

Comparison of Implant-Abutment Interface Misfits After Casting and Soldering Procedures

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The aim of this study was to compare vertical and horizontal adjustments of castable abutments after conducting casting and soldering procedures. Twelve external hexagonal implants (3.75×10 mm) and their UCLA abutments were divided according their manufacturer and abutment type: PUN (plastic UCLA, Neodent), PUC (plastic UCLA, Conexão), PU3i (plastic UCLA, Biomet 3i), and PUTN (plastic UCLA with Tilite milled base, Neodent). Three infrastructures of a fixed partial implant-supported bridge with 3 elements were produced for each group. The measurements of vertical (VM) and horizontal (HM) misfits were obtained via scanning electron microscopy after completion of casting and soldering. The corresponding values were determined to be biomechanically acceptable to the system, and the results were rated as a percentage. Statistical analysis establishes differences between groups by chi-square after procedures, and McNeman's test was applied to analyze the influence of soldering over casting ($\alpha \leq .05$). For the values of VM and HM, respectively, when the casting process was complete, it was observed that 83.25% and 100% (PUTN), 33.3% and 27.75% (PUN), 33.3% and 88.8% (PUC), 33.3% and 94.35% (PU3i) represented acceptable values. After completing the requisite soldering, acceptable values were 50% and 94.35% (PUTN), 16.6% and 77.7% (PUN), 38.55% and 77.7% (PUC), and 27.75% and 94.35% (PU3i). Within the limitations of this study, it can be concluded that the premachined abutments presented more acceptable VM values. The HM values were within acceptable limits before and after the soldering procedure for most groups. Further, the soldering procedure resulted in an increase of VM in all groups.

Key Words: *implant-abutment interface, soldering, fit, dental implants*

INTRODUCTION

The UCLA abutment is a castable plastic cylinder that connects directly to implants and can be modified by the laboratory technician.¹ Some advantages of this abutment include its low cost, the ability to overcome problems such as a limited interocclusal distance, a small interproximal dis-

tance between implants and within a shallow gingival area, and the possibility of counterbalancing implant angulation error.² The most significant disadvantage of the UCLA abutment is that the laboratory preparation associated with its implant-abutment fit has the potential to cause a misfit, which may result in a loosened screw and/or fracture or an implant loss and/or fracture.^{3,4}

The implant-abutment interface has been reported to be a significant factor in the transfer of stress, as well as possibly playing a role in adverse biological responses or prosthetic reconstruction complications.⁵ Several factors related to the manufacture of implant components, as well as

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clinical and laboratory processes, can contribute to a clinical misfit of the prosthesis.⁵ Quantification of the marginal gap in implant dentistry is usually performed by direct measurement of the magnified gap of the superstructure positioned on the master cast or on the experimental model.^{6–13} The UCLA abutments must undergo preparatory steps in the laboratory, such as casting, soldering, and porcelain building, or some combination of these; such processes can result in distortion during the manufacture of the prosthesis.⁶

Two types of complications due to a prosthesis framework misfit may occur: first, the increase of load transfer to the bone can lead to bone loss and bacterial growth at the microgap between the abutment and the implant,^{11,14} and second, prosthetic-screw loosening or fracture and implant loss.¹⁵

Premachined abutments, including those that undergo overcasting and porcelain building, have a better fit than castable abutments.⁶ Some studies have shown that when castable UCLA abutments are used, there is a vertical misfit greater than 10 μm present at every stage in the laboratory; this may pose a risk to the use of these abutments that is exacerbated by the soldering process.^{7,9}

The purposes of this study were to use scanning electronic microscopy (SEM) to evaluate the comparatively vertical and horizontal alterations of 3 different brands of castable UCLA-type abutments in comparison with a premachined UCLA-type abutment after the completion of casting and soldering procedures.

