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ORIGINAL ARTICLE

Marginal and internal fit of four-unit zirconia fixed dental prostheses based on digital and conventional impression techniques

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Abstract
Objectives The aim of this in vitro study was to evaluate the marginal and internal fit of CAD/CAM-generated four-unit zirconia fixed dental prostheses made with digital and conventional impressions.
Materials and method A titanium master model was used. For group conventional impression (CI), 12 polyether impressions of the master model with Impregum™ were made. For group digital impression (DI), 12 digital impressions of the master model using Lava™ C.O.S. system were made. The replica technique was applied. The Mann–Whitney *U* statistical test was applied to detect statistical differences between the groups, in terms of marginal and internal fit. Face-by-face comparisons between groups were also carried out.
Results Groups DI and CI presented mean marginal fit of 63.96 and 65.33 μm, respectively, and showed no statistically significant difference. Groups DI and CI presented significantly different internal fit with mean values of 58.46 and 65.94 μm, respectively. Group DI showed statistically significantly lower values for marginal and internal fit on premolar mesial face, and on molar distal and palatal faces.
Conclusions Frameworks fabricated from digital and conventional impressions showed clinically acceptable marginal fit. Frameworks fabricated from digital impression demonstrated better internal fit than ones fabricated from conventional impression. Reviewing each retainer face, digital impression showed better marginal and internal fit at the premolar mesial and molar distal faces.
Clinical relevance The results of this in vitro study show that digital impressions made with the Lava™ C.O.S. system and its digital workflow are suitable for fabricating four-unit zirconia frameworks, with regard to marginal and internal fit requirements.

Keywords CAD/CAM · Fit · Fixed dental prostheses · Zirconia · Digital impression · Precision

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Introduction

Impressions made with elastomers (polyether and vinyl poly-siloxane) materials, also known as conventional impressions, represent a commonly used procedure in general dental practice. Such materials exhibit an adequate stability and precision [1–6]. Although high-quality impressions are achievable with these materials, conventional impressions are considered as inadequate by many laboratories [7–9]. Low reproduction of the preparation margins, tearing of the impression material, presence of impregnated debris, voids

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within important areas and undistinguishable margins on the stone dies are frequently encountered problems [1, 7–9].

There are several reasons for the problems with conventional impressions, including the knowledge and skill level of the practitioner [1, 8]. However, there are potential sources of error inherent in the entire process that are not practitioner-related. These sources include the potential distortion of the impression material, the disinfection procedures, the total or partial separation of the impression material from the tray and transportation to the dental laboratory under different climatic conditions [10–14].

Low-quality impressions are a significant obstacle for manufacturing restorations with adequate fit. Internal and marginal fit exert great influence over the longevity of indirect restorations [15]. Internal and marginal fit can be measured as the proximity degree between the abutment (surface and cavo-surface angle) and the restoration (inner and marginal surfaces) [16]. Thus generally, the better the impression accuracy is, the closer the proximity degree between restoration and abutment is, and the better the internal and marginal fit of the restoration is [17, 18]. Acceptable marginal fit for full crowns has been widely discussed in the literature, with a general consensus that a marginal fit of 120 μm or less is desirable from a clinical standpoint [19–24].

An inadequate marginal fit, wider than 120 μm, may compromise the longevity of the restoration because a wider cement film is exposed to the oral environment, leading to a more aggressive dissolution rate by the action of oral fluids and chemical–mechanical forces [25]. Wide marginal misfits also contribute to plaque accumulation, leading to occurrence of microleakage, secondary caries, endondontic inflammation, and can induce the onset of periodontal diseases [26–28]. It has also been demonstrated that an excessively thick cement layer, internally, may induce residual tensile stresses, which are capable of initiating cracks on the veneering ceramics [29]. Accordingly, as the production of restorations with adequate fit is dependent on the impression accuracy, optimization of the impressions quality is important.

