Accuracy of a New Fast-Setting Polyether Impression Material

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Purpose: To evaluate the dimensional accuracy of impressions made using a new fast-setting polyether material. Materials and Methods: A metallic reference model with two crown preparations, one inlay preparation, and three stainless steel precision balls was digitized to create a digital reference model. Sixteen one-step impressions were made for each of the four study groups, differing in impression material (regular-setting polyether [RSP] vs fast-setting polyether [FSP]) and technique (monophase vs dualphase), for a total of 64 specimens. Plaster casts fabricated from these impressions were digitized using 3D scans. Global accuracy was studied by evaluating distance and angle deviations between the replica and the reference model. Local accuracy was described in terms of trueness and precision of the aligned individual abutment tooth surfaces.

Results: For all impression materials and techniques, the local accuracy at the abutment tooth level was excellent. For surfaces prepared for crowns, mean trueness was < 10 µm, and mean precision < 12 µm. Inlay surfaces were associated with higher inaccuracies (mean trueness < 21 µm and mean precision < 37 µm). The greatest global inaccuracies were generally measured for the cross-arch span, with mean distance changes between −55 µm and −94 µm. For all aspects of studied accuracy, impressions with FSP were at least comparable to those fabricated with RSP. Conclusion: Within the limitations of this study, all tested polyether materials would allow for clinically acceptable impression making. The new fast-setting material could be an alternative to regular-setting polyether materials, especially for single crowns and small fixed partial dentures.


The trustworthy transfer of the clinical situation to the dental laboratory is a complex and challenging process in prosthetic treatment.¹ When it comes to final impression-making, two kinds of elastomeric materials are primarily used: polyvinyl siloxane (PVS) and polyether.²–⁵ Both materials allow for the required dimensional accuracy and detailed reproduction of the dental hard and soft tissues, and both have their advantages and disadvantages. For example, PVS materials have a neutral taste for the patient and are easily stored after curing. This latter characteristic makes them interesting for documentation purposes.⁶,⁷ On the other hand, polyether materials have been reported to have initially hydrophilic properties, which may result in a better residual flow onto most tooth structures.⁸

Nowadays, several impression systems including hybrid materials with widely varying physical properties and resulting accuracies are available on the market.⁹ In addition, intraoral digital impressions are becoming steadily more popular. For single crowns and small fixed partial dentures (FPDs), the subsequent restorations show a comparable level of accuracy; however, for longer spans or even full-arch rehabilitations, they still show disadvantages compared to using conventional impression techniques.¹⁰
In addition, the conventional approach allows for easier generation of casts and laboratory adjustments (eg, refining of occlusion). Furthermore, the widespread use of digital scans is still limited due to high costs and the frequent need to powder the dentition, which is inconvenient.10,11 Nevertheless, depending on the clinical situation to be transferred, digital impression-making seems to be faster compared to conventional impression-making.10,11

However, besides the impression material itself,6,12–14 the accuracy of the impressions is affected by several clinical and procedural parameters. With regard to clinical conditions, the location of the finishing line15 and the periodontal status—including oral hygiene, saliva, blood, and the angulation of the prepared abutment teeth—affect the accuracy of the impression.16,17

Regarding procedural aspects, the impression technique (monophase vs dualphase, one-step vs two-step)18,19 and the selection of an impression tray (tray design, metal vs plastic trays)6 play crucial roles in terms of the resulting accuracy. It has been found that the disinfectant solution can also influence the accuracy.13,20 Of course, the transfer into the plaster cast can create an error, too.21 Nevertheless, impression-making and further laboratory processing should lead to well-fitting dental prostheses.

