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Effect of clinical and laboratory techniques of cementation on the assessment of marginal and internal fit of prosthetic elements

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Aim: The aim of this in vitro study was to compare machine and manual cementation of prosthetic elements by measuring internal and marginal fits. **Methods:** Eighteen anatomic prefabricated abutments were used to manufacture zirconia copings in the Ceramill (n=9) and Lava systems (n=9). The copings were cemented with a fluid consistency addition silicone using a machine (n=18) and manually (n=18) according to the replica technique. They were then cut in the buccal-palatal and mesial-distal directions. The film thickness was photographed using an optical microscope and measured in the internal and marginal regions. The data collected were analyzed by repeated measures ANOVA and Bonferroni's multiple comparison test (∂=.05). The Bland-Altman test was performed to evaluate the agreement between the methods. **Results:** In the evaluation of the internal and marginal misfits, the mean values observed for the cementation performed with the aid of a machine and manually, were as follows: angular regions, 76.7 µm and 76.2 µm; linear regions, 60.6 µm and 60.7 µm; incisal region, 144.8 µm and 145.2 µm; marginal region, 40.1 µm and 40.2 µm; and overall mean, 80.4 µm and 80.6 µm, respectively. No significant differences were found between the 2 methods, for any of regions and systems (P>.05). The Bland-Altman test showed agreement between the methods (P>.05) and that the limits of agreement found were clinically acceptable. **Conclusions:** Within the limitations of this in vitro study, we can conclude that cementation using manual techniques or mechanical aid produces the same cement films.

Keywords: Dental marginal adaptation. Computer-aided design. Dental prosthesis design.

Introduction

The manufacture of prosthetic elements has always been a challenge due to the difficulty in reproducing, partially or completely, the dental element. The materials need to comply with aesthetic, mechanical and biological requirements, and must be submitted to a confection that requires micrometric precision[1,2]. In order to meet this demand, new materials such as zirconia and lithium disilicate, and new techniques such as those carried out using CAD-CAM systems have emerged and, therefore, further studies are needed to validate such changes[3,4].

Internal and marginal misfits have been the object of study by various authors[5-8]. Reports in the scientific literature indicate that an inadequate internal misfit may compromise the mechanical properties of the prosthesis, as well as altering the marginal misfit[9,10]. Other studies have reported that a poor marginal misfit compromises periodontal health[11,12] and this in turn can compromise the useful life of the cement by increasing its solubility in the oral environment[13].

Recent systematic reviews have pointed to a large variety of methodologies used to measure these misfits, and they also show a lack of clinical studies[14-17]. Other studies have demonstrated that the cementation procedure of a prosthetic element may influence its misfit[18-22]. One of the variables that has been used in these studies without a scientific consensus is the cementation of the prosthetic element. This can be done with the aid of a machine with constant and reproducible force[23-29], or manually, a technique that simulates what happens in the clinic more closely[30-33].

In fact, the 2 techniques have coherent arguments; however, it is certain that for clinical studies it is necessary to use a non-destructive methodology that reproduces as accurately as possible what happens in a clinical situation. In view of the above, this study aimed to evaluate and compare the cementation of single zirconia copings in prefabricated titanium abutments made with the aid of a machine in relation to manual cementation.

Materials and Methods

Study design

In this study, the specimens were prepared as described previously[27]. Briefly, 18 cone Morse (CM) anatomic exact titanium abutments and 20 CM titanium implant analogs were obtained from the manufacturer (Neodent). The analogs were attached with the aid of a dental surveyor (Delineador B2; Bio-Art Dental Equipment) in order to maintain them in the same position. Eighteen of which were fixed with type IV stone plaster (Vigodent) in plastic parts (Monta Tudo; Elka Plásticos) in order to send them to the laboratories in a standardized way and 2 were fixed with liquid epoxy resin (Aradur HY 951; Huntsman Corp) to metal parts similar to the plastic parts in order to perform the cementation Figure 1. This assembly, specially designed for this study, aimed to standardize the position of the CM anatomical abutments, individualize each specimen sent to the laboratory and optimize the cementation step. Eighteen zirconia copings were made in two CAD/CAM systems: Ceramill (Amann Girrbach AG) (n=9) and Lava (3M ESPE) (n=9) Figure 2.