The computer-aided design/computer aided manufacturing (CAD/CAM) techniques for dental restorations have been developed with the aim of automating the production process in order to optimize the quality of the restorations as well as the efficiency of the workflow [13]. Recently, the use of CAD/CAM technology in manufacturing dental restorations was achieved with two independent methods: by the dentist, using chairside CAD/CAM and by the technician, in the laboratory. Prior to this, only one system capable of performing digital impressions was available to dentists: the CEREC 3D system (Sirona Dental Systems, Charlotte, NC). The CAD/CAM technology was almost entirely limited to the laboratory, where stone dies, obtained using conventional impressions, are digitized so that the restorations can be designed and milled [10–12]. New digital impression systems have been introduced to the market and have enabled the total digitization of the workflow, ranging from the chairside impression to the milling of monolithic (not associated to a coping) and polylithic (associated to a coping) restorations, in the laboratory or milling center [1].

The Lava™ Chairside Oral Scanner (Lava C.O.S.) system has recently been introduced. This intraoral scanner is based on the principle of active optical wavefront sampling, which generates 3D information from a single lens imaging system [30]. It has been shown that all-ceramic crowns, manufactured by Lava C.O.S., demonstrate better marginal fit, when compared to all-ceramic crowns fabricated by conventional impressions [31]. Nevertheless, it is not possible to know whether this holds true for fixed prostheses as there is a tendency for higher values of marginal fit in zirconia frameworks with long span configuration, especially when they are manufactured with semi-sintered zirconia blanks [32].

Evaluations of the quality of fit of fixed dental prostheses (FDP) have been carried out by comparing different types of materials and CAD/CAM manufacturing systems [15, 17, 18, 26, 28]. Although some accuracy studies have been already conducted [33, 34], there is insufficient data concerning the accuracy of digital impression and its resulting marginal and internal fits. Accordingly, the aim of this study was to assess the precision of fit of digital and conventional impressions by evaluating marginal and internal fit of CAD/CAM-generated four-unit zirconia fixed dental prostheses. The null hypothesis was that the frameworks from digital impression (group DI) show equal or higher values for marginal and internal fit than the frameworks from conventional impressions (group CI). The alternative hypothesis was that the frameworks from group DI show lower values for marginal and internal fit than the ones from group CI.

Materials and method

In an upper jaw typodont model (Basic Study Model, Kavo Dental GmbH), teeth 14 and 17 were prepared to 6° convergence and chamfer-ended margins, using an occlusal reduction of 2.0 mm and an axial reduction of 1.5 mm, in order to accommodate a four-unit FDP. Subsequently, an impression (Silagum, DMG, Hamburg, Germany) of the model was carried out, in order to obtain a plaster model in Class IV stone (Fujirock white, GC Europe), which was then digitized by the scanner Everest (KaVo, Biberach, Germany). The dataset was sent to KaVo milling center, where a master model made of titanium was milled

(Fig. 1). Within this study, the marginal and internal fit of the frameworks were determined without application of the veneering ceramics. A total of two groups of FDPs, each containing 12 frameworks, were fabricated, according to the type of impression: group CI (conventional impression) and group DI (digital impression).

Workflow of zirconia frameworks by group CI

Twelve polyether impressions, with Impregum Penta Medium Body (3 M ESPE, Seefeld, Germany), of the master model were made with aid of custom trays. Twenty-four hours later, the impressions were poured in a Class IV stone (Fujirock white, GC Europe). After the dies set, pins were placed on the bottom of the dies, and the base of the casts was poured in the same dental stone. Dies were removed from the cast base, and the abutments were sectioned to fabricate saw-cut models. The same investigator made all impressions, and the whole workflow was performed by the same laboratory, under ideal temperature (23 °C) conditions.

The 12 saw-cut models were scanned by the Lava™ Scan ST optical scanning device (3M Espe, Essfeld, Germany), which is based on the operating principle of fringe projection combined with triangulation methods [35]. The frameworks were designed in a dedicated software (Lava™ Design). The following settings were employed: cement spacer 30 μm starting 0.8 mm above the margin, milling cutter radius correction of 0.8 mm and a framework thickness of 0.6 mm.

Workflow of zirconia frameworks by group DI

Twelve digital impressions of the master model using Lava C.O.S. system were made. Prior to scanning, a titanium dioxide powder (Lava Powder) was applied on the master model, in order to create a stochastic pattern on the titanium surfaces to facilitate scanning. Once the preparations had been scanned, and the data had been saved, complementary scannings of a lower jaw typodont model (Basic Study Model, Kavo Dental GmbH) were performed on the right hemi-arch, so that the software could perform occlusion registration. The Lava™ C.O.S. operating principle is active wavefront sampling, using a '3d-in-Motion' technology that allows the capturing of 3D data in video sequence and the modeling of these data [30, 31].

