In vitro evaluation of prosthodontic impression on natural dentition: a comparison between traditional and digital techniques

G. MALAGUTI[1], R. ROSSI[2], B. MARZIALI[2], A. ESPOSITO[3], G. BRUNO[4], C. DARIOL[5], A. DI FIORE[5]

[1] *DDS, Private practice, Bagnolo in Piano (RE), Italy*
[2] *ODT, Private practice, Reggio Emilia, Italy*
[3] *DDS, Private practice, Modena, Italy*
[4] *Student, Department of Neuroscience, School of Dentistry, University of Padua, Padua, Italy*
[5] *DDS, Department of Neuroscience, School of Dentistry, University of Padua, Padua, Italy*

SUMMARY

Objectives. The aim of this *in vitro* study is to evaluate the marginal and internal fit of zirconia core crowns manufactured following different digital and traditional workflows.
Methods. A 6° taper shoulder prepared abutment tooth was used to produce 20 zirconia core crowns using four different scanning techniques: scanned directly with the extraoral lab scanner, scanned with intraoral scanner, dental impressions using individual dental tray and polyether, dental casts from a polyether impressions. Marginal and internal fits were evaluated with digital photography and the silicone replica method.
Results. Medium marginal gaps were 76,00 μm ± 28.9 for extraoral lab scanner, 80.50 μm ± 36,2 for intraoral scanner, 88.10 μm ± 34,8 for dental impression scan and 112,4 μm ± 37,2 for dental cast scan.
Medium internal gaps were 23.20 μm ± 10,3 for extraoral lab scanner, 16.20 μm ± 8.3 for intraoral scanner, 27.20 μm ± 16.7 for dental impression scan and 30.20 μm ± 12.7 for dental cast scan.
Conclusion. Internal gap were extensively lower than 70 μm described in literature. Marginal fit was higher than ideal values for all the techniques but within the limit of clinical success. Intraoral scanners obtained the best results for internal gap.

Key words: dental impression materials, CAD/CAM, intraoral scanner, marginal fit.

Introduction

The planning of a prosthetic rehabilitation is surely influenced by several factors, such as clinical preferences for the materials and preparation, treatment costs, aesthetics and patients chief compliant. The accuracy of the restoration, its mechanical stability and marginal adaptation but also a strict domestic and professional oral hygiene protocol represents the keys to success in the long-term clinical evaluation and patient satisfaction.

Inaccurate margins cause plaque accumulation increasing the risk of biological damage on periodontium (1) while an increased internal gap affect negatively mechanical retention and can cause ceramic fractures (2).

Recent advancements in computer-aided design and computer-aided manufacturing (CAD-CAM) technology for dental restorations allow the use of different materials, improving aesthetics, fit and efficiency of CAD-CAM rehabilitations (3-7). For these reasons digital workflow is already a reality in various clinical practises and dental laboratories.

Marginal adaptation and internal fit have been examined in various *in vitro* and clinical studies (8-10),

showing a wide range of results. Unfortunately all these results are poorly comparable because of the numerous differences in the measurement protocols. In a recent systematic review, Authors concluded that there is a lack of univocal consensus in literature and current state of research does not allow for a proper comparison of the various systems suggesting further investigations (11).
The objective of this *in vitro* study is to evaluate and compare the marginal and internal fit of zirconia copings manufactured following different digital and traditional workflows (12).

Materials and methods

An upper first molar extracted for severe periodontitis was selected for this study. After the tooth has been cleaned and polished, an anti-reflection coating was applied to achieve an optimal accuracy of the 3D scan. From the digital 3D copy of the tooth a digital shoulder preparation with an ideal axial wall taper of 6° was designed (Figure 1). The project was sent to the milling machine (Roland DWX-50, ROLAND 60 DG Mid Europe Srl, Italy) to obtain a zirconia replica of the abutment tooth. Zirconia (NexxZr, Sagemax Europe S.r.l.) was selected as the ideal material for the master cast for its high stability and resistance. The zirconia abutment tooth was finally sintered.
The abutment tooth was used to produce zirconia copings using four different scanning techniques:

