Comparison of the Accuracy of Different Transfer Impression Techniques for Osseointegrated Implants

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The aim of this study was to evaluate 3 transfer techniques used to obtain working casts of implant-supported prostheses through the marginal misfit and strain induced to metallic framework. Thirty working casts were obtained from a metallic master cast, each one containing 2 implant analogs simulating a clinical situation of 3-unit implant-supported fixed prostheses according to the following transfer impression techniques: group A, squared transfers splinted with dental floss and acrylic resin, sectioned, and re-splinted; group B, squared transfers splinted with dental floss and bis-acrylic resin; and group N, squared transfers not splinted. A metallic framework was made for marginal misfit and strain measurements from the metallic master cast. The misfit between the metallic framework and working casts was evaluated with an optical microscope following the single-screw test protocol. In the same conditions, the strain was evaluated using strain gauges placed on the metallic framework. The data were submitted to one-way analysis of variance followed by the Tukey test ($\alpha = 5\%$). For both marginal misfit and strain, there were statistically significant differences between groups A and N ($P < .01$) and groups B and N ($P < .01$), with greater values for group N. According to the Pearson test, there was a positive correlation between the misfit and strain variables ($r = 0.5642$). The results of this study showed that the impression techniques with splinted transfers promoted better accuracy than the nonsplinted technique, regardless of the splinting material used.

Key Words: Implant-supported prostheses, strain gauges, transfer technique

When properly indicated, an osseointegrated implant is the treatment of choice for partially and completely edentulous patients because the surgical technique is less traumatic, and it presents good esthetic results that provide satisfactory prosthetic rehabilitation. The prostheses are fixed to the osseointegrated implants and provide better retention, stability, and esthetics, thereby increasing the patient's satisfaction.[1–3]

Despite the clinical relevance related to implant fixation, the longevity of the treatment is closely related to an accurate adaptation between the prosthetic components and fixations.[4] The most substantial issue with prosthetic misfit is that implants, unlike teeth, do not have periodontal ligament.[5] Therefore, all forces applied to the implants are transmitted directly through the alveolar bone without any form of damping on the bone-implant interface.[6–8] The most common strains induced in implants are caused by mastication, phonation, and excessive overload due to poor adaptation and misfit of the prosthesis. This overload can be reduced when the prostheses are made using accurate procedures, such as impression technique, cast pouring, infrastructure casting, porcelain coating, and prosthesis fixation type.[9–12]

The impression technique is one of the main factors that can cause marginal misfit and increase the strain on the implant-prostheses system, considering that the objective is to reproduce the relationship between the implants as accurately as possible.[13] The impression also has the important purpose of registering the morphology of soft tissues.[14,15] An inaccurate impression may result in prosthesis misfit, which may lead to biological and/or mechanical complications.[13] Mechanical complications, such as screw loosening, screw fracture, implant fracture, and occlusal inaccuracy, have been reported as a result of prosthesis misfit.[16–21] Biologically, the misfit that occurs from marginal discrepancy may cause adverse soft and/or hard tissue reactions due to increased biofilm accumulation.[22–24]

The transfer splint impression technique using acrylic resin has been widely practiced and studied.[25–32] However, the disadvantage of this technique is the clinical time required for implementation. Constant research into improved techniques has led to a modified technique that uses bis-acrylic resin material. The bis-acryl resin is automatically mixed in the automix gun and expressed as a heavy, very soft, and very viscous material.[33] It has shown significantly lower shrinkage values compared with a monomethacrylate-based material.[34] However, the literature is still limited regarding this new technique. There are questions about whether the technique increases the

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DOI: 10.1563/AAID-JOI-D-13-00126

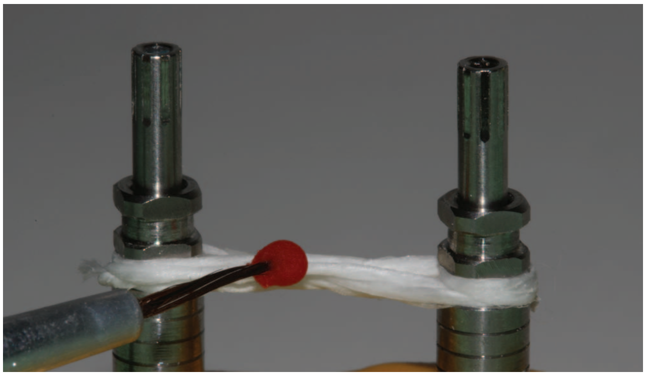

FIGURE 1. Impression technique with dental floss and acrylic resin.

strain on the prostheses system, and whether different impression techniques result in differences in marginal misfit and strain values.

The aim of this study was to evaluate three transfer techniques used to obtain working casts of implant-supported prostheses in terms of misfit and strain induced on the metallic framework.