In terms of marginal fit, the marginal gaps of FPDs are intended to be smaller than 100 to 150 μm.22,23 Routinely, this can be realized using commercially available impression materials; however, and especially with respect to the partially quicker digital impression-making, it is desirable that the impression materials cure within a shorter time span. This would reduce both the exposure time for the patient and the valuable chair time for the dentist. For most polyether and silicone materials, the intraoral setting time is about 5 to 7 minutes, which is rather long for an impression of single crowns or small FPDs. To address this issue, a new polyether impression material with a shortened intraoral setting time (2 minutes) was recently introduced to the market. However, to date, no information about the accuracy of the new material is available.

The objective of this laboratory study was therefore to evaluate the dimensional accuracy of this new fast-setting polyether (FSP) material in comparison to a regular-setting polyether (RSP) material. In addition, the influence of the impression technique (one-step monophase vs one-step dualphase) was investigated. The null hypotheses were that plaster casts of the four study groups would show no significant difference in accuracy regarding (1) the type of polyether used for the impression or (2) the impression technique.

### MATERIALS AND METHODS

The accuracy of the two impression materials—the RSP (Impregum, 3M Oral Care) and the new FSP version (Impregum Super Quick, 3M Oral Care) (Table 1), was indirectly evaluated by measuring the dimensional changes of the plaster casts generated by their respective impressions compared to a reference model.

### Reference Model

The reference model of a stainless steel base with cobalt-chromium (Co-Cr) teeth represented a clinical situation of the mandible in which two tooth stumps were prepared for the incorporation of a small FPD (teeth 34 and 36 [FDI]). In addition, tooth 45 showed an inlay preparation. For analytic purposes, stainless steel precision balls (diameter 3.175 mm, Grade 3: deviation in form < 0.08 μm and mean roughness < 0.01 μm) were welded to precision balls (Table 1), was indirectly evaluated by measuring the dimensional changes of the plaster casts generated by their respective impressions compared to a reference model.

#### Table 1: Global Dimensional and Angular Changes of the Plaster Replicas Compared to Reference Model

<table>
<thead>
<tr>
<th>Material</th>
<th>C1–C2</th>
<th>C2–C3</th>
<th>C1–C3</th>
<th>Distance Changes (µm)</th>
<th>Angular Changes (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSP, DP</td>
<td>−65.0</td>
<td>39.9</td>
<td>−63.5</td>
<td>27.7</td>
<td>0.14 0.06</td>
</tr>
<tr>
<td>FSP, MP</td>
<td>−55.1</td>
<td>29.5</td>
<td>−71.3</td>
<td>21.4</td>
<td>0.14 0.06</td>
</tr>
<tr>
<td>RSP, DP</td>
<td>−93.6</td>
<td>35.3</td>
<td>−36.2</td>
<td>24.9</td>
<td>0.22 0.05</td>
</tr>
<tr>
<td>RSP, MP</td>
<td>−69.6</td>
<td>40.9</td>
<td>−23.6</td>
<td>26.2</td>
<td>0.17 0.09</td>
</tr>
</tbody>
</table>

FSP = fast-setting polyether; RSP = regular-setting polyether; DP = dualphase; MP = monophase.
positioning aids were attached in the vestibular area of the model. This approach also guaranteed that the walls of the trays consistently had a minimum distance of 2 mm to the dentition or the precision balls. To attain a highly accurate digital reference dataset, all relevant metallic teeth were digitized separately by a specialized industrial company using an optical profilometer (μscan custom with CF 4 sensor, NanoFocus) before welding these teeth to the steel base. Subsequently, a digital dataset of the occlusal surface of the total assembly was generated (grid with 50 μm, measurement error < 1 μm). For the total assembly, additional measurements with a coordinate-measuring machine (MarVision MS 222, Mahr Metrology; about 200 measurement points for each tooth or precision ball, accuracy < 2 μm) were conducted. In a final step, the digitized teeth were aligned with the data of the complete reference model. A global coordinate system was defined using the centers of the precision balls (C1 in tooth region 37; C3 in tooth region 46; and C3 in tooth region 31/41), as follows:

- Origin of the coordinate system located at C1
- x axis directed along the vector C1C2
- xy plane defined by the points C1, C2, C3
- y axis in anterior direction

For each prepared tooth, a local coordinate system was added with its origin at the center of the respective preparation line and its axes parallel to those of the global coordinate system.

