EX VIVO DIGITAL COMPARISON OF FOUR IMPRESSION TECHNIQUES USING AN INDUSTRIAL LASER SCANNER

Bálint Jász[1a*], Máté Jász[1b], Szandra Körmendi[1c], Gellért Joós-Kovács[1d], Bálint Vecsei[1e], Péter Hermann[1f], Judit Borbély[1g]

[1]Department of Prosthodontics, Faculty of Dentistry, Semmelweis University, Szentkirályi utca 47, HU-1088 Budapest, Hungary

[a]DMD, Clinical Doctor; e-mail: jasz.balint@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0002-5556-137X
[b]MD, DMD, Assistant Professor; e-mail: jasz.mate@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0002-6717-5126
[c]DMD, Assistant Professor; e-mail: kormendi.szandra@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0003-4694-1342
[d]DMD, Assistant Professor; e-mail: joos-kovacs.gellert_levente@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0002-0522-3751
[e]DMD, Assistant Professor; e-mail: vecsei.balint@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0001-5748-7276
[f]DMD, PhD, MSc, Professor and Head; e-mail: hermann.peter@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0002-9148-0139
[g]DMD, PhD, Associate Professor; e-mail: borbely.judit@dent.semmelweis-univ.hu; ORCIDiD: https://orcid.org/0000-0003-3064-8724

ABSTRACT

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Introduction The aim of the study was to compare different impression techniques used for fixed prosthodontics.

Methodology A master cast with prepared abutments was created from polymethyl-methacrylate (PMMA). A high-resolution industrial scanner was used to create a virtual reference model. Four different impressions were made, three with polyvinyl-siloxane (PVS) (n = 10 for each): one-step putty-wash (1SPW), two-step putty-wash prepared with an escape channel (2SPW-Ch), two-step putty-wash with a polyethylene spacer foil (2SPW-Fo), and one with polyether monophasic technique (MP) from the PMMA model and digitized with an industrial scanner. The stereolithographic (STL) files of the impressions (n = 40) were exported. Each file was compared to the reference using the Geomagic Verify software. Six points were assigned to enable virtual calliper measurement of tooth diameters and distances of varying sizes within the arch.

Results In the case of die diameters, the deviation from the mould ranged from 31.84 to 180.64 µm. At the stump diameter level, the MP and 1SPW techniques showed significantly more minor differences than the 2SPW-Ch, and the MP was significantly more accurate than the 2SPW-Fo. At medium distance, the deviation ranged from 42.74 to 136.47 µm. Therefore, MP was found to be significantly more accurate than 2SPW-Ch. When examining the long distance, the difference was between 162.62 and 348.85 µm. The MP and 1SPW impression techniques proved significantly more accurate than the 2SPW-Ch technique for long distances.

Conclusions With both simultaneous techniques, significantly more true results were achieved than with the two-step techniques.

KEYWORDS

Dental Impression Technique; Scanning of the Impression; Monophase; One-Step Putty-Wash; Two-Step Putty-Wash.

1. INTRODUCTION

One of the most critical steps in our dental processes is to make impressions with reasonable accuracy. The impression allows the dental technician to have the same condition on the model as in the patient's mouth. When examining impressions, trueness and precision can be examined, and these two together constitute accuracy. ISO 5725 uses two terms, trueness and precision, to describe the accuracy of a measurement method. Trueness refers to the closeness of agreement between the arithmetic mean of a large number of test results and the true or accepted reference value. Meanwhile, precision refers to the closeness of agreement between test results [1]. In this study, only the trueness of the impressions was examined. A review article published in 2016 defined the still tolerable inaccuracy in the crown's fit between 50 and 200 µm after the turn of the millennium [2]. The article by McLean and von Fraunhofer from 1972, which is still frequently cited, gives the 120-micron deviation as an inaccuracy threshold, so this level of accuracy must be aimed at for impressions [3-5].

According to the ISO standard, which currently regulates the properties of elastic impression materials, the kneadable material with the lowest reproducibility must have a resolution of at least

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***Corresponding author:** Dr. Bálint Jász, DMD, Department of Prosthodontics, Faculty of Dentistry, Semmelweis University, Szentkirályi utca 47, HU-1088 Budapest, Hungary.
Tel: +36-20-497-4232; **Fax:** +36-1-317-5270; e-mail: jasz.balint@dent.semmelweis-univ.hu

75 µm, so there is no material scientific obstacle to achieving this trueness and accuracy [6]. Therefore, in addition to the spread of digital dentistry, information on the trueness of traditional impression techniques remains of paramount importance. The reason for this is twofold. On the one hand, the digitization of conventional impressions or models is one of the possible routes to CAD / CAM techniques; on the other hand, the vast majority of dental offices still use traditional impressions [7,8]. In addition, numerous studies and factory data are available on the impression materials themselves and their accuracy [9]. However, the trueness and accuracy of the various impression techniques are still not widely researched. Most in vitro examinations of impressions use simplified bodies, such as cones instead of teeth or tooth models [10,11]. In many studies, only two or three techniques are compared in an analogous way or by the evaluation of trained clinicians, but not in a qualitative way [12-14]. In the present in vitro study using a PMMA master cast with prepared stumps, the four most commonly used precision impression techniques are compared to explore whether there was a difference in the sampling trueness of these techniques. The hypothesis is that one-step impression techniques are truer than two-step techniques.