Figure 1. Anatomic titanium abutment on implant analog fixed to metal parts.

Figure 2. Zirconia copings on anatomic titanium abutment.

Cementations

Two cementations were performed for each anatomic abutment and coping set, following the replication technique[6]. Two groups were formed: a control group (CG) with machine cementation (n=18) and a test group (TG) with manual cementation (n=18). To obtain the silicone film, the abutments and copings were cleaned with moist steam under pressure (NV60 Handheld Steam Cleaner; H. Koenig) and air-dried. In the CG (n=18), cementation was performed with the addition of silicone, with a fluid consistency (Express XT; 3M ESPE AG) and submitted to a 50 N load[6], in a universal testing machine (Emic DL 2000) for 5 min, as recommended by the manufacturer Figure 3. In the TG (n=18), the assembly was manually pressed, using a maximum finger pressure, by a single calibrated operator (50 N) simulating a clinical situation[30]. The same silicone was used for the same period of time as the CG Figure 4.

Figure 3. Zirconia coping cementation with silicone in universal testing machine.

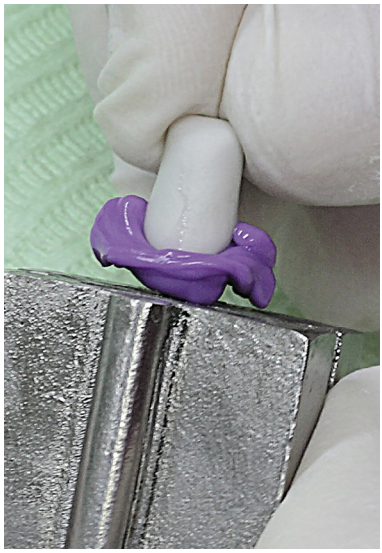

Figure 4. Zirconia coping cementation with silicone manually.

Specimen preparation and analysis

After this, in both cases, the excess silicone was removed with a scalpel blade N.15 (Solier) and then the coping was removed. The film was captured with the addition of light consistency silicone (Adsil; Vigodent) and a dense silicone paste (Express XT; 3M ESPE AG) was used as a base. The metal box, similar to the plastic parts, with a cutting guide made for this study was used as a tray. After capture, the silicone was sectioned through its long axis in the buccal-palatal and mesio-distal directions, following the standardized cutting guide in order to obtain the buccal, palatal, mesial and distal faces and incisal edge Figure 5.

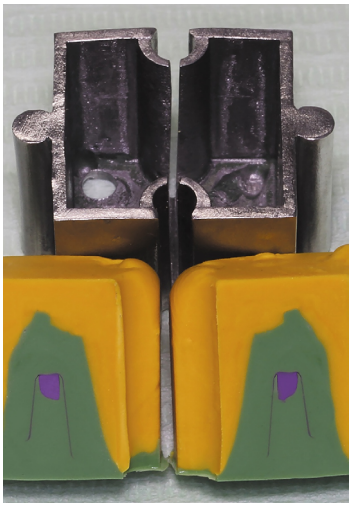

Figure 5. Cross-sections of replicas with cutting guide.

Following the methodology of Licurci et al.[6], the specimens were examined and photographed under an optical microscope (Olympus BX60M; Olympus Corp) with a digital camera (Canon 5D Mark III; Canon Inc) adapted with a measuring device (Multifunction Target Max Levy; Max Levy Autograph Inc). The photographs were standardized to a resolution of 5760 × 3840 pixels in RAW format with ×100 magnification. In order to evaluate the internal misfit, images were taken every 1.7 mm, covering the entire length of the silicone film on the buccal, palatal, mesial and distal surfaces, as well as on the incisal edge. Eleven photographs were taken in the buccal-palatal direction and 8 in the mesial-distal direction. To assess the marginal misfit, the photographs were taken in the cervical region of each face, totaling 4 photographs. The photographs were then transferred to an image management program (Adobe Photoshop CS6 Extended; Adobe Systems Inc) and the logical length was converted to pixel length using the measurement tools of the program.