MATERIALS AND METHODS

Thirty ($n = 10$ of each type) stone working casts were obtained from a type IV dental stone (Herostone, Vigodent, Rio de Janeiro, Brazil), each one containing two implant analogs. A 4.1-mm cervical stand and a prosthetic hexagonal external connection (Conexao Prosthetic Systems, Sao Paulo, Brazil) were placed on the lower first molar (pillar A) and lower first premolar region (pillar B), which simulated a clinical situation with three-unit implant-supported fixed prostheses. The casts were made using 1 of 3 impression techniques. In group A, working casts were obtained using squares transfers (Conexao) splinted with dental floss and acrylic resin (Duralay II, Polidental, Sao Paulo, Brazil) (Figure 1). After polymerization, the acrylic resin was sectioned and splinted again. In group B, working casts were obtained using square transfers (Conexao) splinted by dental floss and bis-acrylic resin (Luxatemp, DMG Chemisch-Pharmazeutische Hamburg, Germany) (Figure 2). In group N, working casts were obtained using square transfers (Conexao) and a nonsplinted impression technique.

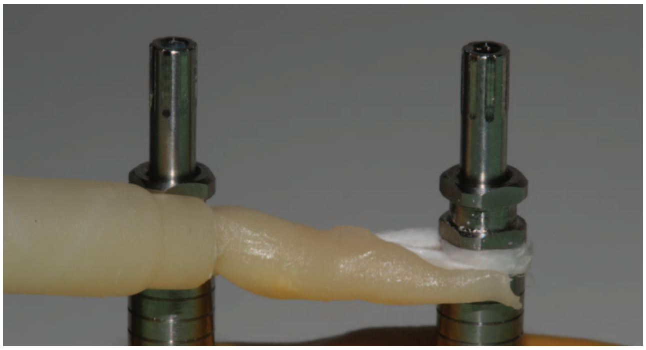

FIGURE 2. Impression technique with dental floss and bis-acrylic resin.

A custom tray was made using methyl methacrylate resin (Jet, Classico, Sao Paulo, Brazil) to ensure uniform thickness of the impression material. The tray has an orifice to allow for use of the open tray impression technique with square transfers. Cylinders were placed on the tray like a tripod to ensure stability during the impression procedure and during pouring of the mold. A base of polyvinyl siloxane material (Flexitime Easy Putty, Correct Flow, Heraeus-Kulzer, Hanau, Germany) was made with notches to fit the custom tray in the same insertion axis. Thus, a uniform pattern impression was obtained according to the master cast, and the stone casts were standardized.

The impression transfers were screwed on the implants of the metallic master cast. The following impression procedures were used for the treatment groups.

In group A, the transfers were screwed on the implants of the metallic master cast and linked using unstrained dental floss; these were subsequently recovered using the powder-liquid paintbrush technique with acrylic resin (the Nealon technique). After polymerization, the dental floss-resin joint was sectioned with a diamond wheel and linked again[25,30–32] to reduce possible strain from the polymerization shrinkage of the acrylic resin. After this step, the impression procedure was performed.

In group B, the transfers were splinted in a manner similar to the procedure used for group A; however, the interlace of dental floss was linked with the bis-acrylic resin using an auto-mix gun, and then the impression was performed.

In group N, the squared transfers were screwed to implant analogs placed in the metallic master cast, and then the impression was performed with square transfers not splinted.

The impressions for the 3 groups were made using polyvinyl siloxane material.[18–24,35–37] The impression material (Flexitime Easy Putty) was manipulated using a tip and auto-mix gun. After 3 minutes, the transfers were unscrewed, the custom tray was removed from the master cast, and the analogs of the implants were screwed to the transfers so the mold could be subsequently filled with type IV dental stone (Herostone).

The dental stone was manipulated manually for 20 seconds and then mechanically for 40 seconds using the proportion of 100 g powder to 22 mL distilled water, according to the manufacturer's instruction. The first portion of the dental stone was poured slowly into the impression without contacting the analog surface following the latex cylinder technique,[38,39] and the latex cylinders were placed around the implant analogs to protect them. After the dental stone set, the latex cylinders were removed, and the resulting space was filled with the second portion of dental stone. After 60 minutes, the cast was removed from the impression. The impression techniques and the working casts were performed by the same operator.