2. METHODOLOGY

The following four impression techniques are examined in the present study:
• the one-step putty-wash technique (1SPW),
• the monophase technique (MP),
• the two-step putty-wash technique prepared with escape channels (2SPW-Ch), and
• the two-step putty-wash technique prepared with a polyethylene spacer foil (2SPW-Fo).

Ten impressions were taken from a PMMA master model using each technique, i.e., altogether 40 impressions were created [15,16]. On the upper jaw master model, supragingival, chamfer shoulder preparation of the right first premolar (14), left first incisor (21), first premolar (24), and second molar (27) were prepared. In all cases, the impressions were made considering the manufacturer's instructions, the literature recommendations, and consensus [11,17,18]. Impression materials with the recommended consistency for the impression technique were applied in all cases, as stated in the factory recommendation [18]. For the 1SPW technique, a metal stock impression tray was used, with ISO-1 (Express XT Penta H; 3M ESPE), and ISO-3 consistency (Express XT Light Body; 3M ESPE) polyvinylsiloxane (PVS) impression material. The tray was filled with heavy-bodied material, its entire surface was covered with the wash material, and on all of the prepared teeth, an impression syringe was used to inject the wash material [15]. For the MP technique, a custom-made tray prepared by the dental technician from Lightplast Baseplate (Dreve-Dentamid, Unna, Germany) and ISO-2 consistency polyether impression material (Impregum Penta Soft; 3M ESPE) were used [19]. For the proper adhesion of the impression material to the tray, the Polyether Adhesive (3M ESPE) was applied as required by the manufacturer. The mixed impression material was filled into the tray, and all the prepared stumps were injected with an impression syringe.

A metal stock tray and ISO-0 putty consistency PVS impression material (Express XT Penta Putty; 3M ESPE) were used for the two-time impressions, followed by ISO-3 consistency PVS wash material (Express XT Light Body; 3M ESPE). Two different techniques were applied to ensure decompression. In the first case, escape channels were cut in the impression on both mesial and distal sides of each prepared tooth while alternating on the oral and buccal sides of the non-prepared teeth (2SPW-Ch) [16]. In the second case, the surface of the putty material was covered with a polyethylene spacer foil (Impression Separation Wafer GC Europe) to provide the proper gap for the wash material (2SPW-Fo) [20]. In all cases, the impression materials were mixed with the impression mixing machine as recommended by the manufacturer (Pentamix; 3M ESPE) or with a factory impression gun (Garant; 3M ESPE) following the manufacturer's instructions [21].

A PMMA master model was applied in the study because its material did not affect the setting of the materials used in any way. As the model is durable, many impressions could be taken without distortion or change. To the best of our knowledge, the model itself did not affect the results of this study in any way [7,22]. The impression-taking procedure was standardized using a Kaán impression tool [23]. Each tray was filled with impression material to the edge of the impression tray. The same 3 kg weights were used at all impressions. At the Kaán tool, you can position the cast only in one way accordingly. The directions and extent of the force were the same at all impressions, thus standardizing the impression conditions (Fig. 1). The impressions were taken by one calibrated person.

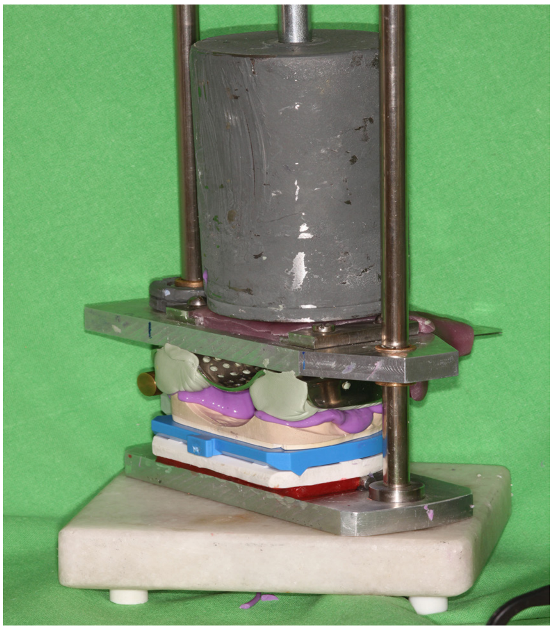
Figure 1. The Kaán impression tool.

