Evaluation of the Accuracy of 3 Transfer Techniques for Implant-Supported Prostheses with Multiple Abutments

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Purpose: *This study evaluated the deformation of a metallic framework connected to 15 stone casts fabricated using 3 transfer techniques to determine the most accurate impression procedure.* ***Materials and Methods:*** *Five stone casts were made from polyether impressions of an epoxy resin master model for each transfer technique. Group 1 samples were created by the direct splinted technique (square transfer copings splinted with carbon steel pins and autopolymerizing acrylic resin, custom tray); group 2 samples were made by the direct nonsplinted technique (square transfer copings, custom tray); and group 3 samples were fabricated using the indirect technique (tapered transfer copings, custom tray). Sixteen strain gauges were fixed on the framework to measure the degree of framework deformation for each stone cast. Pairs of strain gauges placed opposite each other constituted 1 channel to read deformation (half Wheatstone bridge). Deformation readings were collected at the 4 segments between abutments in 4 directions (anterior, posterior, superior, and inferior). Deformation data were analyzed using analysis of variance and the Tukey test at the .05 and .01 levels of significance.* ***Results:*** *Group 1 samples allowed the most accurate reproduction of analog position compared to the samples made using the other techniques. No significant difference was found between the direct nonsplinted (group 2) and indirect (group 3) techniques.* ***Discussion:*** *Although some studies have evaluated transfer techniques with similar methodology, this study demonstrated the most suitable strain gauge setup to record framework deformations in all directions and simultaneously offset the effects of temperature variation.* ***Conclusions:*** *The direct splinted technique was the most accurate transfer method for multiple abutments compared to direct nonsplinted and indirect techniques.* INT J ORAL MAXILLOFAC IMPLANTS 2004;19:192–198

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Increasingly, scientific evidence supports the use of osseointegrated implants for the rehabilitation of partially or totally edentulous patients.[1–10] One fundamental aspect of achieving success for implant-supported prostheses is the passivity of superstructure fit on abutments. The absence of passive fit may lead to prosthetic failures, such as fracture and/or loosening of screws, retention of biofilm caused by misfit components, and even loss of osseointegration.[11–16]

The clinical and laboratory variables intrinsic to the rehabilitation treatment complicate the creation of prostheses with a passive fit. Among those variables, transfer techniques have a decisive influence on the fabrication of accurate working casts. Both

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direct and indirect techniques for transferring implant position to the working cast are commonly used in dental practice. The choice of an indirect technique, which uses tapered transfer copings and a closed stock tray, is controversial because, while it requires less difficult clinical procedures,[17] it probably involves greater instability.[18–20] Likewise, the advantages of splinting, and of each splinting technique used in the direct technique, have not been established.[21–23] One advantage of the direct technique, which uses square transfer copings with an open custom tray, would be greater transfer precision because of the splinting stability during both the impression removal and analog connection.[22,24,25] Nevertheless, distortion can result from the residual polymerization contraction of the resin used for splinting.[26] Different techniques for splinting implant transfer copings with acrylic resin have been tested, such as dental floss, prefabricated acrylic resin bars, and stainless steel burs.[4,25,27,28] The distortion in the resulting working casts has been evaluated by microscopy[21,24] and strain gauges.[22,25,27] Previous studies using strain gauges have analyzed the microdeformation of superstructures positioned on working casts fabricated by transfer procedures using different splinting techniques[27] and tightening sequences and force levels,[25] as well as direct versus indirect techniques.[29]

This study aimed to assess the accuracy of 3 transfer techniques (direct splinted, direct nonsplinted, and indirect) for an implant-supported prosthesis with multiple abutments. To accomplish this, the authors used a new strain gauge setup to record framework deformations in 4 directions (anterior, posterior, superior, and inferior) and simultaneously make up for the effects of temperature variation.

MATERIALS AND METHODS

Fabrication of the Master Cast

An edentulous jaw model was fabricated in epoxy resin (Defama Famasil, São Paulo, Brazil). Five holes were made in the anterior region, 10 mm apart, simulating the Brånemark protocol. Five abutment analogs (STD DCB 175-0, Brånemark System; Nobel Biocare, Göteborg, Sweden) were positioned inside the holes with acrylic resin (Pattern Resin; GC Corporation, Tokyo, Japan). A framework of rectangular section simulating a prosthesis was waxed and cast in gold-palladium alloy (Stabilor G; Degussa, Frankfort, Germany). The 5 analogs were removed from the jaw model and screwed to the gold cylinders (DCA 073-0, Brånemark System; Nobel Biocare) of the metallic framework. This framework/analog structure was then fixed in the holes filled with epoxy resin using a milling machine. This method aimed to obtain a master cast featuring passive fit between the framework and the analog abutments (Figs 1a to 1c).

