Does Splinting the Direct Copings Increase the Impression Accuracy of Two-Unit Nonparallel Implant Restorations?
A Systematic Review and Meta-analysis

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Abstract:

An essential factor influencing the long-term success of implant-supported fixed dental prostheses (FDPs) is the achievement of a passive fit during the restoration procedure. Poorly fitting restorations are thought to create detrimental strain and gaps between the prosthesis components and the implant-bone interface, causing biologic and mechanical complications, such as the accumulation of bacterial plaque, marginal bone loss, screw loosening or fracture, and prosthesis fracture. The appropriate choice of impression technique is one of the major factors influencing the accuracy of implant impressions, which is necessary for the fabrication of passive-fit restorations. Although digital implant impression techniques have been advocated over the last decades, they show less accuracy than conventional impression techniques, especially for multi-implant impressions. Conventional impression techniques can be classified into direct and indirect methods. Direct methods use an open tray, allowing impression copings to remain inside the impression materials after the tray is removed from the mouth, which can be more resistant to displacement. However, in this process, the displacement of impression copings during extraction of the tray and rotational movement of the impression copings during fastening of the implant analogs can also lead to deformation of the implant impressions.

Purpose: The purpose of this systematic review and meta-analysis was to evaluate the effects of splinting impression copings on the accuracy of conventional impressions for two-unit nonparallel implant restorations. Materials and Methods: MEDLINE via PubMed, Embase, and Web of Science databases were searched with no publication year or language limits, and studies comparing the accuracy of conventional impressions for two-unit nonparallel implant restorations made using splinted impression copings and nonsplinted impression copings were identified. A meta-analysis was performed using Review Manager software. The mean difference (MD) with 95% confidence interval (95% CI) for the framework strain and marginal gap of the implant-framework connection between impressions using splinted and nonsplinted copings were statistically analyzed (α = .05). Results: Initially, 142 articles were identified after the removal of duplicates. Five in vitro studies were included in the systematic review, and four in vitro studies were included in the meta-analysis. All the included studies were focused on internal-connection implants and implant-level impressions. The implant angulation in the included studies ranged from 8 to 30 degrees. Impressions using splinted impression copings exhibited significantly smaller marginal gaps than those using nonsplinted impression copings (P = .02; mean difference [MD] = –13.34; 95% CI = –24.31 to –2.36). Moreover, with respect to the framework strain, no significant differences were found between impressions using splinted impression copings and nonsplinted impression copings (P = .47; MD = –12.64; 95% CI = –47.32 to 22.03). Conclusions: Significantly larger marginal gaps were found in the impressions using splinted impression copings, but the clinical significance was low. Based on the limited number of studies included, splinting copings is unnecessary when making conventional impressions for two-unit nonparallel implant restorations. Int J Oral Maxillofac Implants 2022;37:653–659. doi: 10.11607/jomi.9577

Keywords: accuracy, conventional impression, implant, meta-analysis, nonparallel, splinting copings

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Therefore, splinting impression copings with rigid materials has been recommended to stabilize the copings against movement during extraction of the tray and fastening analogs. Various types of splinting techniques have been used, including dental floss with acrylic resin, prefabricated acrylic resin bars, metal bars, and bite registration materials. Notably, the entire procedure is time consuming and technique-sensitive, and it requires sufficient operating space, which may take more chairside time and reduce patient comfort.

To date, for situations in which two implants are placed, most of the studies have shown that direct and indirect methods have the same accuracy when implants are parallel, and the direct method shows more impression accuracy when implants are nonparallel. However, the results for splinting the impression copings of two non-parallel implants have been somewhat conflicting. For two non-parallel (15-degree) implants, significantly greater strain has been reported when using the nonsplinted technique (mean value: 535.0 microstrain) than when using the splinted techniques (mean value: 309.1 με),28 Similar results were reported using the splinted techniques (mean value: 535.0 microstrain [με]) than when using the nonsplinted technique (mean value: 309.1 με).28,29 Based on the current literature, clinicians might be confused and wonder whether it is necessary to splint impression copings when conventional impressions are made for two-unit nonparallel implant restorations.

Therefore, the purpose of this systematic review and meta-analysis was to evaluate the effects of splinting impression copings on the accuracy of conventional impressions for two-unit nonparallel implant restorations. The null hypothesis is that splinting impression copings does not increase the accuracy of conventional impressions for two-unit nonparallel implant restorations.