1. the abutment tooth was scanned directly with the extraoral lab scanner (Dental wings Serie 7) (DE). This ideal situation cannot be repeated clinically and is used as reference for the other three
2. the abutment tooth was scanned with intraoral scanner (MHT scanner, 3D progress) (DI)
3. dental impressions of the abutment tooth were taken using individual resin dental tray and a high viscosity polyether (impregum, 3M ESPE). Dental impressions were directly scanned with extraoral lab scanner (TI)
4. dental casts were prepared with dental stone (Elite stone type IV, Zhermack) from polyether dental impressions and finally scanned with extraoral lab scanner (TC).

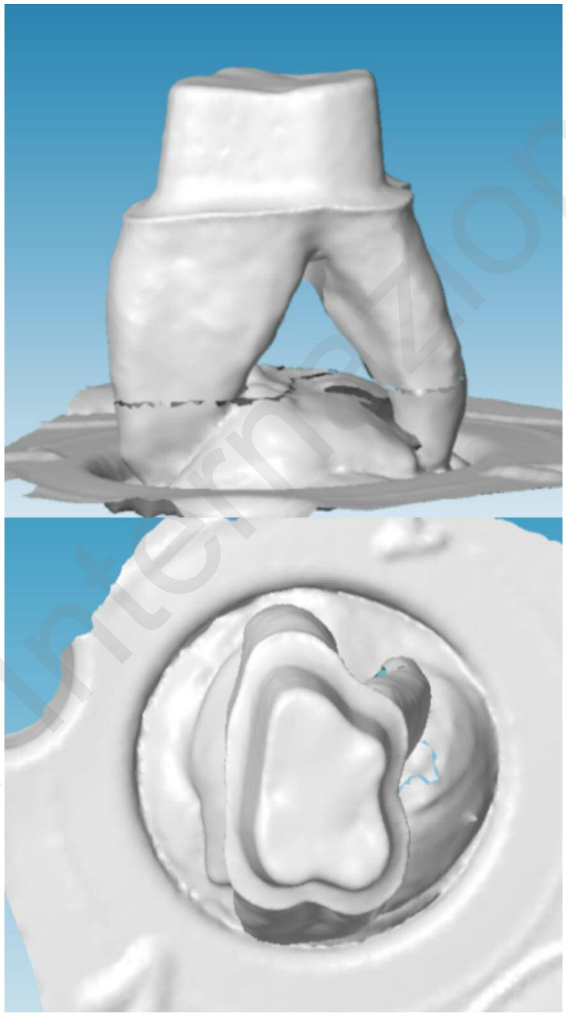

Figure 1
Digital shoulder preparation with an ideal axial wall taper of 6°.

Every workflow was repeated five times for a total of 20 different zirconia copings.
Marginal fit was evaluated with digital photography (Figure 2). Three pictures for each zirconia copings were taken using a SLR digital camera (Canon EOS 350d, 60mm macro lens and ring flash) (13). The camera was positioned on a tripod and the abutment tooth was placed on a support which could only rotate every 60°. All the pictures were imported and analysed using an image processing program (ImageJ, opensource).
Internal fit was evaluated using the silicone replica method for the evaluation of marginal fit of cast crown described in 2008 by Laurent et al. (14). The