The 12 datasets were electronically submitted to the authorized laboratory, for digital die cutting and margin marking. Once the margins of all abutments had been made, the data were submitted to 3M ESPE for digital ditching and bite registration. The zirconia frameworks were designed in a dedicated software (LavaTM Design). The same settings for group CI were employed.

The frameworks of both groups were milled from semi-sintered zirconia, by a five-axis milling machine (Lava™ CNC 500). After milling, all the frameworks were sintered to full density, in a special sintering furnace (Lava™ Furnace 200) at a temperature of 1.500 °C. Once they had been delivered, all frameworks were examined for deformity and debris. No adjustments were performed on the frameworks from both groups.

Production of the replicas and microscopic evaluation

In order to obtain replicas of the marginal and internal gap of the FDP retainers, the technique described by Boening et al. [36] and Molin and Karlsson [37] was applied. The retainers were filled with light body silicone (Virtual, Ivoclar Vivadent, Schaan, Liechtenstein), then the frameworks were placed onto the abutment teeth of the master model and loaded with finger pressure. After the light body silicone had set, the frameworks were removed from the master model, whilst the thin silicone remained on the abutment teeth. The silicone films, representing the space between the abutment teeth and the FDP retainers, were subsequently stabilized by application of a contrasting heavy body silicone (Virtual, Ivoclar Vivadent, Schaan, Liechtenstein). Two replicas, per framework, were made. The first replica was segmented, with a razor blade, at the center of the premolar and then, at the center of the molar, in a

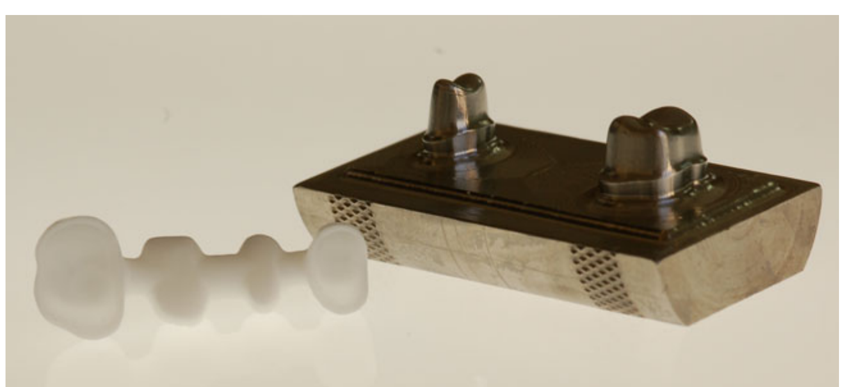

Fig. 1 Titanium master model, which was used as a basis for manufacturing the zirconia frameworks

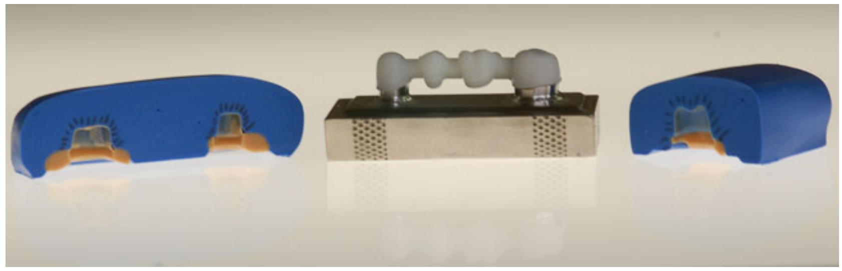

Fig. 2 Replicas obtained per framework: four cross-sectional specimens (buccal-palatal and mesio-distal, for both pre-molar and molar)

buccal-palatal direction, so that the buccal-palatal gap could be measured for both abutments. In order to measure the mesio-distal gap, the second replica was segmented once in a mesio-distal direction at the center of both abutments. Thus, per abutment, two cross-sectional specimens (buccal-palatal and mesio-distal) were obtained (Fig. 2).