MATERIALS AND METHODS

Twelve external hexagon implants (3.75 mm \times 10 mm) from 3 different commercial brands (Neodent, Curitiba, Brazil; Conexão, São Paulo, Brazil; Biomet 3i, Palm Beach Gardens, EUA) were used in this study. The implants were fixed in holes that were created in 4 aluminum master casts (34 mm \times 19 mm \times 19 mm) that displayed the first thread, with the distance between the implants standardized from the center of hole 1 to the center of hole 2 (9 mm) and from holes 2 to 3 (10 mm; Figure 1). The internal threads of the master casts were made with surgery thread-forming devices from the respective manufacturers to provide proper locking and stabilization of the implants upon installation,

simulating a clinical situation. Nine square transfers, analogues, UCLAs, and hexagonal titanium screws were prepared for each group according to the manufacturer's instructions. The groups were divided according to their abutments and manufacturers: PUN (plastic UCLA, Neodent), PUC (plastic UCLA, Conexão), PU3i (plastic UCLA, Biomet 3i), and PUTN (plastic UCLA with Tilite milled base, Neodent). Polyether (Impregum F, 3M-ESPE, St Paul, Minn) impressions were made with square transfers splinted with acrylic resin (Pattern Resin LS, GC, Japan) and metal rods. Three casts with analogues were obtained with type IV plaster (Durone, Dentsply, Petrópolis, Brazil) for each group and were used to perform laboratory procedures for casting and soldering.

Framework construction

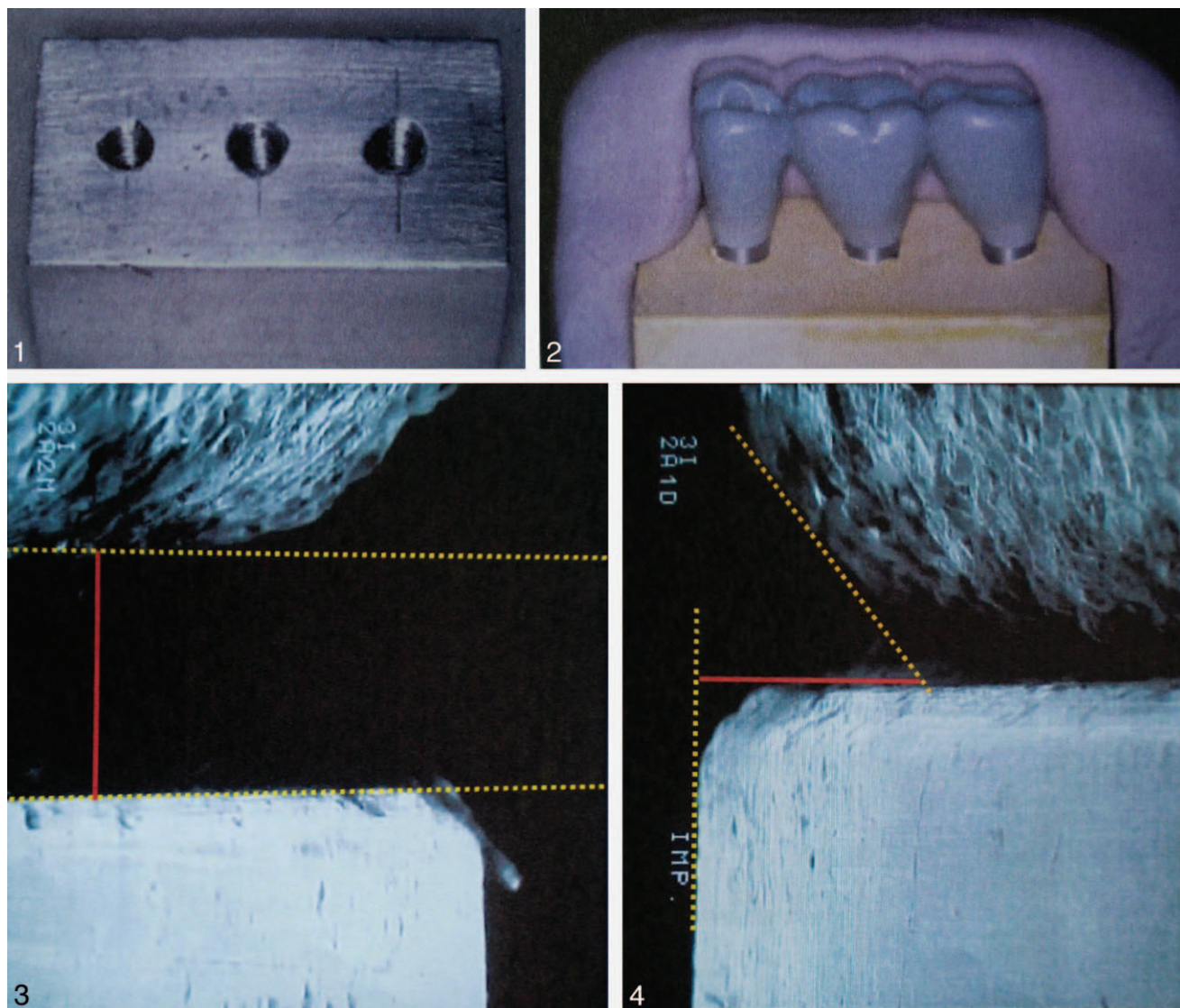
Twelve frameworks consisting of an implant-supported partial bridge with 3 elements corresponding to a second premolar (2PM) and first (1M) and second molars (2M) were made. There were 3 samples per group for each 4 groups.