Fabrication of Custom Trays

Three acrylic resin guide stops (1 anterior and 2 posterior) were added to the master cast to ensure uniform thickness of the impression material. A 3-mm-thick wax spacer was placed on the cast involving the square transfer copings (DCC 026-0, Brånemark System; Nobel Biocare) and the tapered copings (DCB 080-0, Brånemark System; Nobel Biocare) for the fabrication of their respective custom trays. One light-curing resin plate (Stern Tek custom tray materials; Sterngold, Attleboro, MA) was used for each custom tray. Two trays had 5 holes on the upper section to allow access to the square coping screws, and 1 tray was closed for the tapered transfer copings.

Splinting of Transfer Copings

For group 1 (direct splinted technique), 2.5-mm-diameter steel pins were sectioned to fit in between the transfer copings. Autopolymerizing acrylic resin (Pattern Resin; GC Corporation) was applied around the transfer copings using an incremental application technique with a no. 000 brush (Kolinski Rembrandt, Apeldoorn, The Netherlands). The amount of acrylic resin was assumed to be satisfactory when the square surfaces of the copings and the ends of the pins were fully covered. The handling and visual inspection of the amount of resin were carried out by the same operator. A 30-minute interval was allowed after splinting to guarantee complete resin polymerization (Fig 2).

Transfer Procedures and Specimen Preparation

Regular-viscosity polyether (Impregum F; Espe Dental, Seefeld, Germany) was the impression material of choice for all transfer procedures. An appropriate dispenser (Pentamix 2; Espe Dental) was used to standardize all mixtures. Polyether was injected around the transfer copings and placed inside the custom tray using the dispenser. The custom trays were seated over the 3 reference stops with finger pressure at the premolar region. After 15 minutes, the custom trays were removed.

The same operator manually attached analogs to the transfer copings. For the indirect transfer technique, the tapered copings connected to their analogs were replaced in their corresponding holes.

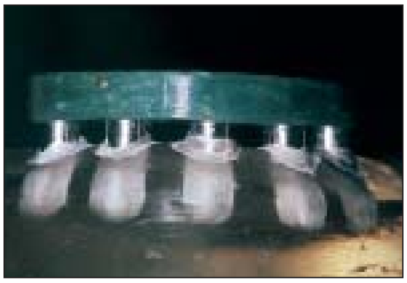


Fig 1a *(Left)* Framework waxing.

Fig 1b *(Right)* The analogs are reassembled to the master epoxy model using the framework to ensure passive fit.

Fig 1c *(Left)* Final master model with analogs and reference stops for impression standardization.

Fig 2 *(Right)* Square transfer copings are splinted with carbon steel pins and autopolymerizing resin.

Each impression was poured with vacuum-mixed type IV dental stone (GC Fujirock EP; GC Europe, Leuven, Belgium) and allowed to rest for 1 hour for complete setting. All transfer steps and specimen fabrication were carried out at temperatures ranging from 23°C to 25°C.

Assessment of Accuracy

Sixteen strain gauges (120 Ω; excitation voltage 4 V; active area 1.5 × 1.5 mm; PA-06-062 AB-120-L, Excel Engenharia de Sensores; Embu, São Paulo, Brazil) were fixed to the metallic framework surface (anterior, posterior, superior, and inferior faces at each of the 4 segments) to measure the framework deformation of each cast. The strain gauges were bonded with a special cyanoacrylate (M-Bond 200; Visha Micro-Measurements, Raleigh, NC) with finger pressure until setting to keep the grade (active area) in complete contact with the surface of the framework. Four strain gauges per face were assembled longitudinally between abutments. Each pair of strain gauges that were placed opposite each other formed a connection denoted the "half Wheatstone bridge," which constituted 1 channel for reading deformation. With this setup, deformation readings could be collected at the 4 segments between abutments in 4 directions (anterior, posterior, superior, and inferior) (Figs 3a and 3b).

Therefore, 8 reading channels (labeled 1 to 8) were built along the framework. The 8 pairs of strain gauges forming the 8 half Wheatstone bridges were then connected to 8 cables (4-way armored cable, AF4×1×28; AWG, Pirelli, São Paulo, Brazil). Those cables led the signals to a 16-channel strain gauge conditioner (Cio-Exp-Bridge 16; Measurement Computing, Middleboro, MA), which was used to supply an excitation voltage in the Wheatstone bridge, thereby improving the signal.