In order to evaluate the internal and marginal misfits, 45 reference points were selected for each specimen, making a total of 810 measurements, as follows: 432 for the angular regions; 234 for the linear regions; 72 for the incisal regions and 72 for the marginal regions.

In the angular regions (internal axiogingival angle, n=3; axioincisal angle, n=3), which are more susceptible to alterations, three measurements were taken. For purposes of standardization, the first reference point corresponded to the central point of the curvature, on the inner face of the cement line, as this is in contact with the anatomical abutment. The two subsequent points were 200 µm equidistant from the central reference point. All measurements were made using a ruler perpendicular to the base of the reference points; in the linear and incisal regions, the reference points were located in the center of the image of the cement line[6]. The classification proposed by Holmes et al.[34]. was used to analyze the marginal discrepancy, which is the perpendicular measurement made between the inner surface of the prosthetic element and the axial wall of the anatomical abutment, in the marginal region Figure 6.

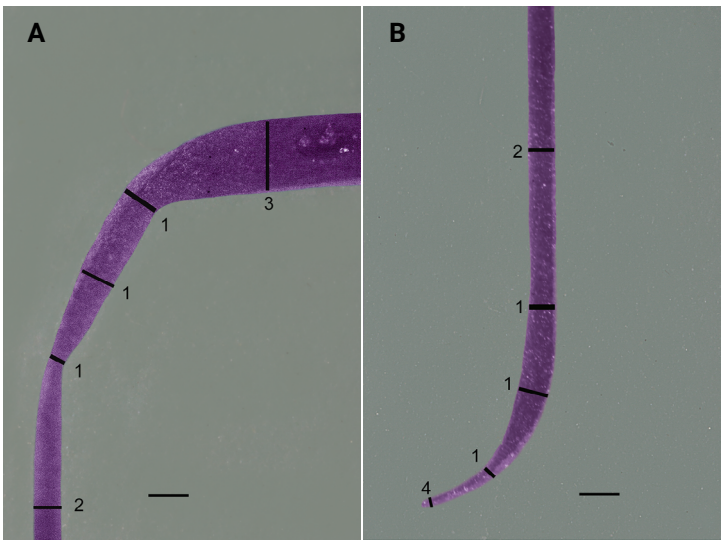

Figure 6. Standardization (original magnification x100) used to measure the regions misfit. A: angular (1), linear (2), and incisal regions (3). B: angular (1), linear (2) and marginal regions (4). Perpendicular line drawn from abutment to internal surface of coping. Scale bar, 100 µm.

Statistical analysis

A pilot study with 6 randomly selected specimens (n=6) was conducted to estimate intraexaminer reliability and sample size. The value obtained from the variability of the standard deviation of the means was 3 µm and the minimum difference to be detected was determined at 5 µm. Based on these values, a power analysis (G * Power 3; Kiel University) was conducted assuming two test groups with an effect size of 1.25 and type I and type II error probabilities of .05 and .95 respectively. Therefore, a minimum sample of 11 specimens was estimated. Intraexaminer reliability was assessed by calculating the intra-class correlation coefficient (ICC). The same operator performed the cementation of the 6 samples manually, following the aforementioned methodology in two moments, with an interval of one week between each measurement. The intraexaminer reliability was .99, with a 95% confidence level.