The frameworks were examined at ×50 magnification with a microscope (Axioscope 2, Zeiss, Oberkochen, Germany). The resolution of the microscope was 0.45 µm. Eight up to ten digital images were made of each cross-sectional specimen, and further merged by the Adobe Photoshop CS software, so that one picture of the whole cross-sectional specimen could be obtained. Photographs were taken with a digital camera (S1 Pro, Fuji, Tokyo, Japan) which was attached to the microscope. The images were transferred to the imaging data software (Optimas 6.5, Media Cybernetics, Silver Spring, MD, USA).

Internal and marginal gap measurements

The measurements were performed using the following method: a series of points was placed on the junction between light and heavy body silicone (outer side) and on the junction between light body silicone and abutment tooth (inner side). The computer software connected the points of each side, by dropping perpendiculars between them. The length of each perpendicular represented the internal and marginal gap, in micrometers. Approximately 6.000 perpendiculars, per cross-sectional specimen, were measured (Fig. 3).

As conducted by Beuer et al. [15], for each framework, the following measurement locations were used to determine the marginal and internal fit, between the retainers and abutment teeth of the master model: Marginal opening (MO): The marginal opening at the point of closest approximation between the master model and ceramic margin of the retainer. Chamfer area (CH): The internal adaptation of the retainer at the area of the biggest diameter. Axial wall (AW): The internal adaptation of the crown walls up to the transition to the occlusal surface. Occlusal (OC): The internal adaptation of such surface of the crown to the master model. Film thicknesses were recorded at the margins at the shortest distance from the retainer to the closest abutment surface, which represented the marginal opening, according to Holmes et al. [38].

Values were taken from the database at MO, CH, AW and OC measurement locations to evaluate the fit of all retainers. The data recorded at the different cross-sectional specimens were averaged for each measurement location. Marginal fit was evaluated for each framework as the conjunction of MO values, for each abutment face: mean gap widths at the

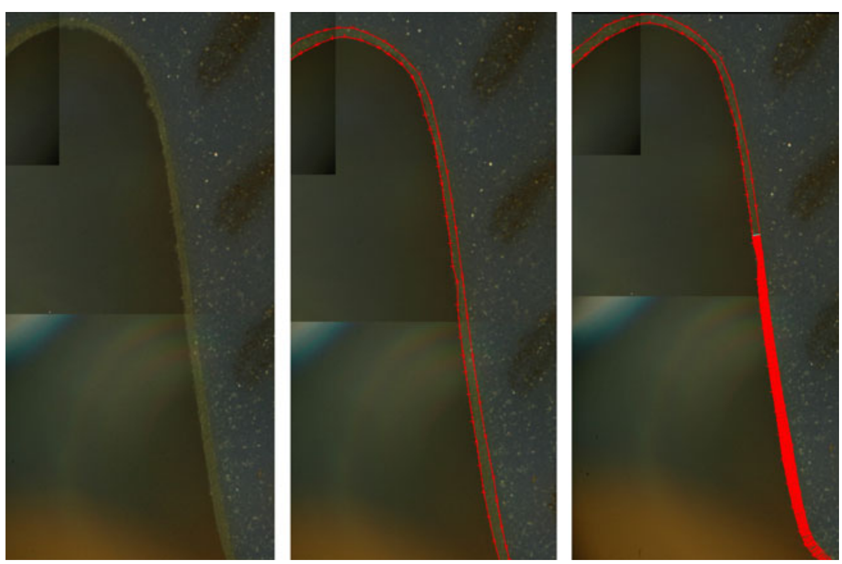

Fig. 3 Microscopic photographs of one specimen. Marginal and internal gap measurements. *Left*: Light-body silicone, representing the space between the abutment teeth and the FDP retainers. *Middle*: Series of points, placed and connected by the software, on the junction between light body silicone and abutment tooth. *Right*: Perpendiculars being dropped (in *red*), in order to register the internal and marginal gap, in micrometers

Table 1 Overview of fit: mean values for marginal and internal fit of zirconia frameworks from digital and conventional impressions in micrometers

	Mean	Maximum	Minimum	N	SD
Marginal fit					
Digital impression	63.96	207.95	20.98	96	36.75
Conventional impression	65.33	234.23	20.03	96	37.27
Level of significance (P)	0.335				
Internal fit					
Digital impression	58.46	194.42	14.42	288	35.91
Conventional impression	65.94	305.81	15.76	288	41.9
Level of significance (P)	0.0035[a]				

[a]Internal fit showed statistically significantly different results (one-tailed Mann–Whitney U test)

mesial, buccal, palatal and distal marginal openings, per group. The internal fit was evaluated for each framework as the conjunct of CH, AW and OC measurements of each abutment face: mean gap widths at the mesial, buccal, palatal and distal faces, per group. Then, each face of both premolar and molar abutments, of each group, was compared according to marginal and internal fit.