**MATERIALS AND METHODS**

**Protocol and Registration**

This systematic review and meta-analysis was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and registered in the PROSPERO database (registration number: CRD42020206744). The present systematic review aimed to answer the following question: Does splinting impression copings increase the accuracy of conventional impressions for two-unit nonparallel implant restorations? The PICOS question was defined as follows: population (P): conventional impressions; intervention (I): impressions with splinting of the impression copings; control (C): impressions without splinting the impression copings; outcome (O): whether splinting the impression copings increases the conventional impression accuracy; and study designs (S): in vitro, in situ, or in vivo studies.

**Search Strategy**

A systematic electronic literature search was conducted in PubMed, Embase, and Web of Science for published papers. To complement the performed searches, manual searches were conducted. No publication year limit was imposed. The search terms and their combinations used in the literature search are listed in Table 1. The last search was performed on March 5, 2021.

**Study Selection and Eligibility Criteria**

The electronic literature search and study selection were conducted by two authors (Y.M. and R.Y.Z.A.R.) independently by screening the titles and abstracts of all studies. The level of agreement between the two reviewers was determined by kappa statistics. Any disagreements between the reviewers were resolved by discussion or by consulting a senior reviewer (H.Y.). Articles satisfying all of the following inclusion criteria were included in this systematic review: (1) studies that compared the accuracy of dental implant impressions with or without splinting impression copings; (2) studies in which two implants were placed; and (3) studies that provided quantitative results (eg, marginal gaps, strain, and interimplant distances). Articles meeting one or more of the following criteria were excluded: (1) case reports, reviews, protocols, or clinical guidelines; and (2) studies investigating parallel implants.

<table>
<thead>
<tr>
<th>Table 1 Search Terms and Combinations Used in the Literature Searches</th>
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<tbody>
<tr>
<td><strong>Database</strong></td>
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<tr>
<td>Web of Science</td>
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<tr>
<td>Embase</td>
</tr>
</tbody>
</table>
Data Extraction and Collection
A protocol for data extraction was defined and evaluated by two independent reviewers (Y.M. and R.Y.Z.A.R.). The following data were extracted from the included studies: authors, year of publication, study type (e.g., in vitro or in vivo), master model, angulation of implants, fixture and implant system, distance between the implants, measurement parameter, impression material, and type of splinting used.

Risk of Bias and Quality Assessment
The risk of bias and quality assessment for the included studies was based on a protocol from previous systematic reviews. The following parameters of each study were evaluated: the sample size calculation, single operator, clearly specified splinting of impression copings protocol, clearly specified impression procedures protocol, adequate statistical analysis, and tests executed by a single-blinded operator.

Specific parameters reported or not by the included studies was recorded with “N” or “Y.” The levels of the risk of bias were classified as follows: 1 or 2 “Y” items represented a high risk of bias, 3 or 4 “Y” items represented a medium risk of bias, and 5 to 6 “Y” items represented a low risk of bias.

Meta-analysis
A meta-analysis was performed using Review Manager software (Review Manager v5.3; The Cochrane Collaboration). For continuous data, the results were expressed as the mean difference (MD) and 95% confidence interval (95% CI). Because of the limited statistical power, publication bias was not evaluated in this meta-analysis, which included fewer than 10 studies.

Statistical heterogeneity was assessed using the $I^2$ test. A random-effects model was used when high heterogeneity ($I^2 > 50\%$) was found. Otherwise, a fixed-effects model was used. The significance level was set at .05. For studies that evaluated more than one type of splinting technique, each technique was considered independently.

RESULTS

Study Selection
The PRISMA statement flowchart summarizing the selection process is shown in Fig 1. The kappa scores were all 0.9, indicating excellent interexaminer agreement. Among the 142 potentially relevant studies, 10 were selected for full-text analysis, and 5 were included in the systematic review. Four studies were included in the meta-analysis.

Characteristics of the Included Studies
All the included studies were in vitro studies. The characteristics of the five studies are presented in Table 2. Different splinting techniques were adopted for the included studies: one study used metal bars with acrylic resin; three studies used autopolymerizing acrylic resin, sectioned and splinted again; and one study used autopolymerizing acrylic resin with dental floss sectioned and then splinted again, autopolymerizing acrylic resin with dental floss without sectioning, and prefabricated autopolymerizing acrylic resin bar.