After obtaining and tabulating the data, Levene's test was performed to verify the equality of variances in the assessment of internal and marginal misfits. Subsequently, a repeated measures ANOVA (∂ =.05) was performed. Bonferroni's test of multiple comparisons was used for the independent variables methods, systems and locations whenever statistically significant differences occurred. The Bland and Altman[35] analysis was used to assess the agreement between the methods. All statistical evaluations were performed using the statistical software program (IBM SPSS Statistics, v21; IBM Corp).

Results

The average misfit values by regions for the CG and TG are shown in Table 1 and Figure 7. The null hypothesis was accepted between the machine assisted and manual cementation, when the overall mean and regions were evaluated (P>.05) Table 2. The interaction effect between systems, techniques and regions was not statistically significant (P>.05) Table 2.

Table 1. Mean ±standard deviation internal and marginal misfits by techniques and regions (µm) (n=18)

Regions	CG	TG
Angle regions	76.1 ±2.8	76.2 ±3.1
Linear regions	60.6 ±3.4	60.7 ±2.7
Incisal regions	144.8 ±2.5	145.2 ±3.3
Marginal regions	40.0 ±3.0	40.2 ±3.0
Overall mean	80.4 ±39.7	80.6 ±39.8

CG, control group; TG, teste group.

Table 2. Repeated measures ANOVA results for techniques

Tests of Within-Subjects Effects		
Source	**F**	**P**
Techniques	0.642	0.426
Techniques/Systems	0.929	0.339

Techniques/Regions	0.054	0.983
Techniques/Regions/Systems	1.21	0.313
Tests of Between-Subjects Effects		
Source	**F**	**P**
Systems	1.387	0.243
Systems/Regions	0.604	0.615

Dependent variable: internal and marginal misfits.

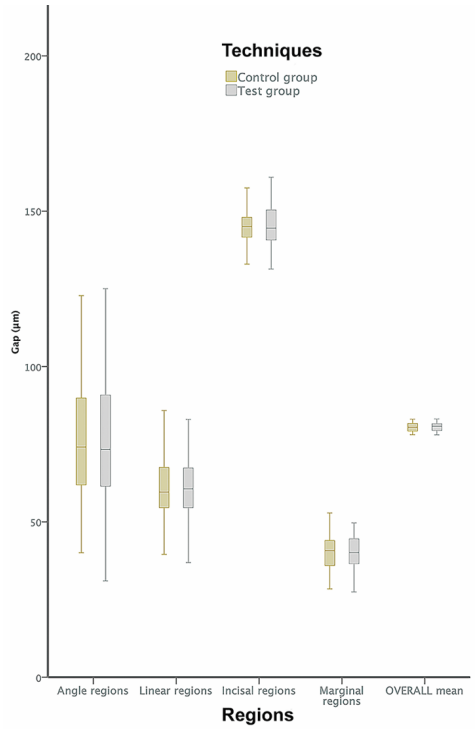

Figure 7. Box-plot diagrams for internal and marginal misfit gap (µm) by technique and regions.

The Bland and Altman[35] analysis is represented by a scatter plot graph showing the means of the two methods in the x-axis and the bias (difference between them) in the y-axis Figure 8. From the calculation of the bias (d) and its standard deviation (sd) the limits of agreement were determined as: d 1.96 sd that are represented in the Y axis of the graph. To evaluate the agreement between the methods, a T test was performed for a sample, whose result showed that the differences are not significantly different from zero (P>.05). This result shows consistent measures, since we can see that the bias is close to zero and is not statistically significant (P>.05). In order to analyze the proportional bias between the distribution of differences, a linear regression was performed, however, there was no statistical difference (P>.05), indicating that there is no proportional bias, that is, the values of the differences between the two methods are distributed homogeneously. The limits of agreement indicate that the differences between the two measurements are less than 5 µm.