Data were then imported into a statistical program (SPSS 15.0, SPSS Germany, Munich, Germany). Mean values were analysed with descriptive statistics. Kolmogorov–Smirnov test was applied to test the groups on normal distribution. One-tailed Mann–Whitney U statistical test was used to detect statistical differences between both investigated type of impressions, in terms of marginal and internal fit overall values and at all abutments' faces. The level of significance was set at 5 %.

Results

Results for marginal and internal fit are shown in Table 1 and in Figs. 4, 5 and 6. The mean marginal fit values were calculated by the MO means of each one of the 96 cross-sectional specimens, per group. Group DI and CI presented a mean marginal fit of 63.96 and 65.33 μm, respectively, and showed no statistical difference. Internal fit was measured by 288 data points (12 frameworks × 8 cross-sectional specimens × 3 measurement locations: AW, CH and OC). Groups DI and CI presented mean values for internal fit of 58.46 and 65.94 μm, respectively. As the groups were not normally distributed, Mann–Whitney U test was performed to compare the groups. CI had significantly higher values than DI (P=0.0035).

Figures 5 and 6 and Tables 2 and 3 show the mean values for marginal and internal fit of the groups face-by-face. As the groups were not normally distributed (Kolmogorov–Smirnov), Mann–Whitney U test was performed to compare the groups. Group DI showed statistically significantly lower values for marginal and internal fit on premolar mesial face, and on molar distal and palatal faces.

Discussion

Both digital impression with Lava™ C.O.S and conventional impression with Impregum™ produce clinical satisfactory values with respect to marginal fit on four-unit zirconia fixed dental protheses. For marginal fit, the null hypothesis was accepted, whereas for internal fit, the null hypothesis was rejected. For group DI, significant lower values for internal fit were found, which confirms the alternative hypothesis.

The higher values of internal fit, achieved with conventional impression, might be explained by its conventional workflow process, where a plaster model is created, which is the basis for the construction of the frameworks, while in the digital workflow, the framework was designed directly from the intraoral scan, without creating an intermediate model. Thus, the digital workflow eliminates the need of a master model for coping fabrication, and since every step in a workflow contributes to the risk of overall failure, the elimination of the conventional impression and its inherent risks, such as expansion or contraction, results in higher accuracy,

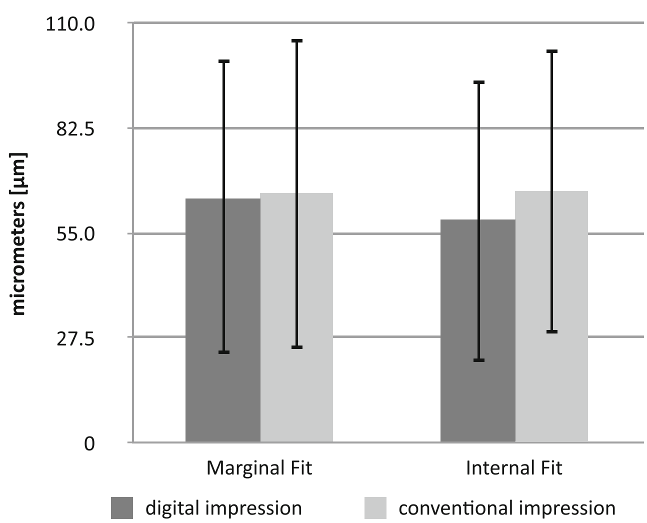

Fig. 4 Mean values for marginal and internal fit of zirconia frameworks from digital and conventional impressions in micrometers

