A Strain Gauge Analysis of Microstrain Induced by Various Splinting Methods and Acrylic Resin Types for Implant Impressions

Nunes M. Cerqueira, DDS, PhD1/Mutlu Özcan, DDS, Dr Med Dent, PhD2/Marianna Gonçalves, DDS, PhD1/Daniel M. da Rocha, DDS, PhD1/Diego K. Vasconcellos, DDS, PhD3/Marco A. Bottino, DDS, PhD4/Esra Yener-Salihoglu, DDS, PhD5

Purpose: The aim of this study was to investigate the level of microstrain that is exerted during polymerization of acrylic resins used for splinting during implant impressions. Material and Methods: Two acrylic resins (GC Pattern Resin, Duralay II) and square transfer coping splinting methods were evaluated by means of strain gauge analysis. Two implants were embedded in a polyurethane block, and the abutments were positioned. Sixty specimens were prepared using two square transfer copings that were rigidly connected to each other using the acrylic resins. The specimens were randomly divided into three groups of 20 each for the splinting methods: Method 1 was a one-piece method; in method 2, the splint was separated and reconnected after 17 minutes; and in method 3, the splint was separated and reconnected after 24 hours. In each group, half the specimens were splinted with GC Pattern Resin and the other half were splinted with Duralay II. Three microstrain measurements were performed by four strain gauges placed on the upper surface of the polyurethane blocks at 5 hours after resin polymerization for all groups. The data were analyzed statistically.

Results: Both resin type and splinting method significantly affected microstrain. Interaction terms were also significant. Method 1 in combination with Duralay II produced significantly higher microstrain (1,962.1 µε) than the other methods with this material (method 2: 241.1 µε; method 3: 181.5 µε). No significant difference was found between splinting methods in combination with GC Pattern Resin (method 1: 173.8 µε; method 2: 112.6 µε; method 3: 105.4 µε). Conclusions: Because of the high microstrain generated, Duralay II should not be used for one-piece acrylic resin splinting, and separation and reconnection are suggested. For GC Pattern Resin, variations in splinting methods did not significantly affect the microstrain created. Int J Oral Maxillofac Implants 2012;27:341–345

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Osseointegration has changed various aspects of restorative dentistry, leading to a significant improvement in the quality of life for edentulous patients. Osseointegrated implants used for oral rehabilitation consistently provide clinical success, and this type of therapy has a considerable positive impact on the psychosocial condition of edentulous patients.

Osseointegrated implants are completely embedded in bone, and their interfaces are not resilient. Therefore, only minimal movements occur, which are attributed to bone deformation under load. The stress generated by the absence of passive fit for implant-supported fixed dental prostheses (FDP) does not dissipate over time because of the anklyotic nature of osseointegration, confirming the need for prosthetic precision (ie, passive fit).

The appropriate impression materials and techniques are fundamental to the precision of fit of implant-
supported FDPs. It is imperative for the impression to accurately register the three-dimensional positions of the osseointegrated implants. Two impression methods are commonly used in implant dentistry: indirect and direct. The indirect method uses tapered transfer copings and a closed tray. In this method, the impression is removed after the elastomer material has set. The transfers are removed from the mouth, connected to the analog, and repositioned in the mold. When the indirect technique is used, a lack of parallelism between the implants may produce an undesirable pathway during removal from the mouth; this may distort the impression material and generate an inaccurate model. In addition, previous studies have shown that precise replacement of the tapered transfers in their original positions is difficult. Moreover, the weak union between the tapered coping and the impression material may facilitate the movement of the analogs as a result of expansion of the dental stone during setting.

The direct technique uses square transfer copings that are rigidly connected to each other with autopolymerized acrylic resin in a customized open impression tray. The direct impression technique is the most effective impression method for implant-supported FDPs, since the rigidity of the acrylic resin splint resists potential distorting forces, increasing the precision of the working cast. However, according to Dumbrigue et al., the use of relatively large amounts of resin to connect the transfer copings could contribute to significant polymerization shrinkage and consequent inaccuracy of the mold. Therefore, it is recommended that segments connected with acrylic resin should be separated after resin polymerization and then reconnected with a small amount of this material to relieve the stress and minimize any adverse effects of polymerization shrinkage. The timing of this separation is of great importance since dimensional alterations could still be taking place. Mojon et al. demonstrated that 80% of acrylic resin shrinkage occurs during the first 17 minutes. Thus, the effects of polymerization shrinkage could be considerably reduced by separation and reconnection 17 minutes after the polymerization reaction. Other studies have identified no critical dimensional alterations in acrylic resin structures after 24 hours. These studies, however, did not consider chemical variations in the different commercially available acrylic resins.

