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

Nunes M. Cerqueira, DDS, PhD[1]/Mutlu Özcan, DDS, Dr Med Dent, PhD[2]/
Marianna Gonçalves, DDS, PhD[1]/Daniel M. da Rocha, DDS, PhD[1]/
Diego K. Vasconcellos, DDS, PhD[3]/Marco A. Bottino, DDS, PhD[4]/
Esra Yener-Salihoğlu, DDS, PhD[5]

***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

**Key words:** *acrylic resin, microstrain, osseointegrated implants, splinting techniques, strain gauge*

[1]Researcher and Senior Lecturer, Department of Dentistry, Health Sciences Center, Federal University of Santa Catarina, Lima, Brazil.
[2]Professor and Head, Dental Materials Unit, University of Zürich, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zürich, Switzerland.
[3]Adjunct Professor, Researcher, and Senior Lecturer, Department of Dentistry, Health Sciences Center, Federal University of Santa Catarina, Lima, Brazil.
[4]Adjunct Professor, Department of Dental Materials and Prosthodontics, São Paulo State University, São José dos Campos School of Dentistry, São José dos Campos, Brazil.
[5]Researcher, University of Yeditepe, Department of Prosthodontics, Istanbul, Turkey.

**Correspondence to:** Prof Dr Mutlu Özcan, University of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Plattenstrasse 11, CH-8032, Zürich, Switzerland. Fax: +41-44-6344305. Email: mutluozcan@hotmail.com

Osseointegration has changed various aspects of restorative dentistry, leading to a significant improvement in the quality of life for edentulous patients.[1–3] 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.[1–3]

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.[4–6] The stress generated by the absence of passive fit for implant-supported fixed dental prostheses (FDP) does not dissipate over time because of the ankylotic nature of osseointegration, confirming the need for prosthetic precision (ie, passive fit).[7–9]

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.[10–12] 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.[11]

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.[13–16] However, according to Dumbrigue et al,[17] 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.[16,18,19] The timing of this separation is of great importance since dimensional alterations could still be taking place. Mojon et al[20] 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.[20–22] 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.[23] 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.[13,15,24] 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.[25]

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

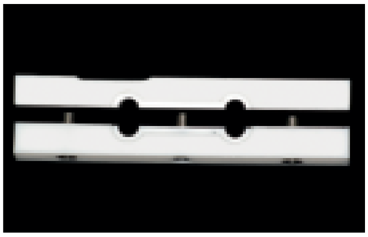

**Fig 1** Two-piece PTFE mold used for rigidly connecting the transfer copings for multiple standardized specimens.

**Fig 2** Positioned PTFE mold in the experimental model, which allowed a minimal amount of acrylic resin to be applied with the powder/liquid paintbrush technique.

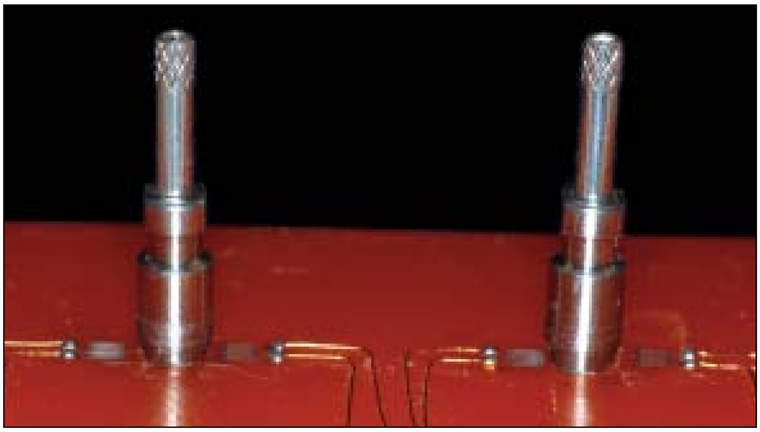

**Fig 3** Positions of the strain gauges bonded to the upper surface of the experimental model with cyanoacrylate adhesive.

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 ($\mu\varepsilon$) 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 ($\mu\varepsilon$) 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 $\mu\varepsilon$) than those of other methods with this resin (method 2: 241.1 $\mu\varepsilon$; method 3: 181.5 $\mu\varepsilon$) ($P < .0001$; Table 1). In contrast, no significant difference was found between the splinting methods in combination with GC Pattern Resin (method 1: 173.8 $\mu\varepsilon$; method 2: 112.6 $\mu\varepsilon$; method 3: 105.4 $\mu\varepsilon$) ($P > .05$) (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).

**Table 1 Mean Microstrain (με) and Standard Deviations for Three Different Splinting Methods in Combination with Two Different Acrylic Resins**

| Acrylic resin | N | Splinting method | Mean microstrain (με) | Standard deviation |
|---|---|---|---|---|
| GC Pattern Resin | 10 | One-piece | 173.8[a] | 15.49 |
| GC Pattern Resin | 10 | 17 min | 112.6[a] | 17.35 |
| GC Pattern Resin | 10 | 24 h | 105.4[a] | 16.31 |
| Duralay II | 10 | One-piece | 1,962.1[b] | 80.92 |
| Duralay II | 10 | 17 min | 241.1[a] | 59.96 |
| Duralay II | 10 | 24 h | 181.5[a] | 52.62 |

[a,b]Different superscript letters within the same column indicate significant differences ($P < .05$).

**Table 2 Results of Two-Way Analysis of Variance**

| Effect | df | Sum of squares | QM | F | *P* |
|---|---|---|---|---|---|
| Resins | 1 | 6,619,590 | 6,619,590 | 106.36 | .0001* |
| Splinting methods | 2 | 10,990000 | 5,499,203 | 88.35 | .0001* |
| Interaction | 2 | 9,481,839 | 4,740,919 | 76.17 | .0001* |
| Residue | 54 | 3,360,985 | 62,240 | | |
| Total | 59 | 30,460,000 | | | |

df = degrees of freedom.
*$P < .05$.