In addition, two studies used polyether as the impression material, and three studies chose vinyl polysiloxane (VPS). All the included studies involved implant-level impressions. Four studies used a block as the master model, which was made from metal, resin, and dental stone. One study used an edentulous mandibular dental study model as the master model. All the master models in the included studies were focused on internal-connection implants. The implant angulation in each study was 8 degrees, 10 degrees, 15 degrees, 25 degrees, and 30 degrees.

Two studies set the distance between the implants to 15 mm and 20 mm, measured from center to center of each implant or analog. Two studies set the distance to 4 mm and 10 mm, measured from edge to
edge of each implant or analog. One study did not state the distance between the implants.

Risk of Bias and Quality Assessment
All studies presented a medium risk of bias. Two studies received 4 “Y” responses, and three studies received 3 “Y” responses. A lack of sample size calculation and blinded examiner were the main shortcomings of the included studies (Table 3).

Meta-Analysis Outcomes
The marginal gap of the implant-framework connection was measured in two studies, and the mean values ranged from 33.5 to 78.7 μm. The meta-analysis showed a significant difference between the impressions using splinted and nonsplinted impression copings, favoring splinted copings (P = .02; MD = –13.34; 95% CI = –24.31 to –2.36) and presented low heterogeneity (I² = 0%; P = .39; Fig 2).

Two studies compared the amount of strain produced in the framework, and absolute values of mean strain ranged from 1,443.6 to 43.2 με. The meta-analysis revealed no significant difference between the impressions using splinted and nonsplinted impression copings (P = .47; MD = –12.64; 95% CI = –47.32 to 22.03) and presented high heterogeneity (I² = 54%; P = .07; Fig 3).

Table 2 Characteristics of the Included Studies

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Study type</th>
<th>Master model</th>
<th>Angulation of implants</th>
<th>Distance between implants</th>
<th>Parameter (measuring device)</th>
<th>Impression material</th>
<th>Type of splinting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saboury et al (2017)</td>
<td>In vitro</td>
<td>Edentulous mandibular dental model</td>
<td>30 degrees convergent</td>
<td>20 mm (center to center)</td>
<td>Marginal gap (Stereo-microscope)</td>
<td>Vinyl polysiloxane (Monopren Transfer, Kettenbach)</td>
<td>Metal rods with acrylic resin</td>
</tr>
<tr>
<td>Lee et al (2009)</td>
<td>In vitro</td>
<td>Dental stone block</td>
<td>10 degrees convergent</td>
<td>4 mm (edge to edge)</td>
<td>Marginal gap (Light microscope)</td>
<td>Polymethacrylate (Impregum Penta, 3M ESPE)</td>
<td>Autopolymerizing acrylic resin, sectioned and splinted again</td>
</tr>
<tr>
<td>Choi et al (2007)</td>
<td>In vitro</td>
<td>Dental stone block</td>
<td>8 degrees divergent</td>
<td>10 mm (edge to edge)</td>
<td>Strain values (Strain gauge)</td>
<td>Vinyl polysiloxane (Examix Fine, GC)</td>
<td>Autopolymerizing acrylic resin, sectioned and splinted again</td>
</tr>
<tr>
<td>Dang et al (2020)</td>
<td>In vitro</td>
<td>Resin block</td>
<td>15 degrees divergent</td>
<td>15 mm (center to center)</td>
<td>Strain values (Strain gauge)</td>
<td>Vinyl polysiloxane (Extrude Extra type 1, Kerr)</td>
<td>Autopolymerizing acrylic resin, sectioned and splinted again</td>
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NR, not reported.

Table 3 Risk of Bias in the Included Studies

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<td>Y</td>
<td>Y</td>
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<tr>
<td>Impression procedures protocol</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Statistical analysis</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Blinded examiner</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Risk of bias</td>
<td>Medium</td>
<td>Medium</td>
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</table>
DISCUSSION

Nonparallel placement of implants is a common clinical situation due to certain anatomical and operational considerations.\textsuperscript{37,38} Implant inclination may decrease the accuracy of implant impressions and increase the level of difficulty.\textsuperscript{35} The effects of splinting impression copings on the accuracy of conventional impressions for two-unit nonparallel implant restorations are controversial, and the present study was the first systematic review and meta-analysis in this field. The null hypothesis that splinting impression copings does not increase the accuracy of conventional impressions for two-unit nonparallel implant restorations was partially rejected. In terms of framework strain, splinting impression copings was not effective at improving the accuracy of impressions for two-unit nonparallel implant restorations, whereas when considering the marginal gap of the implant-framework connection, splinted copings had a positive effect on the impression accuracy.

