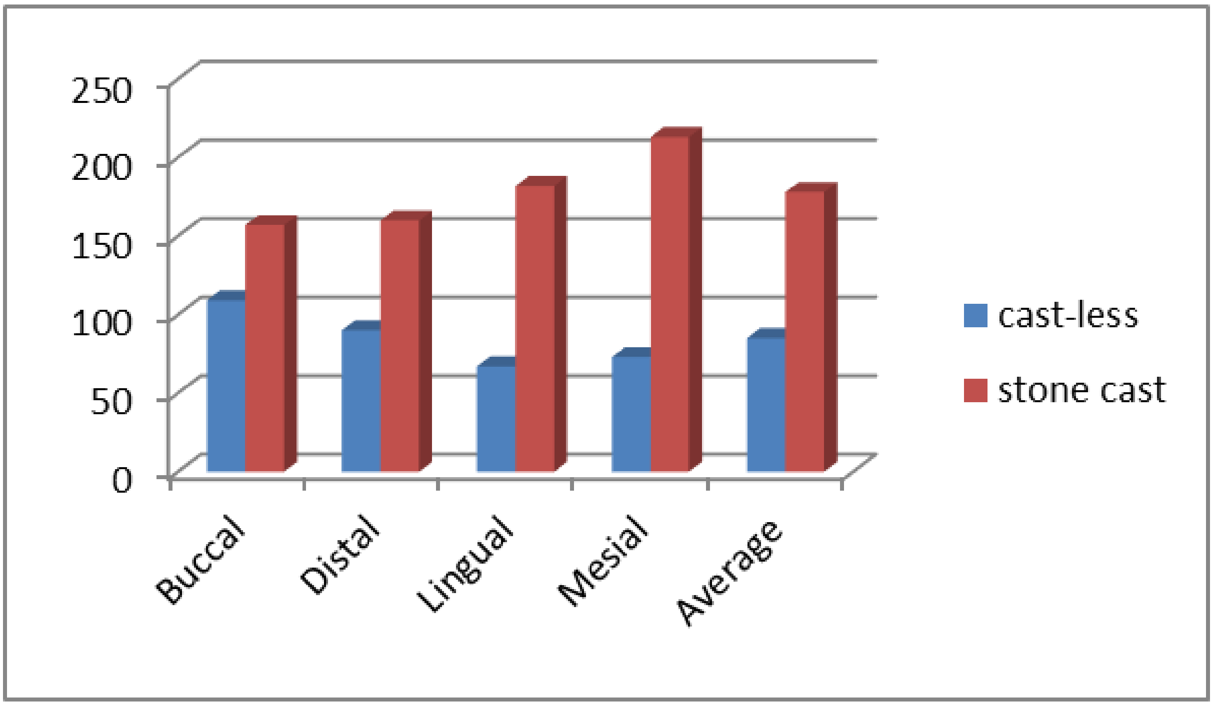

Figure 1.Marginal adaptation for each tooth surface and the overall average for both groups.