The analog signal of electric resistance variation was converted into a digital signal via a 12-byte resolution converter (PC-Card 16/330; Computer Board) and processed by custom software (SAD; UFRGS, Porto Alegre, RS, Brazil). Channel signals were originally measured in millivolts and then converted to microstrain units (μm/m).

Prior to the deformation readings on the working casts, the framework was seated on the master cast and the screws were tightened to 10 Ncm using a torque controller (DEC 600-1 Osseocare Drilling Equipment; Nobel Biocare) so that the strain gauges were calibrated to zero. This procedure aimed to discharge any residual stress because of the impossibility of achieving passive fit of the framework connected to the master cast. This occurred probably because of the polymerization distortion of the epoxy resin around the analogs.[22] The analogs were numbered (1 to 5) clockwise, and the tightening sequence was: 2, 4, 3, 1, 5.[6] The implication of this tightening sequence is not discussed further because this issue is still controversial in the literature. Nissan and coworkers[25] compared different sequences and found no difference in framework deformation, whereas Watanabe and associates[30] found the lowest deformation levels when the terminal abutments were tightened at the end of the tightening sequence.

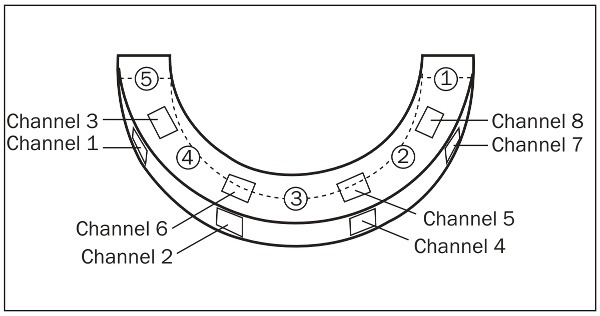


Fig 3a Illustration of the deformation channels on the framework.

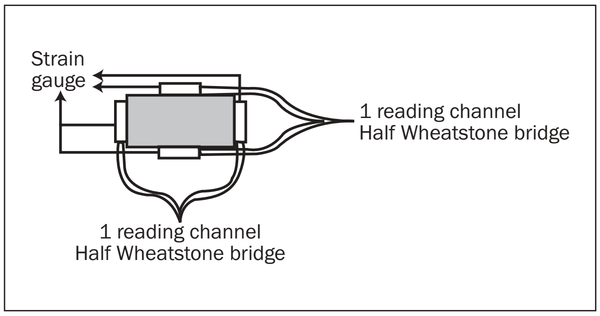


Fig 3b Cross section of the metallic framework showing the strain gauge setup.

Fig 4a Test specimen (final stone cast).

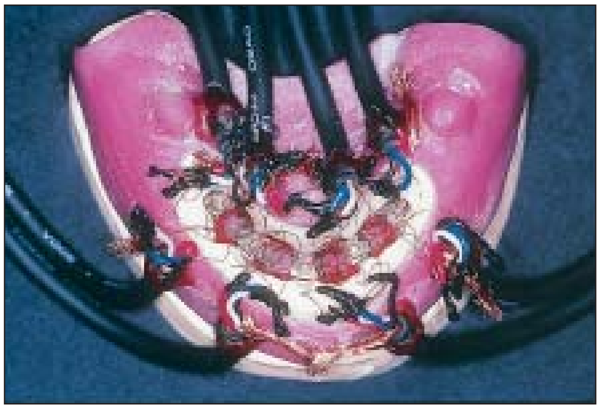


Fig 4b Assessment of framework deformation in a specimen with the assembled strain gauges.

The 15 specimens (n = 5 for each transfer technique tested) were measured twice with the same tightening sequence at 10 Ncm. To guarantee the same degree of screw wear, 1 sample per technique was measured 1 at a time. After the first readings of the 15 specimens were completed, a new series of readings was performed using a new set of screws (Figs 4a and 4b).

The 2 measurements of framework deformation for each specimen were averaged for statistical analysis. Deformation data were analyzed using analysis of variance and the Tukey test at the .05 and .01 levels of significance.

RESULTS

Original data were transformed by logarithmic and square root functions to better fit into normal distribution. Analysis results were retransformed to be displayed in tabular format.

Table 1 shows the overall mean values for deformation for the samples in the 3 groups. Group 1 samples (direct splinted technique) exhibited statistically lower deformation than samples in group 2 (direct nonsplinted technique) and group 3 (indirect technique). No statistically significant difference in deformation between group 2 samples and group 3 samples was found.

Mean deformations for each of the 8 channels are displayed in Table 2. Statistically significant differences were observed between channels 1, 2, and 6. The lower and higher deformation values were labeled *a* and *b*, respectively.