The UCLAs were installed over the analogues for the initial wax up. A silicone index (Zetalabor, Zhermack, Rovigo, Italy) was made over this waxing to standardize the volume of wax in all the casts (Figure 2). The waxed frameworks were sectioned (0.6 mm) for soldering and fixed in the sprues for casting. The frameworks were cast with nickel-chromium alloy (Verabond II, Aalba Dent Inc, Cordelia, Calif). After casting, the frameworks were cleaned and sandblasted with aluminum oxide, and the edges were cut to provide a proper fit.

The frameworks were cleaned with acetone, dried, positioned in the master casts with the aid of tweezers so as to avoid contamination, and torqued with 20 Ncm using a previously calibrated manual torquimeter. The first SEM evaluation of the frameworks was then performed.

Misfit analysis of the implant-abutment interface

The misfit of the interface between implants and abutments was evaluated by SEM (LEO-940, Carl Zeiss NTS GmbH, Oberkochen, Germany). The amplifications were standardized between $\times 300$ and $\times 500$, where the first was used for a larger misfit. For each specimen, 6 images were taken from the mesial and distal superficies of each



FIGURES 1–4. **FIGURE 1.** Aluminum master cast. **FIGURE 2.** Silicone index to standardize the volume of wax in all the casts. **FIGURE 3.** Standard assessment of vertical misfit ($\times 500$). **FIGURE 4.** Standard assessment of horizontal misfit ($\times 500$).

interface, totaling 18 images for each group at each stage (ie, casting and soldering) of analysis ($n = 18$).

The vertical and horizontal misfit values were measured in 2 stages: the first measurements were taken after casting, and the second measurements were obtained after soldering. Each value was determined by calculating the average of 3 measurements taken by a single examiner. The vertical misfit was determined by measuring the distance between 2 straight lines drawn tangentially to the abutment and the implant platform (Figure 3). The horizontal misfit was represented by the magnitude of the alignment between the parts; its quantification was verified and was quantified by measuring the distance between the lines that were

drawn tangentially between the abutment and the implant (Figure 4). When misalignment occurred, the presence of the implant beyond the abutment was stipulated as being “+” (positive). When the diameter of the abutment was a larger diameter than that of the implant, it was stipulated as “–” (negative).

Soldering procedures

Following the first SEM evaluations, the frameworks were splinted for soldering with metal rods and cyanoacrylate adhesive (Loctite Super Bonder, Henkel Ltda, São Paulo, Brazil) and reinforced with acrylic resin (Pattern Resin LS, GC, Japan). The soldering procedure was performed with Ni-Co-Cr-