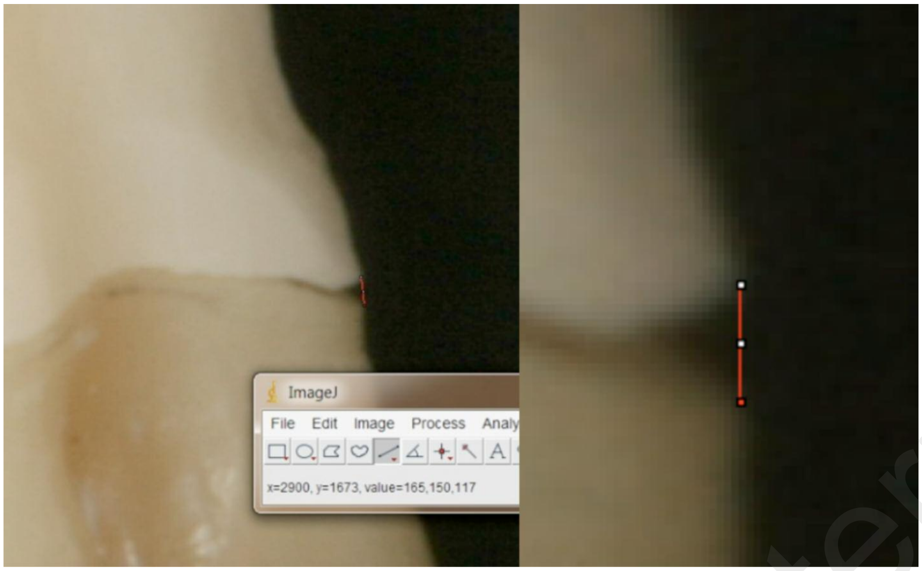

Figure 2
Marginal fit evaluated with the image processing program (ImageJ, opensource).

impressions were taken with a low viscosity polyether (Permadyne Light Body, 3M ESPE).

Measurements were performed at five points (occlusal, vestibular, palatal, distal and mesial) for each silicone replica. These five points were marked on the abutment tooth and then reported on the silicone replica to measure always the same points. Measurements were performed using a thickness gauge (Figure 3).

Figure 3
Measurement of internal fit was evaluated using the silicone replica method and a thickness gauge.

Statistical analysis

All the values were reported as individual data on the statistic software (SPSS, IBM). Median and standard deviation were calculated. Statistical analysis was performed using non-parametric Kruskal-Wallis test and Wilcoxon-Mann-Whitney test setting comparing groups results for both marginal and internal fit using data obtained for extraoral lab scanner (DE) as references. The value $p<0.05$ was considered as the limit of statistical significance.

Results

In this study 20 zirconia copings obtained from four different scanning techniques of an ideal abutment tooth were evaluated.

Regarding marginal fit data are shown in Table 1. Medium marginal gaps were 76,00 µm ± 28.9 for extraoral lab scanner (DE), 80.50 µm ± 36,2 for intraoral scanner (DI), 88.10 µm ± 34,8 for dental impression scan (TI) and 112,4 µm ± 37,2 for dental cast scan (TC). A statistical significant difference was found for both dental cast (p= 0.005) and dental impression (p=0.024) but not for digital intraoral scanner (p>0.05). Regarding internal fit data are shown in Table 2.

Table 1 - Marginal gap values for the three positions. Values are expressed in micrometre.

	DE	DI	TI	TC
Position 1				
DX	52	130	73	61
	49	25	127	181
	77	57	98	101
	81	15	102	163
	60	75	115	146
SX	93	141	34	180
	120	50	137	96
	30	78	102	160
	117	124	56	112
	119	29	126	119
Position 2				
DX	48	66	52	53
	63	24	30	38
	19	86	39	170
	35	54	34	75
	85	83	52	128
SX	49	82	90	147
	83	90	85	74
	89	98	123	125
	73	126	84	113
	58	123	113	78
Position 3				
DX	67	80	46	68
	106	101	53	116
	54	18	108	83
	53	61	103	135
	96	89	78	98
SX	112	106	128	118
	126	86	83	114
	65	124	159	99
	103	64	113	113
	98	130	100	108
mean	76,0	80,5	88,1	112,4
DS	28,9	36,2	34,8	37,2

Table 2 - Internal fit values for the four different zirconia core caps in occlusal, buccal, palatal, mesial and distal position. Values are expressed in micrometre.