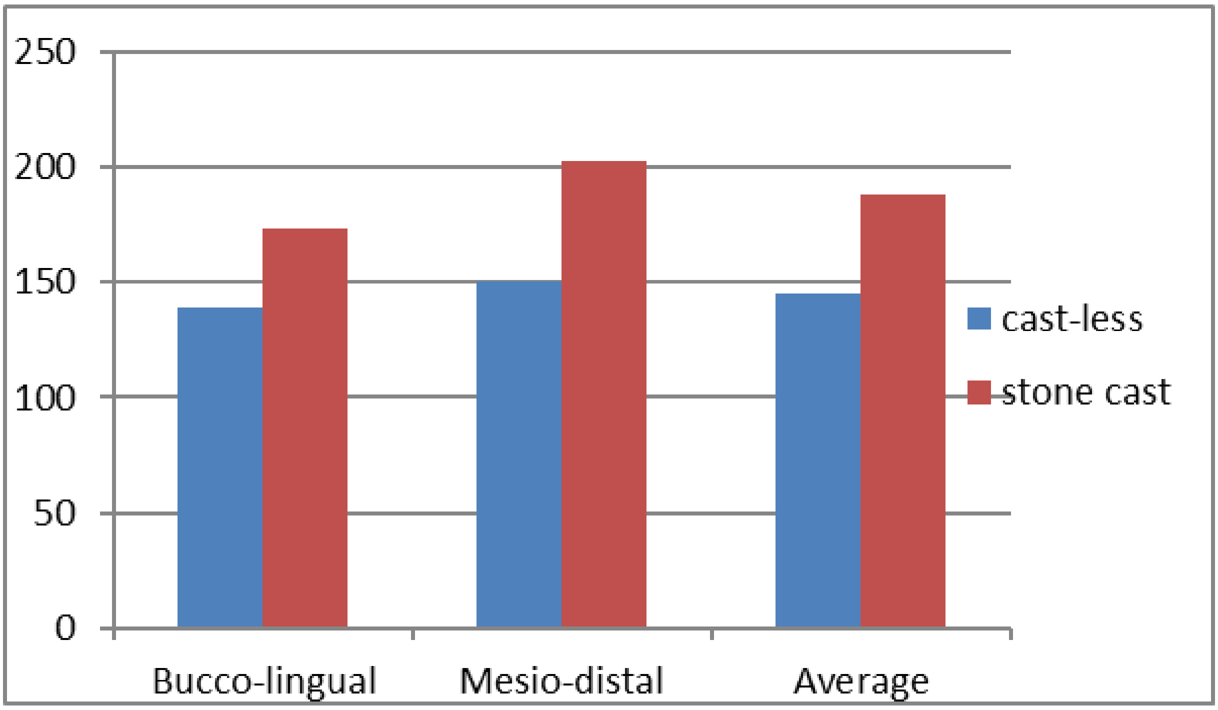

Figure 2.Internal adaptation for the bucco-lingual and mesio-distal tooth surfaces and the overall average for both groups.

lingual and the mesio-distal measurements (p <0.001; Table 1, Fig. 2).

Discussion

Crown adaptation is the most critical factor that enhances the quality and success of any dental prosthesis, therefore, both marginal and internal adaptation were measured to give an overview of how close the crown is adapted to the tooth surface. According to Holmes et al.,[21] the internal gap is "the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation but the same measurement at the margin is called the marginal gap."

The marginal gap was measured using a direct view technique of the gap between the crown and the margin of the master die with the aid of microscope. Although this technique is cheap and less time consuming, it can only be used in-vitro, and it did not provide any information about the overall internal space between the die and the crown.[22]

Therefore, beside that, replica technique was used to evaluate the internal gap of zirconia crowns. It offers various advantages that enhance it is use, being easy, reliable and efficient to carry out, permit accurate adaptation measurements before cementation and it is quite inexpensive, non-invasive and non-destructive.[23,24]

Many in vitro studies have been conducted to compare traditional and digital impression regarding the crown adaptation (marginal and internal). Most of the studies showed that the restorations produced with intra-oral impression have marginal fit less than 100 µm. Some studies showed that the digital impression systems had similar accuracy to classical impression methods to fabricate fixed restorations.[23,25]

Meanwhile, Euán et al.,[26] and Ng et al.,[16] found better marginal fit resulted from digital intra oral impression. Similarly, this study showed better marginal and internal fit of the digital group (85 µm and 145µm) than the classical group (178 µm and 188µm) which could be due to the nature of the traditional workflow with the multiple steps both in clinical (impression making) and laboratory(die-stone model fabrication). Other factors such as the ambient temperature, the length of the time till pouring and surface wet-ability of pouring materials may cause this difference.[16,26]

When CAD/CAM systems are used to fabricate dental prosthesis, the cement space set by CAD software plays a major role to ensure complete crown seating. Cement space of 60-µm was used in this study as reported by Iwai et al.,[27] Similarly, Rinke et al.[28], suggested that for CAD/CAM fabricated zirconia prosthesis the cement space should not be set at smaller value than 60 µm to enhance its seating on the abutment and to decrease the necessity of manual adaptation. The mean marginal and internal gap space for the CAD/CAM fabricated zirconia crowns in this study was slightly higher the one reported in the literature. This could be due to the fact that the specimens being full anatomic crowns, while other studies deal with zirconia copy such as Syrek et al.,[29] or Pradíes et al.[30], in which the thickness of milled zirconia may affect the result.

In the literature there are no general agreements made on the number of the measurements necessary to evaluate the marginal and internal fit of the crown.[31] In general manner, the larger the number of the measurements, the more precision could be obtained.[32] lack of standardization of the methods of measurement, leads to difficulty in comparing between different studies, because of variation in sample size, measurement method, number of measuring point per specimen, cement space used by CAD/CAM system, kind of scanner and other devices used.[33]

Apart from the impression technique and its effect on crown adaptation, the manufacturing process has it is rule in the proper overall fit of the crown. Every single step of manufacturing using a CAD/CAM system, from scanning to machining procedure contributes to this proper fit.[34] Furthermore, the type of zirconia block used, type of CAD/CAM system used, and geometry of the tooth preparation also may affect the proper fit. This study was taken using single prepared tooth, in which single crown was fabricated and evaluated for adaptation which reveals excellent accuracy of digital workflow further studies regarding multiple prepared tooth and complex fixed partial denture evaluation is suggested.

Conclusion

Within the limitation of this study, the CAD/CAM fabricated full anatomic zirconia crowns with digital impression had a comparable or even better marginal and internal fit than the one produced with the classical impression. The results were within the limit of clinical acceptability.

Conflict of interests

The authors report no conflict of interests.

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