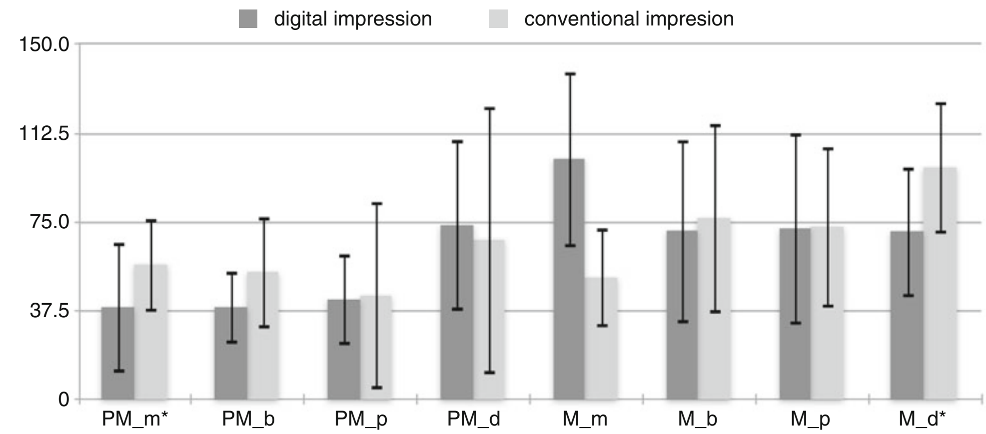

Fig. 5 Values of marginal fit and standard deviation (SD) in micrometers: face-by-face comparisons considering marginal fit of zirconia frameworks for each tested group. *PM* premolar, *M* molar, *m* mesial, *b* buccal, *p* palatal, *d* distal. *Statistically different (one-tailed Mann–Whitney *U* test)

as reported by Syrek et al. [31]. Furthermore, the fact that the internal fit of the frameworks from digital impression, presented significantly smaller values and lower standard deviation than frameworks from conventional impressions, seems to indicate that, performing intraoral scans with Lava™ C.O.S. produces a higher level of reproducibility of the impressions than that of the ones achieved by traditional polyether impressions.

The marginal fit of digital impression group showed higher mean values than its own internal fit. Although both groups have shown clinically acceptable values for marginal fit, the authors believe that the production of the frameworks did not reach their full potential as the data analysis indicates that the frameworks from digital impression could not be properly seated, which caused the wider values at the marginal openings. The reasons for this problem are debatable. The presence of internal tension due to misbalanced cement gap along the retainer can compromise the mechanical stability of zirconia-based restorations and promote higher risks of veneering fracture [26, 39, 40]. Another possible reason is that the titanium dioxide powder, necessary for scanning with Lava™ C.O.S., might exert an influence since the marginal area of the abutments is the spot that is more susceptible to powder accumulation, and therefore could promote a misreading of the scanning procedure. Further researches on the matter are necessary to clarify this issue.

In a systematic review of marginal and internal fit of zirconia fixed dental prostheses, Abduo et al. [41] verified that there is a significant variation between values obtained by different studies and that this variation occurs even when the same systems are used, and that it can be explained by the different methodologies applied by each study. Because of the differences between the measurement methodologies, comparisons between studies must be performed selectively. The methodology used in the present study is based on the replica technique, which is considered as a reliable, non-invasive and non-destructive method to determine the in vitro and in vivo adaptation of crown/retainer-to-tooth surfaces [31, 36, 37]. Additionally, the measurement method used captured approximately 6.000 values (perpendiculars) per cross-sectional specimen, which provided a reliable dataset for acquiring the mean values for each measurement location [15].

When comparing these data with other studies that also used the replica technique with the Lava™ system, it is apparent that the results regarding marginal fit of zirconia frameworks are comparable. Reich et al. [26] found comparable marginal fit mean value of 65 μm. However, in contrast to our study, Reich's study was conducted in vivo, with three-unit veneered frameworks. Another study from Reich et al. [27] that was conducted in vivo using four-unit veneered