**Sampling and Impression-Making**

Sixteen one-step impressions were performed for each of the four study groups (64 impressions in total) differing in impression technique (monophase vs dualphase) and impression material (RSP vs FSP) (RSP monophase technique: Impregum Penta Soft; RSP dualphase technique: Impregum Penta H DuoSoft/Penta H DuoSoft/Impregum Garant L DuoSoft; FSP monophase technique: Impregum Penta Super Quick medium-body; FSP dualphase technique: Impregum Penta Super Quick heavy-body consistency/Impregum Penta Super Quick light-body consistency). For in vitro impression making, the following settings were defined:

1. To consider the longer curing time at room temperature in contrast to body temperature, removal times given by the manufacturer for clinical use were doubled. During the tests, these times were monitored using a stopwatch.
2. Impressions with RSP were made by one trained operator. For impressions with FSP, an additional operator filled the impression tray while the main operator overmolded the tooth stumps in the model and finally placed the impression tray in the one-step impression technique, all impression materials are used and cured at the same time).
3. Border-Lock metal trays were used for impression-making (Ergolock size XL, Omnident). The trays were dabbed with polyether adhesive to guarantee optimal retention of the impression material (Polyether Adhesive, 3M Oral Care).
4. After their removal, the impressions rested for 5 minutes in a disinfectant solution (Omnisept IMP, Omnident). All impressions were checked for imperfections. If present in relevant areas, these impressions were excluded and repeated. Finally, plaster casts were fabricated after a minimum reset time of 60 minutes.

**Fabrication and Scanning of the Plaster Casts**

To enable a complete digitization of relevant surfaces via 3D scans and to follow the clinical procedure during FPD fabrication, saw-cut models were fabricated using pinned base plates (Giroform, Amann Girrbach). The impressions were poured with stone plaster Type IV (Esthetic-Base Gold, Dentona). The plaster was mixed according to the manufacturer’s instructions under a vacuum (Multivac, Degussa). After a resting time of at least 60 minutes, casts were demolded from their impressions, cut into segments, and checked for imperfections. If any were apparent, the impression-making and fabrication of the cast were repeated.

All saw-cut models were positioned similarly on the base plate. One corresponding secondary plate (for fixation in an articulating device) was luted to an interface plate of the 3D scanner (D800, 3Shape). Hence, the positioning and orientation of the plaster casts in the scanner could be standardized, and a scan sequence adjusted a priori (Convince, 3Shape; with tilts of 15, 50, and 70 degrees, six circumferentially distributed scans) could be used for all samples. Triangulation parameters (detail accuracy 9/10, threshold for noise filtering 1/10, iterative optimization of mesh deactivated) were chosen such that a fine and uniform mesh was given for the final 3D surfaces (mean edge length of triangles: 109 ± 5 μm). Procedures manipulating the original scan data (closing of holes, smoothing) were omitted.

**Evaluation of Deviation Between the Reference Model and Plaster Replicas**

Deviations of the distances between the ball centers as well as between the local coordinate systems attached to the prepared teeth measured for plaster cast scans in comparison to the reference values were analyzed using MATLAB R2015a (MathWorks) and Geomagic Design X (3D Systems). Ball centers were identified by fitting spheres with a given radius (r = 1.5875 mm) to the regions of interest within the respective scan. The reference model and scans were aligned using the global
RESULTS

Global Accuracy of the Plaster Replicas (Distance and Angular Changes)

The distances between the precision ball centers (located above the occlusal surface) in the reference model were 40.338 mm (C1 to C2), 35.916 mm (C1 to C3), and 31.927 mm (C2 to C3). The deviations of the respective path lengths extracted from plaster cast scans for the four study groups are summarized in Table 1. Significantly higher deviations ($P < .05$) were observed for the RSP dualphase group when compared to the other three test groups, which all showed similar results. However, for any pairwise comparison of the four study groups, differences in mean measured deviations never exceeded 30 µm.