TABLE 1
Vertical misfit values after casting*

| Vertical Misfit After Casting | | | | | | | |
|-------------------------------|--------|--------|--------|--------|--------|--------|--------|
| PUPN | | PUPC | | PUP3i | | PUTN | |
| ≤10 μm | >10 μm | ≤10 μm | >10 μm | ≤10 μm | >10 μm | ≤10 μm | >10 μm |
| 4.88 | 13.47 | 0 | 14.22 | 5.77 | 15.23 | 7.63 | 15.7 |
| 4.43 | 15.8 | 5.23 | 13.32 | 6.66 | 19.99 | 2.37 | 10.05 |
| 0 | 21.81 | 9.53 | 18.56 | 6.2 | 31.71 | 3.55 | 11.53 |
| 6.06 | 25.32 | 0 | 71.97 | 7.32 | 11.99 | 0 | |
| 9.75 | 10.1 | 5.71 | 13.8 | 7.53 | 12.88 | 7.53 | |
| 0 | 19.55 | 0 | 17.35 | 6.83 | 28.5 | 0.88 | |
| | 49.04 | | 14.2 | | 11.09 | 5.71 | |
| | 16.14 | | 12.85 | | 21.97 | 5.83 | |
| | 14.75 | | 11.08 | | 17.47 | 6.2 | |
| | 10.22 | | 12.32 | | 17.31 | 0.95 | |
| | 12.22 | | 22.66 | | 17.07 | 6.32 | |
| | 11.37 | | 24.29 | | 15.7 | 7.12 | |
| | | | | | | 0 | |
| | | | | | | 2.68 | |
| | | | | | | 8.39 | |

*PUTN indicates plastic UCLA with Tilite base, Neodent; PUC, plastic UCLA, Conexão; PU3i, plastic UCLA, Biomet 3i; PUN, plastic UCLA, Neodent.

Mo-based solder (Dentarium Export Ltda, New York, NY), which was first applied between the premolars and first molars and then between the first and second molars. The frameworks were soldered by brazing at high temperature (1200°C–1315°C), then subjected to an initial finishing by sandblasting with aluminum oxide. The samples were then prepared for the second test and analysis as follows: samples were cleaned via ultrasound with acetone for 60 seconds and then installed in the master cast. First, the ends were bolted to ensure passivity, and then the center screw was installed. The infrastructure was tightened with a torque of 20 Ncm using the manual torque wrench from each respective commercial brand.

Data analysis

The minimum critical value of vertical misfit was determined to be 10 μm for the purpose of data analysis.^{9,16} Therefore, the samples were divided into groups whose measurements were higher and lower than this value and then categorized for risk verification after completion of the casting and soldering. The horizontal misfit values were also categorized; it was determined that the negative values (ie, cases in which the abutment was larger than the implant) would indicate potential damage to the biomechanical system. After categorizing the misfits, the following statistical analysis was per-

formed on the data: descriptive analysis of the misfit and establishment of differences between groups by the chi-squared test after casting and soldering procedures ($\alpha \leq .05$). McNemar’s test was also applied to analyze the influence of the soldering procedure on casting ($\alpha \leq .05$). Data analysis was performed on a commercially available computational statistics program (SPSS 17.0 for Windows, SPSS Inc, Chicago, Ill).

RESULTS

The values calculated for the misfits were considered to be potentially dangerous. These values were then divided into 2 tables, the first with values after the casting procedure and the second after soldering had occurred (Tables 1 and 2). The values were also rated as a percentage of values that were less than or equal to 10 μm (Table 3). At the casting procedure, PUTN exhibited a higher frequency of acceptable adjustments to vertical misfits (80%); by contrast, all other groups presented the same frequency (33%). After soldering, acceptable adjustments decreased for PUTN, PUP3i, and PUPN (50%, 27.75%, and 16.6%, respectively); however, for PUPC, this frequency increased (38.85%). PUTN exhibited lower vertical misfit values than groups with castable abutments ($P < .05$). For the soldering procedure, there was no significant difference between groups ($P > .05$).

TABLE 2
Vertical misfit values after soldering*

| Vertical Misfit After Soldering | | | | | | | |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|
| PUPN | | PUPC | | PUP3i | | PUTN | |
| ≤10 μm | >10 μm | ≤10 μm | >10 μm | ≤10 μm | >10 μm | ≤10 μm | >10 μm |
| 7.61 | 11.88 | 5.71 | 16.66 | 2.38 | 18.57 | 2.38 | 28.09 |
| 0 | 17.14 | 0 | 10.94 | 4.28 | 57.14 | 0 | 23.8 |
| 4.76 | 33.33 | 3.8 | 27.61 | 6.18 | 28.38 | 0.47 | 23.8 |
| | 35.23 | 0 | 34.12 | 0 | 14.75 | 9.52 | 33.33 |
| | 29.52 | 0 | 13.33 | 0.95 | 35.23 | 0.47 | 10.47 |
| | 22.85 | 0.47 | 17.61 | | 12.37 | 8.72 | 27.61 |
| | 11.9 | 3.8 | 25.39 | | 32.37 | 0.79 | 12.37 |
| | 34.28 | | 12.69 | | 26.18 | 3.32 | 38.09 |
| | 63.33 | | 19.04 | | 14.28 | 8.56 | 13.48 |
| | 17.61 | | 16.66 | | 65.7 | | |
| | 27.14 | | 20.97 | | 11.9 | | |
| | 16.66 | | | | 39.99 | | |
| | 10.94 | | | | 12.37 | | |
| | 11.89 | | | | | | |
| | 13.23 | | | | | | |