Methyl methacrylate polymers (MMAs) have proven to be very useful in a wide variety of dental and biomedical applications. One of the inherent properties of polymer-based materials is shrinkage during polymerization. This shrinkage can cause distortion that may jeopardize accurate fit. Mixtures of monomers can be used to balance properties of polymers. This is possible because of the ease of copolymer formation via free-radical polymerization. The most commonly used acrylic resins for the brush technique in splinting are MMA-based. Their favorable flow properties make them ideal for intraoral splinting of transfer abutments. In fact, it can be anticipated that MMAs with vinyl monomers, such as 2-hydroxyethylmethacrylate (HEMA), which contain sol-gel active functional groups, may reduce shrinkage as opposed to those of acrylic copolymers of methacrylate polymers.

The objective of this study was to investigate the microstrains that occurred during polymerization of two different acrylic resins used for splinting techniques during direct implant impressions. The tested hypotheses were that an MMA/HEMA-based acrylic resin would induce less microstrain than an MMA acrylic resin and that the splinting method would not affect the results.

MATERIALS AND METHODS

Two cylindric implants (diameter 3.75 mm, length 15 mm; Master Screw 517715, Conexão Sistemas de Prótese) with an external-hex connection were embedded in a polyurethane block (F 16 AXSON) 25 mm apart from each other (as measured from the center of each implant). Abutments were screwed to the implants (Microunit, 132023, Conexão Sistemas de Prótese) with the use of a torque wrench (400000, Conexão Sistemas de Prótese) at 20 Ncm torque.

Two autopolymerizing acrylic resins were used in this study: GC Pattern Resin (GC Dental Industrial) and Duralay II (Reliance Dental Mfg). Sixty specimens were prepared for the experiments using two square transfer copings (094000, Conexão Sistemas de Prótese), which were placed on the abutments at a torque of 10 Ncm. The implants were then rigidly connected to each other using the resins. A two-piece polytetrafluoroethylene (PTFE) (Teflon, DuPont) mold was created to allow multiple standardized specimens. The mold enabled standardized splinting where the thickness of the resin bar was 4 mm in the buccolingual and 2 mm in the cervico-occlusal direction.

The acrylic resin was placed in the PTFE mold using the powder/liquid paintbrush technique (Nealon Technique) and the transfer copings were rigidly connected (Fig 1). After acrylic resin polymerization was completed according to each manufacturer’s recommendation, the splinted transfers were removed from the PTFE mold. The implant components were used only one time for each measurement.

The specimens were randomly divided into three groups (n = 20 per group), which were splinted using one of three methods. Method 1 was a one-piece splinting method (control). In method 2, the acrylic
Resin splint was separated equidistantly from the abutments with a 0.3-mm double-faced diamond disk (40601-001 Microdont). The segments were placed on the PTFE mold and reconnected 17 minutes after polymerization. In method 3, the acrylic resin splint was separated and reconnected, as described in method 2, 24 hours after polymerization. Reconnection in methods 2 and 3 was performed with a torque wrench at 10 Ncm, which allowed a minimum amount of acrylic resin to be applied with the powder/liquid paintbrush technique (Fig 2).

For each method, half of the specimens (n = 10) were splinted with the MMA/HEMA-based GC Pattern Resin, and the other half (n = 10) were splinted with the MMA-based Duralay II.

**Microstrain Measurements**

Three microstrain (µε) measurements were recorded by four strain gauges (Model PA-06-60CA-120 L, Excel Sensores) that were placed on the upper surface of the experimental model with cyanoacrylate adhesive (Super Bonder, Loctite). Four strain gauges were aligned next to the implants, 1 mm away from their platforms, and labeled 1 to 4 (from left to right) (Fig 3). The strain gauges were connected to an electric signal amplifier (ADS 2000 IP, Lynx), and microstrain data were processed by specific software (AqDados & AqAnalysis, Lynx). Measurements were performed 5 hours after resin polymerization for method 1 and 5 hours after reconnection of the segments for methods 2 and 3. The microstrain produced in each strain gauge was recorded as soon as the second screw had been tightened.

**Statistical Analysis**

Statistical analysis was performed using SPSS 11.0 software for Windows (SPSS). The data (µε) were submitted to two-way analysis of variance, with microstrain as the dependent variable and acrylic resin type and splinting method as the independent variables. Multiple comparisons were made using the Tukey post hoc test. P values less than .05 were considered to be statistically significant.