A rectangular structure was waxed on the master cast with 20 mm × 5.0 mm × 5.0 mm dimensions. The wax pattern was included in investment (Rematitan Plus, Dentaurum, Insprin-gen, Germany) in a special ring for titanium melting. The ring was positioned in a heating oven (Vulcan 3.550, Dentsply International, Bogotá, Colombia). Commercially pure titanium (Tritan, Dentaurum) was melted in equipment composed of voltaic arc-melting by injecting molten metal in a vacuum

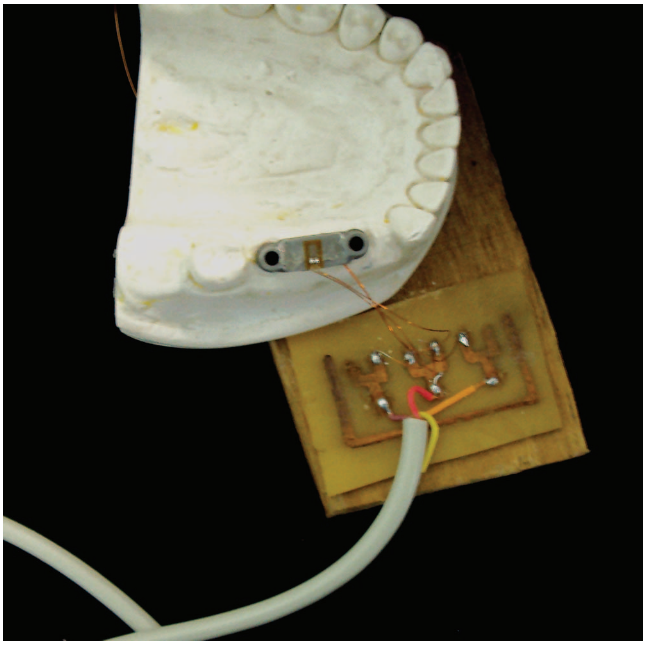

FIGURE 3. Circuit for strain gauges.

(Dentaurum). The metal framework finishing was made with aluminum oxide blasting and burs for titanium polishing.

The marginal misfit measurements were performed with an optical microscope with accuracy of 1.0 μm and 120× magnification, according to the protocol for the single-screw test,[40,41] to evaluate the passivity in implant-supported structures. The measurements were performed for a single examiner 3 times (intraclass correlation coefficient = 0.8691). An average for each framework-pillar set was performed. The gaps between the base of the implant analog and the gingival surface of the metallic framework in pillar B were observed when the screw of the pillar A was tightened.[42] To standardize the position of the readings, a reference was made on each abutment with a hydrographic pen. The strain was assessed after the metallic framework was placed on the implant analogs of the cast. The framework screw was tightened with 32 Ncm torque, according to the manufacturer's instructions. The measurements were performed by using strain gauges (Excel Sensors Engineering, Embú, Sao Paulo, Brazil), following the formation of a half Wheatstone bridge (Figure 3). One metal strain gauge[30] was placed on the upper and lower surfaces of the framework, leaving a distance of 90° between them. The readings of the framework elastic deformation were made after all prosthetic screws were tightened. The electric signals were captured by a computer-controlled apparatus (ADS0500, Lynx Electronics, Sao Paulo, Brazil) and processed using a specific software (AqDados 7, Lynx Electronics).[30,39]

TABLE 1

The means values (standard deviations) of marginal misfit measurements for each group.

	Marginal Misfit (μm)	
Group A	77 (± 4)	B
Group B	72 (±11)	B
Group N	251 (±152)	A

*Means followed by distinct capital letters differ among themselves by the Tukey test ($\alpha = 0.05$), between groups A and N ($P < .01$) and between groups B and N ($P < .01$).

Table 2

Means values (standard deviations) of microstrain (μm) for each treatment group

	Microstrain (μm)	
Group A	471.87 (±15.56)	B
Group B	468.66 (±15.07)	B
Group N	496.94 (±20.91)	A

*Means followed by distinct letters differ among themselves by the Tukey test ($\alpha = 0.05$), between groups A and N ($P < .01$) and between groups B and N ($P < .01$).

Statistical analysis

The data submitted to the Kolmogorov-Smirnov test revealed normal distribution. Afterward, the Pearson test was used to evaluate the correlation between marginal misfit and strain. The between-groups comparison was done using one-way analysis of variance for the marginal misfit and strain followed by the Tukey test. A significance level of 5% was considered for all analyses.

RESULTS

Table 1 shows the means and standard deviations of the vertical misfit obtained for each group. The Tukey test revealed statistically significant differences between groups A and N ($P < .01$) and groups B and N ($P < .01$), with greater values for group N.

Means and standard deviations of the strains are shown in Table 2. The Tukey test showed statistically significant differences between groups A and N ($P < .01$) and groups B and N ($P < .01$), with greater values for the group N.

Table 3 presents the Pearson correlation coefficient for marginal strain and misfit.