Reference distances between the prepared teeth (reference points located at the center of the respective finishing line) were 15.400 mm between teeth 34 and 36, 41.515 mm between teeth 36 and 45, and 36.578 mm between teeth 34 and 45. The measured distance changes when analyzing scans of the plaster replicas are presented in Table 1 and Fig 2a. Again, the test series with the RSP dualphase impression showed the highest dimensional changes ($–35.5 ± 22.3$ µm), and significant differences were found when compared with all other test groups (DP FSP: $23.1 ± 23.0$ µm, $P = .045$; MP FSP: $–17.3 ± 21.7$ µm, $P = .001$; MP RSP: $–20.7 ± 25.7$ µm, $P = .011$). Furthermore, significantly greater distance changes were observed for long spans (teeth 36 and 45, teeth 34 and 45) compared to the short span between teeth 34 and 36 (situation of a three-unit FPD). When set in relation to the reference distances, the mean relative deviations were rather small and ranged between

Statistical Evaluation

All statistical analyses were performed using SPSS version 24 (IBM). Local statistical significance was observed at $P < .05$. Mean deviations and their standard deviations ($±$) in distance between the plaster replicas and the reference model were calculated. These calculations were performed for each impression material and technique. Box plots were used when appropriate to visualize the descriptive outcome. Analysis of variance (ANOVA) was used to determine the effect of impression material and technique used. Pairwise post hoc testing was performed using Tukey tests.
1% and 3% at the occlusal level and between 0.3% and 1.4% at the level of the finishing line. All evaluated distances in the plaster casts, both for precision balls and prepared teeth, were consistently slightly shortened when referring to the reference model. In Fig 2b, angular changes between tooth axes are illustrated. Analogous to the distances, the smallest changes (less than 0.3 degrees) were found between teeth 34 and 36. For the tooth pairs 36/45 and 34/45, the relative angular changes ranged between 0.5 and 1.3 degrees. No significant differences were found between the different impression materials. The same was true for both techniques ($P > .05$).

Local Accuracy of the Plaster Replicas (Deviations of the Prepared Teeth)

Table 2 presents the trueness and precision for the prepared teeth of the replicas for the impression materials and techniques. For both trueness and precision, an effect of the factor prepared tooth was detected ($P < .001$), while no effect was seen for the factors impression material or technique. The pairwise comparisons yielded significantly less accurate results ($P < .001$ for

### Table 2 Local Accuracy of Plaster Replicas for the Prepared Tooth Surfaces Depending on Impression Material and Technique

<table>
<thead>
<tr>
<th>Tooth 45</th>
<th>Tooth 34</th>
<th>Tooth 36</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trueness</strong></td>
<td><strong>Precision</strong></td>
<td><strong>Trueness</strong></td>
</tr>
<tr>
<td>FSP DP</td>
<td>16.6 ± 4.6</td>
<td>25.7 ± 11.1</td>
</tr>
<tr>
<td>RSP DP</td>
<td>14.4 ± 2.4</td>
<td>31.8 ± 17.9</td>
</tr>
<tr>
<td>FSP MP</td>
<td>20.4 ± 9.3</td>
<td>36.7 ± 31.2</td>
</tr>
<tr>
<td>RSP MP</td>
<td>12.5 ± 4.9</td>
<td>20.6 ± 7.5</td>
</tr>
</tbody>
</table>

All data are reported as mean ± standard deviation (µm). FSP = fast-setting polyether; RSP = regular-setting polyether; DP = dualphase; MP = monophase.
all tests) for the inlay preparation of tooth 45 (mean trueness: 16.0 μm, mean precision: 28.7 μm) in contrast to the crown preparations of tooth 34 (mean trueness: 7.9 μm, mean precision: 7.8 μm) and tooth 36 (mean trueness: 8.3 μm, mean precision: 11.4 μm). This outcome is also visualized in Fig 3.