*PUTN indicates plastic UCLA with Tilite base, Neodent; PUC, plastic UCLA, Conexão; PU3i, plastic UCLA, Biomet 3i; PUN, plastic UCLA, Neodent.

With regard to the horizontal misfit values (Table 4), positive values (ie, those that were obtained when the implants were larger than the abutments) were considered to be acceptable biomechanical adjustments. After soldering, PUP3i exhibited the same frequency of horizontal misfits that were present at casting; PUTN and PUP3i presented the same frequency of positive values (94.35%), and PUPN and PUPC showed similar same behavior (77.7% of positive values). The casting procedure did not significantly increase horizontal misfit values ($P > .05$); although, after the casting, PUN showed more misfits as compared with the other groups ($P < .05$). The soldering procedure did not appear to increase misfits, and no significant difference was observed between groups ($P > .05$). No correlation

was observed between procedures ($P > .05$), indicating that solder application did not influence the increase of vertical and horizontal misfits.

DISCUSSION

Premachined components presented significantly more values below 10 μm (83.25%) than all other groups with castable abutments (33.3%; Table 1). In addition, the casting procedure exerted effects on the vertical misfit. Our results are in agreement with previous studies that found that vertical adjustment of premachined or machined abutments was superior to that of castable abutments.^{7,10}

Each step of prosthesis fabrication influences the final fit.^{5,12} To ensure a better fit, the use of premade components has been highly recommended.^{6,10} However, premade cylinders that use high gold and silver-palladium alloys for framework casting are not compatible with alternative alloys due to melting range mismatches.⁸ The high cost of this type of framework has led to the development of plastic components, which allow the use of alternative materials such as base metal alloys. Without proper care, the clinical and laboratory procedures that are used in the manufacturing of these prostheses frameworks can lead to displacement of the abutments in relation to the implant platform.¹⁷

After the soldering procedures, there were

TABLE 3
Percentage of vertical fit values ≤10 μm after casting and soldering*

| Group | Percentage of Values ≤10 μm | |
|-------|-----------------------------|-----------|
| | Casting | Soldering |
| PUPN | 33.3 | 16.6 |
| PUPC | 33.3 | 38.85 |
| PUP3i | 33.3 | 27.75 |
| PUTN | 83.25 | 50.0 |

*PUTN indicates plastic UCLA with Tilite base, Neodent; PUC, plastic UCLA, Conexão; PU3i, plastic UCLA, Biomet 3i; PUN, plastic UCLA, Neodent.

TABLE 4

Percentage of positive horizontal fit values after casting and soldering*

| Group | Percentage of Positive Values | |
|-------|-------------------------------|-----------|
| | Casting | Soldering |
| PUPN | 27.75 | 77.7 |
| PUPC | 88.8 | 77.7 |
| PUP3i | 94.35 | 94.35 |
| PUTN | 100 | 94.35 |

*PUTN indicates plastic UCLA with Tilitte base, Neodent; PUC, plastic UCLA, Conexão; PU3i, plastic UCLA, Biomet 3i; PUN, plastic UCLA, Neodent.

changes in the percentage of vertical misfit values below the critical value (Table 3). PUTN presented 50%, while the percentages of castable abutments consisted of 16.6% (PUN), 38.85% (PUC), and 27.75% (PU3i), indicating that after soldering, the acceptable measurements of premachined abutments were still greater than those of the other groups. This finding agrees with results from an earlier study that evaluated both processes and verified that acceptable values decrease after the soldering procedures.⁹ However, in this current study, the differences were not statistically significant.