Analyses of the deformation values in function of the 2 reading series attest to the reliability of the method (Tables 3 and 4). Table 3 shows the summary of the analysis of variance for the 3 transfer techniques and the 2 series of deformation readings. No significant difference was found for the 2 reading series or for the interaction between transfer technique and reading series. Table 4 shows that channels 2 and 6 were statistically different at the .01 level of significance, and channel 1 was statistically different at the .05 level. No difference was detected for reading series or interaction.

Table 1 Deformation (µm/m) for Each Transfer Technique Group

Experimental group	Mean deformation (SE)
Group 1 (direct splinted technique)	68.03 (2.61)^{b}
Group 2 (direct nonsplinted technique)	105.64 (1.61)^{a}
Group 3 (indirect technique)	111.05 (4.70)^{a}

Means followed by the same letter do not statistically differ (Tukey test .05 level of significance).

Table 2 Deformation Means (µm/m) and Standard Errors for Each of the 8 Reading Channels Per Transfer Technique Group

	Mean deformation (SE)		
Channel	Group 1	Group 2	Group 3
1	165.67 (25.49)^{a}	112.17 (11.81)^{ab}	63.43 (44.70)^{b}
2	58.98 (14.43)^{b}	370.56 (37.35)^{a}	325.80 (64.36)^{a}
3	26.21 (4.92)	17.14 (3.35)	37.45 (7.86)
4	60.95 (12.22)	103.54 (16.70)	111.05 (69.20)
5	26.32 (6.26)	35.16 (12.77)	31.02 (8.13)
6	26.01 (4.58)^{a}	12.39 (2.71)^{b}	43.56 (5.43)^{a}
7	75.94 (26.42)	66.02 (17.39)	31.50 (7.00)
8	2.46 (1.75)	2.82 (0.52)	2.10 (0.29)

Means followed by the same letter in the column do not statistically differ (Tukey test .05 level of significance).

Table 3 Results of Analysis of Variance for Groups (Transfer Techniques) and Deformation Reading Series

Sources of variation	Degree of freedom	Mean
Transfer techniques	2	0.73*
Reading series	1	0.03
Transfer techniques vs reading series	2	0.02
Coefficient of variation (%)		6.60

*Statistically significant at .01 level of significance.

DISCUSSION

The 3 transfer techniques evaluated in this study are often used for the fabrication of implant-supported prostheses with multiple abutments. Although the dental literature encompasses several articles on the accuracy of transfer techniques, no consensus has been reached.

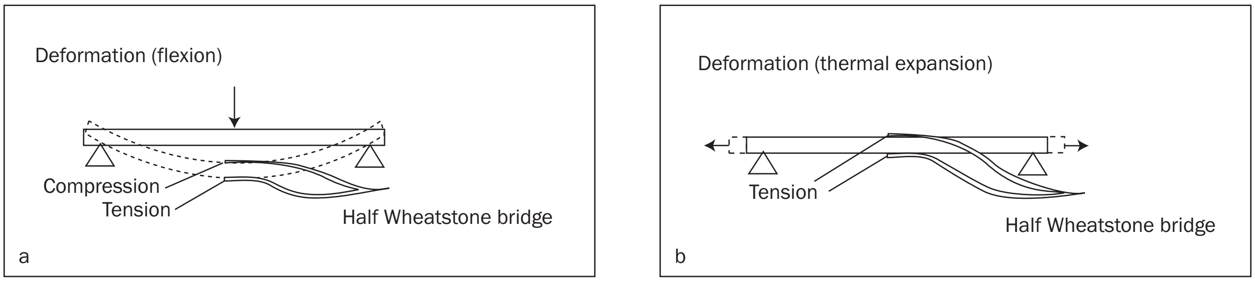
With respect to the comparison of indirect versus direct splinted techniques, the present findings showed that the latter reproduced the position of abutments more accurately. In the direct technique, the maintenance of transfer copings in the impression would be an advantage, as this procedure avoids replacement of the copings in the impression.[20] However, Humphries and coworkers[17] perceived greater accuracy using the indirect technique with tapered copings. They stated that the torque necessary to fasten square copings on analogs in the direct technique creates more distortion than any inaccuracy derived from replacement of the copings. Rotation of the square coping during tightening of the analog screw may also occur in the direct nonsplinted technique.[20] This could be one reason for the similar results in distortion between direct nonsplinted and indirect transfer techniques.