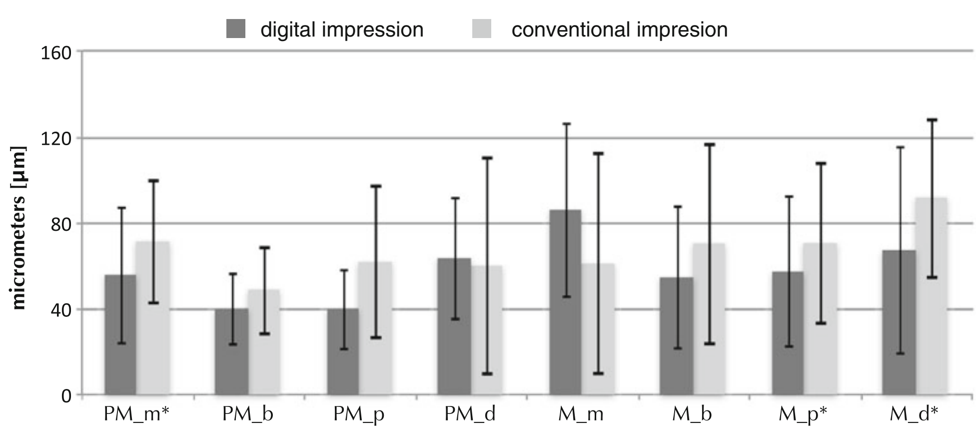

Fig. 6 Values of internal fit and standard deviation (SD): face-by-face comparisons considering internal fit of zirconia frameworks for each tested group. *PM* premolar, *M* molar, *m* mesial, *b* buccal, *p* palatal, *d* distal. *Statistically different (one-tailed Mann–Whitney *U* test)

Table 2 Values of marginal fit and standard deviation (SD) in micrometers: face-by-face comparisons considering marginal fit of zirconia frameworks for each tested group

Marginal fit	*N*	PM-m	PM-b	PM-p	PM-d	M-m	M-b	M-p	M-d
Digital impression	12*	39.18*	39.27*	42.51*	73.84*	101.73*	71.46*	72.4*	71.26*
Standard deviation		27.46*	15.4*	19.17*	36.06*	37.16*	38.95*	40.51*	27.74*
Conventional impression	12*	57.14*	54.03*	44.14*	67.65*	51.64*	76.75*	73.12*	98.17*
Standard deviation		19.84*	23.71*	39.47*	56.64*	20.84*	40.03*	34.07*	27.92*
Level of significance (*P*)		0.001[a]	0.072	0.257	0.854	0.999	0.378	0.466	0.017[a]

PM premolar, *M* molar, *m* mesial, *b* buccal, *p* palatal, *d* distal

[a] Statistically different (one-tailed Mann–Whitney *U* test)

**P*–value = 0.05

frameworks showed higher overall values of marginal fit (91 μm). It is important to emphasize that more variables are added for in vivo studies, and their frameworks had been internally adjusted. Thus, it can be assumed that there is room for improvement by selective internal adjustments of the retainers inner surfaces of four-unit frameworks, produced either by digital or by conventional impressions.

Unlike studies regarding the fit of zirconia restorations produced by conventional impressions, little is available in the literature concerning fit of restorations manufactured by digital workflow. Syrek et al. [31] conducted an in vivo study, in which single zirconia crowns, produced either by Lava™ C.O.S digital impression or by silicone impression, were clinically evaluated by the replica technique. Their results indicated that single crowns from intraoral scans revealed better marginal fit than crowns from silicone impressions. Even though a polyether impression material was used for our study, similar values of marginal fit for conventional impression were found. However, our results revealed a marginal fit mean value of 63.9 μm for digital impression, whereas Syrek et al. [31] found marginal fit of 49 μm, which is also in accordance with Scotti et al. [42] who similarly evaluated marginal fit of single zirconia crowns resulting from digital impressions with Lava™ C.O.S. This difference, between marginal fit mean values from the aforementioned studies and the ones from ours, can be explained by the tendency towards higher marginal inaccuracies in longer span restorations, given by the greater distortion that four-unit frameworks undergo, compared to single crowns, during the fabrication process [32].

Zirconia frameworks can be milled using two fabrication strategies. Depending on the system, either densely sintered or pre-sintered blanks can be machined. Densely sintered zirconia blanks can be milled to the actual size of the frameworks. However, the high strength and brittleness of such blanks have some drawbacks, including longer milling times and greater attrition of the milling cutters; moreover, milling of the thin sections of a framework is difficult to achieve [32, 41]. Pre-sintered blanks, which are available in a semi-sintered porous state and have a chalk-like consistency, are more easily machined in the CAM unit, causing less chipping formation on the frameworks and less damage to the milling tools [40]. However, after milling, the frameworks have to be sintered in order to achieve final density and maximum strength of the material. This sintering process is characterized by a high sintering shrinkage, of circa of 20–30 % that must be compensated in the milling procedure. The extent of the shrinkage exerts an extra challenge to the software that has to accurately calculate the milling of a 20–30 % enlarged framework that will shrink precisely to the required dimension during sintering [32, 42]. Despite the tendency of the fully sintered milling to provide superior accuracy, the CAD softwares