Soldering procedures have produced good results by reducing the buildup of stresses around the implants and also reducing the frequency of loosened screws. Nevertheless, a passive fit is not absolutely guaranteed.⁷ The addition of a solder in areas where there is only a small distance between the parts to be joined provides satisfactory results. However, it is sometimes necessary to cut infrastructure to achieve a passive fit, and these gaps may be larger than typically recommended for soldering a gap. Therefore, a distance of 0.6 mm was chosen to be a standard for the areas to be united.

A vertical misfit on a prosthesis may lead to a loosened screw,⁴ and previous studies suggest a more significant microbial flow at the implant-abutment interface.¹⁴ Although there is no specific research that relates to a clinically acceptable misfit value,¹² the present study indicates that a misfit level that is equal to or below 10 μm may be considered acceptable, which is in accordance with previous information about osseointegration.^{9,16}

The horizontal misfit analysis showed that after casting, the PUTN values were all positive (100%). The groups with castable abutments showed a high percentage of positive measurements, except for

PUN, which showed only 27.75% of positive measurements. After the soldering procedure, the analysis of horizontal misfits showed a significant amount of variation among all groups.

When plastic cylinders are cast, a significantly higher horizontal misfit is to be expected.¹⁰ In addition, when analyzing the horizontal misfit of frameworks, it has been shown that the incorrect alignment of implant parts can increase the susceptibility of the internal connecting screws to loosening or fracture.¹⁸ In contrast, abutments that are smaller than the implant platform have exhibited better biological performance, as was observed in platform-switching systems.¹⁹ Although manufacturing components with the highest precision at the implant-abutment interface requires higher manufacturing costs, manufacturers produce abutments with smaller diameters than the implant platform to increase the security margin during laboratory procedures.

Premachined abutments with a milled base require an overcasting procedure that is technically standard and predictable. However, the type of coating that is used in this procedure is crucial and must undergo adequate expansion to compensate for weld shrinkage.²⁰ In addition, the material and technical procedures involved in the manufacture of metal frameworks and the handling of prefabricated components are not dimensionally accurate and can affect the mechanical performance and efficiency of the work.^{3-5,7,9} There is a minimum gap (20 μm to 100 μm) between the transfers and analogues or abutments, and this factor should be considered.

Evaluation of the implant-abutment interface by SEM is a valid procedure and enables acquisition of direct measurements on the photomicrographs, using the scale provided.^{13,21} The assessments described in the literature were made under different magnifications.⁶⁻¹² In addition, SEM provides greater magnification that can lead to a more detailed assessment than can be made using optical microscopy.^{7,10,13}

The choice of a fixed prosthesis to replace the second premolar and the first and second molars is justified because it represents an area that often requires rehabilitation. However, the placement of aligned implants can be challenging because, regardless of the technique or alloy that is used, the distortion in metal structures occurs at all levels.

It is directly proportional to the increased width or curvature of the dental arc,⁵ which suggests that some results might be different if the implants were not in line. Moreover, the uses of nickel-chromium alloy in infrastructure casting and overcasting procedures are questionable with regard to biocompatibility and represent some limitations of the present study.

The clinical procedures that are used to evaluate framework adjustment are empirical and are based on direct visualization, radiographic images, and tactility, all of which are uncontrolled and unreliable. Therefore, more studies should be performed to determine possible improvements to soldering procedures and the evaluation of misfits, so that the settlement of implant-supported prosthetic frameworks may in turn be improved.

CONCLUSION

Within the limitations of this study, it is possible to conclude that premachined abutments containing a Ni-Cr-Ti alloy exhibit better mechanical properties after the casting procedure than did the other abutments that were studied, showing more vertical misfits below the limit of 10 μm and thus being biomechanically acceptable. In addition, the horizontal misfit values for most of the abutments were within acceptable limits before and after the soldering procedure. Furthermore, the casting procedure resulted in an increase of vertical misfits among the abutments that were studied; application of soldering did not result in significant additional misfits.

ABBREVIATIONS

PU3i: plastic UCLA, Biomet 3i
 PUC: plastic UCLA, Conexão
 PUN: plastic UCLA, Neodent
 PUTN: plastic UCLA with Tilite base, Neodent
 SEM: scanning electron microscope

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