Various methods for measuring the accuracy of impressions have been adopted in the literature. Measurements of the strain or the marginal gap discrepancy of the framework screwed on the test model, which achieved passive fit on the master model to the greatest extent, were similar to those in the clinical assessment methods.\textsuperscript{39} The present findings indicated that the measured strain was similar between the splinted and nonsplinted groups. The absolute values of the mean strain (1443.6 to 43.2 με) were all under the physiologic ranges described by Frost\textsuperscript{40} (1500 με) and Himmlová et al\textsuperscript{41} (3000 με). However, a significant difference in the marginal gap of the implant-framework connection was found in the meta-analysis, favoring splinted copings. The MD between the impressions using splinted and nonsplinted impression copings was 13.34 μm. The reason for this discrepancy might be due to the implant angulations set in each study. Specifically, the implant angulations in studies measuring marginal gap were relatively larger (10 and 30 degrees) than those in studies measuring strain (8 and 15 degrees). It has been reported that a greater angulation between implants can increase the amount of impression deformation.\textsuperscript{42} However, in previous studies, splinting impression copings was preferred when the implant angulation was 10 degrees,\textsuperscript{27} whereas no difference was found between splinted and nonsplinted copings when the implant angulation was 15 degrees.\textsuperscript{28} The contrasting findings might be due to the different impression materials used (polyether vs VPS).\textsuperscript{43,44} However, the impact of impression materials could not be further explored in the present meta-analysis due to the limited number of included studies.

Previous studies reported that misfit of the restoration seems to have no negative effects on clinical outcomes.\textsuperscript{45,46} Therefore, most researchers believe that a
specific range of clinical tolerance may be present. In a previous study including 14 patients with fixed prostheses supported by four to seven implants, a misfit of approximately 100 µm was considered acceptable based on the change in marginal bone levels for the different degrees of prosthesis misfit. Andriessen et al set the maximum biologic tolerance of two-implant-supported frameworks as 100 µm on the basis of clinical guidelines with a biomechanical rationale. The mean gap values of the included studies were all within the tolerable range. Moreover, there were baseline gaps (29.1 to 38.2 µm) in the master casts, meaning that the gaps in the test casts caused by the impression process would be even smaller. Therefore, the MD in the marginal gap has little clinical significance. Considering the abovementioned issues, it may be concluded that nonsplinted copings can meet the clinical requirements for impressions of two-unit nonparallel implant restorations and that splinting the copings is unnecessary.

The implant angulations of the studies included in this review ranged from 8 to 30 degrees. It is possible that the marginal gap can be even greater in some cases with higher degrees of angulation. Hence, the conclusion of the present review might not apply to situations with larger angulation. However, it can be difficult to dislocate the copings in this case, especially when they are linked by rigid materials, so greater angulation may not be suitable for splinting.

Because of the scarcity of relevant research and the variety of measurement methods used, only four studies were included in the meta-analysis. Moreover, all four studies included in the meta-analysis used internal connection implants. To date, no related information is available regarding external-connection implants. Nevertheless, in a previous study, the connection types of implants were found to be one factor that can influence impression accuracy. Further studies on external connection implants are necessary. All included studies were performed in vitro, probably due to the difficulty of obtaining the intraoral position of implants as a reference to assess the discrepancy of impressions. The force and direction of tray removal may influence the results of impressions of in vitro studies. Further clinical studies are needed to add further evidence to support the present findings.

**CONCLUSIONS**

No significant difference was found in the framework strain between the impressions using splinted and nonsplinted impression copings, but significantly larger marginal gaps were found in the impressions using splinted impression copings. However, the difference in the marginal gap between impressions using splinted and nonsplinted impression copings was small, and the values were within the range of clinically tolerable misfit. Therefore, it may be unnecessary to splint copings when making conventional impressions for two-unit nonparallel implant restorations. However, considering the limited number of studies included, our findings should be used with caution in clinical application. Additional clinical studies are required to clarify this issue.

**ACKNOWLEDGMENTS**

The authors declare no conflicts of interest related to this study.

**REFERENCES**