Table 3 Values of internal fit and standard deviation (SD) in micrometers: face-by-face comparisons considering marginal fit of zirconia frameworks for each tested group

Internal fit	*N*	PM-m	PM-b	PM-p	PM-d	M-m	M-b	M-p	M-d
Digital impression	12*	56.22*	40.33*	40.28*	64.05*	86.28*	55.13*	57.75*	67.69*
Standard deviation		32.38*	17.02*	19.14*	28.94*	40.75*	33.73*	35.46*	48.62*
Conventional impression	12*	71.85*	49.37*	50.52*	60.49*	61.42*	70.95*	71.01*	91.92*
Standard deviation		29.39*	21.33*	35.92*	51.15*	51.92*	47.49*	37.99*	37.62*
Level of significance (*P*)		0.007[a]	0.365	0.06	0.959	0.999	0.055*	0.017[a]	0.0005[a]

PM premolar, *M* molar, *m* mesial, *b* buccal, *p* palatal, *d* distal

[a] Statistically different (one-tailed Mann–Whitney *U* test)

**P*–value = 0.05

demonstrate efficiency in compensating zirconia shrinkage during sintering [32]. Furthermore, the cost-effectiveness and simplicity of milling pre-sintered zirconia blanks should be weighed against the benefit that can be gained from the tendency of minor superiority of fit that densely sintered zirconia blanks present [32, 41, 43].

Accordingly, as pre-sintered blanks were used in the present study, zirconia sintering shrinkage might have influenced the marginal and internal fit. Our results show marginal and internal fit inaccuracies that might be linked to the anisotropic sintering shrinkage of the frameworks, which results in a smaller shrinkage rate for the vertical tooth axis than for the horizontal tooth axis [32]. Such anisotropic shrinkage causes bending stresses, and as a result, the axes of the abutment portion incline, leading to a discrepancy in the marginal gap between the pontic and non-pontic sides of the frameworks [32]. Indeed, the distribution of the marginal and internal fit mean values along the frameworks was not homogenous between the tested groups, as shown in Tables 2 and 3. By analysing the face-by-face comparisons, some marginal and internal fit mean values were statistically different. The frameworks from digital impression seemed to present a horizontal convex warpage, whereas a concave warpage seems to have occurred on the frameworks generated from conventional impressions. As all frameworks were manufactured using the same design parameters, milling and sintering procedures, the differences between the tested groups should be due to the different impression methods.

Group DI showed significantly better marginal and internal fit at the premolar mesial and molar distal faces. However, considering the premolar distal and the molar mesial faces, group DI showed higher values than the ones yielded by the conventional impression. Besides the warpage as result of the sintering shrinkage, another possible explanation for such pattern of warpage could lie on the fact that it is difficult to capture the opposing inner surfaces (PM-d and M-m) with the intraoral scanner.

In this study, a tendency of increased marginal and internal values for the molars can be observed. The same has been verified by Reich et al. [27] using Lava™ four-unit frameworks by Boening et al. [36], who evaluated the marginal gap of Procera™ crowns, and by Moldovan et al. [44], who examined the internal fit of zirconia copings. Such a common outcome can be attributed to the fact that the volume of a molar crown is larger than that of a premolar. Thus, small inaccuracies when calculating the proportional sintering shrinkage may influence the geometry of molars more strongly than that of premolars [27].

Although the data from this study indicate that there might be a higher level of reproducibility of digital impressions using Lava™ C.O.S., than that of conventional impressions using Impregum™, it is important to highlight the limitations of the present study, due to the marginal and internal fit being measured on two cross-sectional specimens, per abutment. This clearly does not represent the whole area of cement gap. Moreover, all frameworks were produced and tested under laboratory conditions which might not reflect the reality of in vivo conditions.

Conclusion

1. Frameworks fabricated from digital and conventional impressions showed clinically acceptable marginal fit.
2. Frameworks fabricated from digital impression demonstrated better internal fit than ones fabricated from conventional impression.
3. Reviewing each retainer face, digital impression showed better marginal and internal fit at the premolar mesial and molar distal faces.

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Conflicts of interest The authors declare no conflict of interest.

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