## 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 monoblock 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.[26] Nonetheless, controversy exists in the dental literature regarding whether or not to splint. While some authors have favored nonsplinted square transfers,[11,27–29] others found no difference between direct and indirect transfer techniques.[18,30] 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 methods did not significantly affect the microstrain produced; therefore, the quickest option, one-piece monoblock splinting, appears to be the most appropriate.

## REFERENCES


1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Emami E, Heydecke G, Rompré PH, de Grandmont P, Feine JS. Impact of implant support for mandibular dentures on satisfaction, oral and general health-related quality of life: A meta-analysis of randomized-controlled trials. Clin Oral Implants Res 2009;20:533–544.
3. Brennan M, Houston F, O'Sullivan M, O'Connell B. Patient satisfaction and oral health-related quality of life outcomes of implant overdentures and fixed complete dentures. Int J Oral Maxillofac Implants 2010;25:791–800.
4. Suedam V, Souza EA, Moura MS, Jacques LB, Rubo JH. Effect of abutment's height and framework alloy on the load distribution of mandibular cantilevered implant-supported prosthesis. Clin Oral Implants Res 2009;20:196–200.
5. Cehreli MC, Akkocaoglu M, Comert A, Tekdemir I, Akca K. Human ex vivo bone tissue strains around natural teeth vs immediate oral implants. Clin Oral Implants Res 2005;16:540–548.
6. Juodzbalys G, Kubilius R, Eidukynas V, Raustia AM. Stress distribution in bone: Single-unit implant prostheses veneered with porcelain or a new composite material. Implant Dent 2005;14:166–175.
7. Gomes EA, Assunção WG, Tabata LF, Barão VA, Delben JA, de Sousa EA. Effect of passive fit absence in the prosthesis/implant/retaining screw system: A two-dimensional finite element analysis. J Craniofac Surg 2009;20:2000–2005.
8. Baig M, Gunaseelan R. Implant-supported, screw-retained, ceramometal, fixed dental prosthesis with an intra-oral luted framework to improve passive fit. J Oral Implantol 2010 Oct 8 [epub ahead of print].
9. Barbosa GA, das Neves FD, de Mattos Mda G, Rodrigues RC, Ribeiro RF. Implant/abutment vertical misfit of one-piece cast frameworks made with different materials. Braz Dent J 2010;21:515–519.
10. Cabral LM, Guedes CG. Comparative analysis of 4 impression techniques for implants. Implant Dent 2007;16:187–194.
11. Del'Acqua MA, Chávez AM, Compagnoni MA, Molo Fde A Jr. Accuracy of impression techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implants 2010;25:715–721.
12. Hariharan R, Shankar C, Rajan M, Baig MR, Azhagarasan NS. Evaluation of accuracy of multiple dental implant impressions using various splinting materials. Int J Oral Maxillofac Implants 2010;25:38–44.
13. Liou AD, Nicholls JI, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. Int J Prosthodont 1993;6:377–383.
14. Jemt T, Lekholm U, Adell R. Osseointegrated implants in the treatment of partially edentulous patients: A preliminary study on 876 consecutively placed fixtures. Int J Oral Maxillofac Implants 1989;4:211–217.
15. Vigolo P, Majzoub Z, Cordioli G. Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent 2003;89:186–192.
16. Naconecy MM, Teixeira ER, Shinkai RS, Frasca LC, Cervieri A. Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants 2004;19:192–198.
17. Dumbrigue HB, Gurun DC, Javid NS. Prefabricated acrylic resin bars for splinting implant transfer copings. J Prosthet Dent 2000;84:108–110.
18. Spector MR, Donovan TE, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 1990;63:444–447.
19. Ivanhoe JR, Adrian ED, Krantz WA, Edge MJ. An impression technique for osseointegrated implants. J Prosthet Dent 1991;66:410–411.
20. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent 1990;64:684–648.
21. Takahashi J, Kitahara K, Teraoka F, Kubo F. Resin pattern material with low polymerization shrinkage. Int J Prosthodont 1999;12:325–329.
22. McDonnell T, Houston F, Byrne D, Gorman C, Claffey N. The effect of time lapse on the accuracy of two acrylic resins used to assemble an implant framework for soldering. J Prosthet Dent 2004;91:538–540.
23. Kim SH, Watts DC. Polymerization shrinkage-strain kinetics of temporary crown and bridge materials. Dent Mater 2004;20:88–95.
24. Burguete RL, Johns RB, King T, Patterson EA. Tightening characteristics for screwed joints in osseointegrated dental implants. J Prosthet Dent 1994;71:592–599.
25. Li S, Shah A, Hsieh AJ, et al. Characterization of poly(2-hydroxyethyl methacrylate-silica) hybrid materials with different silica contents. Polymer 2007;48:3982–3989.
26. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: A systematic review. J Prosthet Dent 2008;100:285–291.
27. Inturregui JA, Aquilino SA, Ryther JS, Lund PS. Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent 1993;69:503–509.
28. Burawi G, Houston F, Byrne D, Claffey N. A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques for the Bone-Lock implant system. J Prosthet Dent 1997;77:68–75.
29. De La Cruz JE, Funkenbusch PD, Ercoli C, Moss ME, Graser GN, Tallents RH. Verification jig for implant-supported prostheses: A comparison of standard impressions with verification jigs made of different materials. J Prosthet Dent 2002;88:329–336.
30. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 2000;83:555–561.