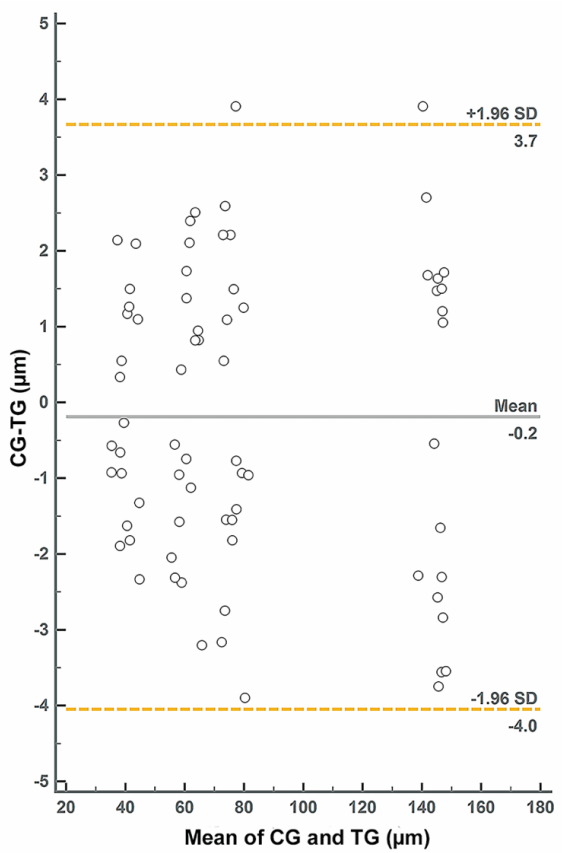

Figure 8. Bland and Altman[35] difference plots. Differences in misfit measured by machine cementation (CG) and by manual cementation (TG) against their means. Solid line represents mean; upper dashed line shows the mean +1.96 SD and lower dashed line the mean −1.96 SD. CG (control group); TG (test group); SD (standard deviation).

Discussion

This study found no statistical difference between cementation performed manually or with the aid of a machine. Therefore, the null hypothesis was accepted. The results obtained for the internal and marginal misfits are in agreement with the values cited in the literature, which recommend a maximum internal misfit of 100 µm[1,27] and marginal misfit of 120 µm[2,14,15]. The Bland and Altman[35] agreement analysis between the two methods showed that they both agreed with each other and that the limits of agreement presented acceptable differences from a clinical point of view. Boitelle et al.[7] compared a 2D method (replica technique) with a 3D method (triple optical scanning) and concluded that both methods showed good reliability and were able to measure the marginal misfit of zirconia copings. In that study, the reliability and repeatability of the two methods were evaluated. The value for the replica technique of .99 in the intra-class correlation coefficient and 3.7 µm in the repeatability coefficient[7]. These values meet those achieved in this study in which the limits of agreement were less than 5 µm.

In the clinical evaluation of the adaptation of a prosthesis, the manual cementation process is essential, regardless of the method to be used. However, it should be noted that such a procedure must be non-destructive and may, on the one hand, simulate cementation using the replica technique and perform a traditional 2D evaluation[33], or, on the other hand, perform a 3D evaluation through microcomputed tomography scans[8]. In this case, it is noteworthy that we would have a variable in which the simulation of cementation would be in silicone or another non-destructive material and the final work would be in definitive cement, such as zinc phosphate, resin cements, etc.

Some studies were carried out in order to obtain answers to this question. Licurci et al.[6] in a recent study, showed that, for the assessment of internal and marginal misfits, the replica technique, a non-destructive method, had similar results to a destructive technique that used zinc phosphate cement. In that study, cementation was performed with the aid of a machine in both techniques and with a constant load of 50 N[6]. Laurent et al.[31], in a study to validate the replica technique compared to a destructive technique that used the zinc phosphate cement, found no statistical differences between the groups. In that study, the cementation was performed manually in both techniques with the aim of simulating a clinical situation[31]. In both studies mentioned, zinc phosphate cement behaved similarly to addition silicone, regardless of whether the cementation process was carried out with the aid of a machine or manually.