One study found that nonsplinting of transfer copings in the direct technique is the most accurate transfer method.[26] Others found no difference between splinted and nonsplinted techniques using a low-flexibility impression material (polyether).[21,31] However, the present study as well as 2 other studies[21,31] showed that splinting may provide stabilization of transfer copings under the torque from analog tightening and reduce rotational freedom within a resilient impression material. Splinting is the determining factor for the most accurate cast fabrication, regardless of the impression material.[22,24,25,27,32]

Table 4 Results of Analysis of Variance for Each Channel as a Function of Transfer Technique and Reading Series

	Sources of variation			
Mean square	Transfer techniques	Reading series	Transfer techniques vs reading series	Coefficient of variation (%)
Degrees of freedom	2	1	2	
Channel 1	2.32*	0.05	0.25	17.98
Channel 2	405.38**	0.02	3.61	26.30
Channel 3	9.85	4.02	1.45	35.09
Channel 4	1.10	0.22	0.05	22.82
Channel 5	1.59	0.09	1.87	41.27
Channel 6	23.80**	2.94	0.25	26.74
Channel 7	1.93	0.30	0.06	22.00
Channel 8	0.04	—	—	56.97

*Statistically significant at .05 level of significance; **statistically significant at .01 level of significance.



Figs 5a and 5b Illustration of the strain gauge setup of a framework under deformation. *(a)* Bending; *(b)* thermal expansion.

The contradictory results for transfer accuracy that have been reported in the literature may be partially explained by the use of different methodologies to assess accuracy. Some experiments used microscopy to measure the displacement of analogs in the test specimens in comparison to the master cast at selected points.[17,24] However, since inaccuracy was expressed in only 2 dimensions, information was lost. Furthermore, the assessment of total assembly fit was impossible.

Electrical resistance strain gauges enable the measurement of deformation in multiple directions with high sensitivity (µm/m). Few studies have used strain gauges to determine which transfer technique causes the least distortion.[22,25–27] In the method employed by Assif and associates[22] and Nissan and colleagues,[25] 4 strain gauges were fixed on the top surface of the framework to measure deformation during screw tightening. This linear setup of strain gauges on the top surface allowed only readings of vertical deviation for upward and downward deformation.

The purpose of the present approach was to measure framework deformation in 4 directions while controlling for some confounding variables. The strain gauge setup was based on the use of half–Wheatstone bridge connections, which are composed of 2 strain gauges on opposite sides. This concept has 2 main advantages: First, the electric signal (measured in millivolts) is amplified, because when one strain gauge undergoes compression, the other is under tension. These 2 phenomena produce variations in electric resistance. The electric resistance of the strain gauge under tension increases, whereas the opposite affects the strain gauge under compression. Thus, the total variance (imbalance) in electrical resistance increases, since the strain gauges are interconnected (Fig 5a). Second, half Wheatstone bridges compensate for temperature variation. For instance, when thermal expansion occurs, the 2 strain gauges are under tension and exhibit similar electrical resistance readings. In this case, the electric resistance variation was zero (Fig 5b).[33]

The use of 8 half Wheatstone bridges enabled the reading of deformation in all 4 segments between abutments. Although Inturregui and coworkers[26] used a similar method with strain gauges to measure accuracy in analog position when square copings were not splinted, the authors obtained different results. Their experimental model (with 2 implants) would tend to be less sensitive to distortions than a 5-abutment model.[15] Furthermore, the authors used only 2 strain gauges—1 for each direction—originating quarter–Wheatstone bridge connections, which as expected, exhibited low sensitivity to electric signals and did not compensate for changes in temperature.

The selected strain gauge method is highly sensitive. The present efforts were directed toward obtaining a passive fit of the framework on the master cast before the transfer procedures. Therefore, analogs were removed from the jaw model after casting the framework, screwed into the framework gold cylinders, and again fixed to the jaw model using epoxy resin. In this manner the master cast was adjusted to the framework. However, the strain gauge readings revealed signs of deformation in the framework fixed to the master cast under 10-Ncm torque. This showed that small deformation strains might be present because of resin polymerization shrinkage or minimal misfit of screws and gold cylinders.

The definition of acceptable clinical values for passivity represents an ultimate goal of transfer studies. Nevertheless, evidence of the real outcomes of strains within the prosthesis/implant/bone complex still is not available. This study design aimed to establish which transfer technique produces the most accurate casts with analogs. Further studies are needed to evaluate the amount of resulting stress and clinical acceptability of a given technique.

In conclusion, this study suggested that:

1. The direct splinted technique was the most accurate transfer method for multiple abutments compared to direct nonsplinted and indirect techniques.
2. Direct nonsplinted and indirect techniques resulted in similar transfer deformation.

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