DISCUSSION

Both null hypotheses were rejected, since dualphase impressions with RSP led to slightly but significantly higher inaccuracies compared to all other test groups.

The results of this laboratory study suggest that the new FSP impression material shows an adequate accuracy, which is, in summary, at least on par with the RSP material. In general, the plaster replicas generated by all impression materials and techniques showed slightly shortened distances between the measurement points in comparison to the reference model (precision ball distances, distances between reference points attached to the prepared abutment teeth), suggesting an overall downscale of the clinical situation captured. This observation is worth discussing. In the literature, when it comes to studies of the accuracy of impressions, the direction of changes in scale is controversially reported. Some authors are convinced that the abutment teeth of plaster casts are reproduced larger if one-step dualphase PVS or polyether impression materials are used; on the contrary, with kneadable impression materials, the situation is downscaled. Others, however, have observed inconsistently directed changes of the dimensions. From a physical point of view, it is expected that impression materials entail a moderate shrinkage. However, when replicas are involved, one should also consider the dimensional behavior of the used plaster (expansion). In the present study, stone plaster with an expansion of less than 0.1% was used, which may be a causative factor for the slightly shortened dimensions of the replicas (ie, no full compensation for the shrinkage of the impression material within the tray). Nonetheless, it is worth underlining that mean deviations in path lengths compared to the reference model were at maximum 100 μm and only observed for long distances between approximately 30 and 40 mm, correlating with a relative error of about 0.3%. All examined structures were subject to a slight tilt in the lingual direction, resulting in a more pronounced shortening of cross-arch distances in the plaster casts at the occlusal level compared to distance changes at the finishing-line level.
Interestingly, the dualphase RSP impressions showed greater deviations compared to the other three test groups. Some previous laboratory studies, accordingly, found a higher accuracy of impressions made with the monophase technique, which was judged to be subjected to the higher contraction of the light-body material used in the dualphase technique. However, in the clinical setting, this effect was not confirmed. Nevertheless, the better flow-off of these low-viscosity materials is needed for subgingival preparations to assure detailed reproduction of fine (subgingival) tooth structures. However, in the present study, no significant difference was seen between the dualphase FSP and either polyether material for the respective monophase polyethers. Angular changes between the vertical axes of the prepared abutment teeth were small (<1.3 degrees) for larger spans and almost negligible (<0.4 degrees) between abutment teeth 34 and 36, which represents a common prosthetic task (ie, small FPD situation). Here, no significant differences regarding the impression material or technique were found. Both changes in angle, moreover, lie within the tolerance margin of physiologic tooth mobility; in implant dentistry, however, the larger tolerance (1.3 degrees) could not be assumed.

With regard to the local accuracy of the impression (ie, the examination of how accurate the single prepared abutment teeth could be replicated), both trueness and precision showed superb results for full-crown preparations (trueness <12 μm, precision <23 μm) with all impression materials and techniques used. These results suggest that the internal and marginal fit of a restoration fabricated by use of these impressions would be clinically adequate. However, in the area of the inlay preparation (tooth 45), both trueness and precision were three to four times larger than for the full-crown preparations (significant difference), indicating that very accurate impressions/plaster casts of inlay preparations may be more challenging compared to conventional full-crown preparations. For a high percentage of plaster casts, the accuracy was still satisfactory for the clinical use of inlays (Fig 3). In summary, impression material and impression technique did not significantly affect the local accuracy, but preparation design had a large impact. This may be due to the much worse accessibility of the inlay cavity during the scanning process compared to full-crown preparations or to the more challenging situation during impression-making and pouring of the plaster casts. However, in general, the observed accuracy of the tested impression materials/techniques is in the range of that demonstrated in previous studies. With respect to the FSP materials, one should also consider that this material is especially interesting for single crowns and small FPDs. Since accuracy—including trueness and precision—is especially high in the reproduction of shorter distances, use of the new materials allowed for accelerated impressions without making any compromises in prosthetic results. It should be noted that the impression-taking process is just one of many steps in which inaccuracies add up until a restoration is finished. The fit of a restoration is affected, among other factors, by preparation parameters (type of preparation, preparation angle), design parameters (wall thickness, marginal gap, and cement widths), and fabrication method (casting, milling/sintering, pressing). This was shown in two recent studies, one by Duqum et al that investigated the fit of crowns differing in material (lithium disilicate vs zirconia) and workflow (cast models vs printed models), and one by Schestatsky et al, who observed better adjusted margins for pressed lithium disilicate crowns when compared to computer-assisted-manufactured crowns. Therefore, an accurate impression is important, but does not guarantee a good fit of the final restoration.