**RESULTS**

The mean microstrain values and standard deviations for each group are presented in Table 1. Method 1 in combination with Duralay II produced significantly higher microstrains (1,962.1 µε) than those of other methods with this resin (method 2: 241.1 µε; method 3: 181.5 µε) (P < .0001; Table 1). In contrast, no significant difference was found between the splinting methods in combination with GC Pattern Resin (method 1: 173.8 µε; method 2: 112.6 µε; method 3: 105.4 µε) (P > .05) (Table 1).

Both resin type (P < .0001) and splinting method (P < .0001) significantly affected the microstrain generated. Interaction terms were also significant (P < .0001) (Table 2).
DISCUSSION

Two different acrylic resins were used in conjunction with three different splinting methods for this investigation. The application procedures were based on the powder/liquid paintbrush technique (Nealon technique) to reduce polymerization shrinkage and incorporate the smallest possible amount of acrylic monomer to the bulk, as described earlier.\(^{21}\) The materials varied slightly in their chemical composition. While the liquid of Duralay II was MMA stabilized and its powder contained a blend of acrylic copolymer and methacrylate polymer, the liquid of GC Pattern Resin contained MMA and the powder was composed of HEMA, with benzoyl peroxide as a radical initiator to induce polymerization. GC Pattern Resin showed significantly lower microstrain values than Duralay II with the one-piece splinting method (method 1). In combination with other splinting methods, lower strains were observed with GC Pattern Resin, but these were not significantly different from those seen with Dur-alay II. Therefore, the first hypothesis could only be partially accepted. Apparently, the acrylic resin type was an issue in terms of polymerization stresses when separation and reconnection were not done. However, this was not the case for the other splinting methods. Since the polymerization shrinkage of GC Pattern Resin did not affect the microstrain values obtained with all three methods tested, the option for the one-piece monocrown method with this material appears to be suitable for clinical use.

In contrast, the splinting method had a significant effect in combination with Duralay II. Hence, the second hypothesis was rejected. Duralay II with the method of one-piece splinting delivered the highest microstrain value among all groups, indicating higher polymerization stresses within this material. Because no significant difference was observed between the two time points of reconnection, 17 minutes could be preferred to 24 hours, as the latter requires a second clinical appointment. The clinical relevance of reducing the time for sectioning and reconnection procedures needs to be verified.

Precise impressions are fundamental to ideal fit of implant-supported FDPs. The impression method that uses square transfers rigidly connected with acrylic resin and an open custom tray has been advocated as the most effective impression method for such restorations.\(^{10,13,24,25}\) The time required for impression making is considerably longer with splinted methods compared to the nonsplinted method. However, splinting with resin has been recommended for obtaining a more accurate interimplant relationship because it prevents rotation of impression copings in the impression during fastening of the implant analog, which is one of the drawbacks of the direct impression method.\(^{12}\) The rigidity of an acrylic resin splint resists the potential forces of distortion, increasing the precision of the working cast.

In a recent systematic review of the accuracy of implant impressions on the level of the abutment or the internal-connection implant, a large number of studies reported greater accuracy with the splinted method.
versus the nonsplinted one. Nonetheless, controversy exists in the dental literature regarding whether or not to splint. While some authors have favored nonsplinted square transfers, others found no difference between direct and indirect transfer techniques. Differences in the acrylic resins used could be responsible from the reported variations between studies.

In the present study, three microstrain measurements were recorded for each specimen with the objective of minimizing errors during measurements. All specimens seemed to passively fit the abutments in the experimental model. However, measurable strains were still produced for both resins and for all splinting methods at all time points. Polymers that produce less polymerization stress may have potential use for splinting purposes; this may possibly add cost to the materials tested.

The experimental design of this study enabled standardized splinting using a PTFE (Teflon) mold 4 mm thick and 2 mm high. This design cannot be transferred easily into a clinical setting, in which splinting would be more difficult. However, this method was useful for comparing the microstrain levels of different materials.

The objective of this study was not to measure the precision but the possible stresses occurring in the acrylic resin. Future studies need to verify correlations between the precision measurements and polymerization stresses.

**CONCLUSION**

When used in a one-piece splinting method, Duralay II produced high microstrains; therefore, this technique is not advised for this acrylic resin. Instead, separation and reconnection are a better option, whether after 17 minutes or after 24 hours. For GC Pattern Resin, splinting did not significantly affect the microstrain produced; therefore, the quickest option, one-piece monoblock splinting, appears to be the most appropriate.

**REFERENCES**