DISCUSSION

In a recent systematic review related to implant impressions, a large number of studies reported better accuracy with the splinted technique than the nonsplinted one.[13] However, controversy exists in the literature regarding whether or not to adopt the splint procedure. Although some authors have

Table 3

Pearson correlation coefficient for variables of marginal misfit and strain*

	r	P value
Misfit × strain	0.5642	.0012

*Pearson correlation coefficient ranges between −1 and 1.

favored nonsplinted square transfers,[28,43–45] others have found no difference between direct and indirect transfer techniques.[32,46]

When the 3 impression techniques were compared in this study, the results showed that the splinted transfer techniques presented higher accuracy in making working casts, in agreement with previous studies.[26,29,30,36,47–49] The current results showed no significant reduction in vertical misfit and strain on the frameworks when comparing groups A and B, although there are differences between these techniques. Polymers that produce less polymerization stress may have potential use for splinting purposes; however, this may raise the cost of materials tested.[25] While the bis-acrylic resin (automix gun) procedure quickly reproduces the impression, the time used for separation and repair with acrylic resin is greater than with a single piece made with bis-acrylic resin.

The main challenge with implant-supported procedures is to develop an acceptable prosthesis that does not compromise long-term treatment.[16] Passive fit is assumed to be a significant prerequisite for maintaining the bone-implant interface.[4] To provide a passive fit, the framework should theoretically not induce any strain on the implant components and peri-implant bone.[50]

Previous studies showed that none of the assessed frameworks exhibited passive fit.[42,51] The average vertical misfit in the current study was 77 μm for group A, 72 μm for group B, and 251 μm for group N. Branemark[5] proposed 10 μm of vertical misfit to allow bone maturation and remodeling in response to occlusal load; however, these values of vertical misfit are difficult to achieve. Jemt[52] defined passivity as the level that did not cause long-term complications and suggested that values of vertical misfit <150 μm are clinically acceptable. In this study, the mean passive-fit values were considered clinically acceptable for groups A and B and not acceptable for group N. These results showed the accuracy of the splinted transfer technique.

Considering the procedures to obtain an impression, each step has some importance and should not be neglected. The procedures between the impression and the final cast could influence the analog's position in the working casts, which could increase distortion and the occurrence of misfit and strain in the prosthesis.[38] The open tray technique allows the coping to remain in the impression. This fact decreases the deformation of the mold during the impression material recovery time outside the mouth, eliminates concerns about replacing the coping back into its respective space in the impression, and reduces the effect of implant angulations.[53]

Splinting squares transfer with resin has been recommended for obtaining a more accurate inter-implant relationship because it prevents rotation of the copings in the impression during fastening of the implant analog. The weak union between the tapered coping and the impression material may facilitate the movement of the analogs as a result of the dental stone expansion during setting.[54] The hardness of the acrylic resin splint resists the potential forces of distortion, increasing the accuracy of the working cast.[25] The impression material and impression technique,[29,55] disinfection of the mold, waiting time, and conditions of cast pouring are factors that can influence accuracy in reproducing the desired clinical situation.[8]

The polyvinyl-siloxane impression material was chosen for this study as it has been widely used in clinical practice and presents a dimensional stability compatible with achieving adequate, accurate casts for implant-retained impressions.[18–24,35–37] A lower-expansion type IV dental stone was used because its main characteristics are high resistance, hardness, and low hygroscopic expansion.[56] In addition, some previous studies used the strain gauges measurement method to determine which technique introduces fewer distortion.[25,28,30,57–59]

The present study used the arrangement following the formation of a half-Wheatstone bridge by using 2 strain gauges on the framework (one parallel on the upper surface and the other perpendicular on the lower surface).[30] This condition allowed for the measurement of the strain in the metallic framework, which represents a complementary way to do the linear analysis of the marginal misfit and not to measure the strain induced. The higher values of strain (496.94 μm) were found in group N, the same group that induced a higher level of marginal misfit; this demonstrates the inaccuracy of the nonsplinted technique.

The present study found that marginal misfit was responsible for the strain level induced on the infrastructure. The Pearson coefficient obtained for misfit and strain was $r = 0.5642$, indicating a moderate, though positive, relationship. According to this result, it can be understood that when the marginal misfit increases, the strain values also increase. In other words, the strain level establishes a dependency with the marginal misfit. This result is in accordance with the findings of some previous studies.[51,60–63]

The limitation of the study was that no cyclic loading was applied in the framework. It is claimed that the location and magnitude of occlusal forces can affect the amount and quality of the strain transmitted to the components of the bone-implant-prosthesis system.[16] Based on this consideration, further studies are needed to verify the influence of different metals in fabricating the framework and the effect of mechanical cycles under different clinical situations.

CONCLUSION

Based on the results of this study, the following conclusion can be considered: the impression techniques with splinted transfers promoted better accuracy than a nonsplinted technique, regardless of the splinting material used.

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