The replica technique was also compared with 3D methods. Cunali et al.[32] evaluated the marginal and internal adaptations of zirconia copings using two non-destructive gauging methods, namely, the replica technique and the use of microcomputed tomography. Boitelle et al.[7] compared a 2D method (replica technique) with a 3D method (triple optical scanning) and the 2 studies concluded that both methods presented good reliability and were able to measure the marginal misfit of the zirconia copings[7,32]. In view of the above, the present study opted for the replica technique due to its reliability and repeatability, for being non-destructible and for simulating the cementation of the prosthetic element similar to a permanent cement[5,6,31,32].

Studies have shown that the procedure for cementing a prosthetic element may influence its misfit. Yildirim et al.[18] showed an increase in the marginal misfit of metal ceramic crowns influenced by cementation. The same was found by Kale et al.[20], who evaluated the effect of the different stages of manufacture and cementation in the marginal misfit of zirconia crowns made in CAD-CAM systems. Goujat et al.[14] in a systematic review to investigate the parameters that may influence the internal and marginal misfits of prosthetic elements made in the CAD-CAM system, found that the cementation procedure can increase the marginal misfit. Such a procedure, in turn, can be influenced by factors such as the materials being cemented and the design of the prosthetic[21,22]; the type of cement[19,21,22]; the predetermined space for the cement[20]; and the force applied to the prosthetic element[29].

Some studies that evaluated the misfit of prosthetic elements chose to control the force applied at the time of cementation with the aid of a machine. However, in these studies, there is no standardization regarding the minimum force to be applied. In this sense, we can find in the literature some values such as: 17.8 N[26]; 19.6 N[8]; 20N[28,29];

30N[7]; 39.2 N[25]; 50 N[6,23,24]. Most studies that recommend the manual cementation in order to simulate the clinical procedure, cannot measure the real value of the force being applied. In order to measure and predict the force exerted by one or more fingers in everyday applications, DiDomenico and Nussbaum[30] carried out a study that also sought to assess whether there would be differences between sex and age in relation to these forces. In the measurements related to the force exerted in a pressing movement, the mean e value and standard deviation (SD) found were 50.9 N (18.3) for males and 35.2 N (14.9) for females, with significant differences. In the control group of the present study, the use of a machine with a force of 50 N was intended to be a standard in relation to other studies[6,23,24], as well as the use of a force that can be manually reproducible in the test group[30].

Cementation is a step that can be influenced by factors such as cement viscosity, the design of the prosthetic and cement flow in different materials. Thus, it requires a minimum force that should be applied in each situation to achieve a result without the bias of these factors. Some of the limitations of this study are: the use of a single operator, although experienced and properly calibrated; performing manual cementation under optimal conditions, that is, it did not have the obstacles that normally occur in clinical care, such as limitations in the work area, limitations in visibility, presence of saliva, tired operator, etc.; and a single design of the prosthetic element.

Bland and Altman[35] postulated that agreement quantifies the proximity of two measurements made on the same subject and that are measured on the same scale as the measurements themselves. Two measurements of the same subject can differ for a number of reasons, depending on the conditions under which they were taken. In a method comparison study, there will be differences due to the variability inherent in each method, as well as potentially a bias between method measurements. If measurements are made by different observers or evaluators, the differences may be due to biases between individuals. One way to quantify agreement is to estimate its limits at 95%. These limits are defined in such a way that we expect that, in the long term, 95% of future differences between measurements made on the same subject will be within these limits[35]. In view of the above, new studies are necessary in order to evaluate whether other clinical variables could influence these limits of agreement, as well as to test the reliability of the procedure with several evaluators.

Conclusion

Within the limitations of this in vitro study, we can conclude that cementation using manual techniques or mechanical aid produces the same cement films.

Acknowledgments

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Data availability

Datasets related to this article will be available upon request to the corresponding author.

Author Contribution

CCP, LALS, CAAL and AC contributed to the conception, design, analysis and interpretation of data. LALS and AC wrote the paper and all authors revised the final version of manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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