Strengths and Weaknesses of the Study

The reference model was digitized with a much higher accuracy (<1 to 2 μm) compared to the laser scanner used in this study. Temperature was monitored during all steps and deviated less than 2°C from the temperature during reference measurements. With the stainless steel base, such a temperature change would lead to a distance change of <1 μm on a track of <50 mm in length. Therefore, differences in accuracy between test groups exceeding 4 μm were not caused by any limitations of the test setup. What was not taken into account in this in vitro study is the cooling of the cured impression from body temperature to room temperature after removal from the patient’s mouth. On the cross-arch distance, the metal tray, which supports the impression material, would show a thermal contraction of \[\alpha_T \times \Delta T \times L = 10 \times 10^{-6} \text{K}^{-1} \times (-15 \text{ K}) \times 40 \text{ mm} = -6 \text{ μm}\], and the impression material itself would show shrinkage and distortions.

When interpreting and generalizing the study outcome, one should keep in mind that this was a laboratory study and it is therefore unable to fully capture the clinical reality. Other aspects, including temperature, moisture, bleeding, and periodontal state, as well as subgingival preparation, can also affect the accuracy of dental impressions.

The possible benefit of a shortened chair time for both patient and dentist was not evaluated in this study. This topic should be the focus of future investigations, preferably in a clinical setting, taking into account the patient’s perspective.

**CONCLUSIONS**

Irrespective of the used impression technique, the newly introduced FSP material has, at worst, an equal accuracy
compared to the RSP material, and would therefore be a viable alternative for impression-taking with a focus on single crowns and small FPDs. However, clinical studies would be desirable to confirm these results.

ACKNOWLEDGMENTS

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REFERENCES


Can Early Dental Extractions Reduce Delays in Postoperative Radiation for Patients with Advanced Oral Cavity Carcinoma?

This study sought to evaluate the effectiveness of early extractions on the timing of postoperative radiation for patients with advanced oral cavity squamous cell carcinoma. All patients with oral cavity squamous cell carcinoma who required resection, reconstruction, and dental extractions over a 10-year period were retrospectively reviewed. The study included patients who had advanced disease preoperatively, indicating the need for adjuvant radiation therapy. Multivariable logistic regression models were created to estimate the risk factors for initiation of postoperative radiation therapy more than 6 weeks after surgery. A total of 24 patients were included in the study. Thirteen patients underwent early extractions (before or at the time of surgery), and 21 patients underwent extractions after the surgery. Extractions included all teeth with periodontal disease within the expected radiation field. Most patients underwent full-mouth extractions. Postoperative radiation therapy was initiated at more than 6 weeks in 30.8% of patients in the early group, whereas 72.4% of patients in the late group experienced a delay. Early extractions were significantly associated with a decreased risk of postoperative radiation therapy delay. Early involvement of the Dental Oncology Department and oral and maxillofacial surgeons can aid in the timely delivery of care for patients with advanced oral cancer.