	O	B	P	M	D
1	20	10	30	5	30
2	30	20	40	5	20
3	30	15	40	5	30
4	20	15	25	10	20
5	20	10	30	5	20
Mean	23,2				
DS	10,3				
DI					
1	40	20	20	15	20
2	30	10	10	15	10
3	20	5	10	15	10
4	20	5	30	10	20
5	20	10	20	10	10
Mean	16,2				
DS	8,3				
TI					
1	60	20	50	50	30
2	30	10	20	20	40
3	40	10	10	10	50
4	40	15	10	15	40
5	50	10	10	10	30
Mean	27,2				
DS	16,7				
TC					
1	30	40	50	60	60
2	30	40	20	15	25
3	30	20	30	15	30
4	30	20	30	40	30
5	20	10	30	20	30
Mean	30,2				
DS	12,7				

Medium internal gaps were 23.20 μm ± 10,3 for extraoral lab scanner (DE), 16.20 μm ± 8.3 for intraoral scanner (DI), 27.20 μm ± 16.7 for dental impression scan (TI) and 30.20 μm ± 12.7 for dental cast scan (TC). A statistical significant difference was found for both dental cast (p= 0.007) and dental impression (p=0.028) but not for digital intraoral scanner (p>0.05) that even obtain a better performance than extraoral lab scanner.

Discussions

In the last few years, advancements in CAD-CAM technologies and digital intraoral scanners allowed a complete digital workflow for prosthetic rehabilitations in order to eliminate the impression taking phase and all traditional dental casts. Several studies evaluated the accuracy of intraoral scanners comparing their performance to traditional impressions, highlighting many limits in intraoral conditions particularly for subgingival margins and particular areas such as retromolar region. There is a lack of univocal consensus in literature regarding which workflow is more accurate: some Authors show better results for traditional workflow (15), while others show comparable (16, 17) or even better for digital workflow (18). Marginal and internal fits are objective factors for the clinical success of our rehabilitations. Marginal accuracy is important to reduce plaque accumulation and secondary cavities (19-21). Authors suggested the goal of 25-40 μm for marginal fit while nowadays 75-160 μm are considered clinically successful (22). Internal fit is necessary to avoid crowns fracture and mechanical dislocation. Tuntiprawon et al. (23) set a 70 μm cut-off for internal gap beyond which crown fracture occurs even for physiological bite force.
The aim of this *in vivo* study was to compare both marginal and internal fit of zirconia copings obtained from four different impression techniques. The first technique, scanning the abutment tooth with an extraoral lab scanner, is obviously not achievable clinically and was used as reference for the following three: intraoral scanner, scan of a polyether impression and scan of a type IV dental stone cast obtained by a traditional impression.

Marginal fit was evaluated with a specific software of image processing. Statistical significant differences were found for both traditional protocols. The most inaccurate procedure results the scan of dental cast surely affected by dimensional alterations of both impression material and dental stone. Intraoral scanner showed comparable result to extraoral reference scanner confirming previous researches (15, 16, 24-26). It must be kept in mind that results for intraoral scanners can be affected positively in *in vitro* studies due to ideal condition that are impossible to achieve clinically. For these reasons Authors expect a worsening of intraoral results in real clinical situation.
Internal gap was evaluated using the silicone replica technique validated by Laurent in 2008 (14). All the values that we obtained were extensively lower than 70 μm described in literature suggesting that both digital and traditional workflow are sufficiently precise. A particular interesting finding was that intraoral scanner showed even better results than the extraoral scanner. Obviously these results are not affected by saliva, crevicular fluid, teeth position and oral conformation but anyway highlight the high quality of recent intraoral scanners.
In conclusion marginal fit was higher that ideal values for all the techniques but comparable with other studies in literature and within the limit of clinical success. Intraoral scanner obtained the best results for internal gap but further clinical *in vivo* research are needed to confirm these results.

Disclosure

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Correspondence to:
Adolfo Di Fiore
Department of Neuroscience,
School of Dentistry
University of Padova
Via Giustiniani 2
35100 Padova, Italy