In the first step, the master model was scanned by an industrial dot laser scanner (Two Scan; Varinex Informatikai Zrt., Budapest, Hungary), and then the forty prints were scanned as well [24]. As previously recommended, a minimum of 1, a maximum of 24 hours elapsed between the impressions being completed and the scan [25]. After scanning the impressions, the resulting .stl files had to be compiled to allow comparison of the data set with the data set obtained during the master model scan [26].

During the measurement, an incision plane was determined in the virtual space manually, which intersected all the prepared teeth examined. The reference points were determined automatically. The program selected points that could be used as reference points. Both the plane and the reference points were determined only once and were transferred between each measurement. The distances between measurement points were selected on the master model scan to establish the baseline data. Then the corresponding distances on each impression scan were measured and compared to the baseline (Software: Geomagic Verify, Geomagic Inc., Morrisville, NC, USA).

The mesiodistal (MD) and bucco-palatal (BP) diameters of the prepared teeth 14, 21, 24, 27 were measured in the incision plane. Furthermore, distances between 24 distal (24D) and 27 mesial (27M) measuring points (20 mm small distance), between the 24 mesial (24M) and 27 distal (27D) measurement points (32 mm medium distance), and 52 mm large distance between 21 mesial (21M) and 27D were measured [13,27]. GraphPad Prism 5 Software (GraphPad Software Inc., San Diego, CA, USA) was used for statistical analysis. The Kruskal–Wallis Test and Dunn's multiple comparison post-hoc test were applied to examine the correlation between groups, with a significance threshold of $p < 0.05$.

3. RESULTS

Thus, six stump diameters (14BP, 21MD, 24BP, 24MD, 27BP, 27MD) and two distances (medium distance between 24M–27D and large distance between 21M–27D) were analyzed further (Fig. 2). Since the diameters of the stumps fell in the same size range, a common average of the six stump diameters was calculated for better statistical processability. Furthermore, only six instead of the originally planned eight diameters and two instead of three distances were examined. The problem arose when selecting the incision plane: some of the measuring points were in an area with undercuts during the scan. This is a problem, because in the invisible regions, the computer-calculated data were displayed partially, which significantly distorted the measurement results [28]. Therefore, the study did not consider the apparently false results between the 14 MD diameter and the 21 BP diameter and 24D–27M (short distance) [29].

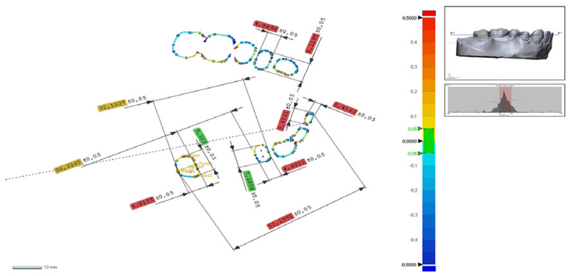

Figure 2. Measurement report. The selected distances and the intersection plane on the master model are shown in the top right corner.

The mean deviation for the six stump diameters was 31.84 µm for the MP impression technique (SD: 28.29), 56.48 µm for the 1SPW (SD 89.07), 74.04 µm for the 2SPW-Fo (SD 157.51), and in the case of 2SPW-Ch, it was 180.64 µm (SD 338.17). Examining the trueness of the stump sampling, we can observe the following trend: the truest was the MP technique followed by 1SPW, 2SPW-Fo, and finally the 2SPW-Ch. In terms of die diameters, MP was significantly truer than 2SPW-Fo and 2SPW-Ch, while 1SPW was significantly truer than 2SPW-Ch. The other differences were statistically not significant (Fig. 3).

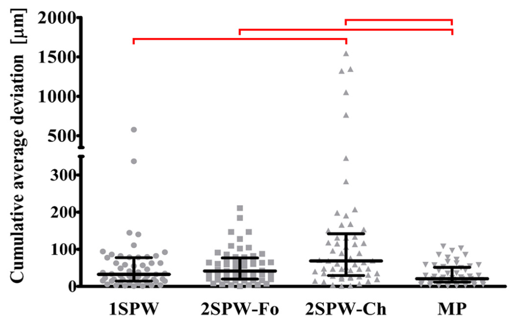

Figure 3. The cumulative average deviation for the six stumps. The red clasp indicates a significant difference ($p < 0.05$).

For the medium distance between 24M and 27D, the trend was the same as found at the level of the stumps. The MP technique proved to be the truest; the deviation from the sample was 42.74 µm (SD: 31.22), followed by 1SPW 71.37 µm (SD: 53.67), 2SPW-Fo 83.46 µm (SD: 57.25), and then 2SPW-Ch 136.47 µm (SD: 61.57). A significant difference was found only between MP and 2SPW-Ch. The other differences were not significant statistically (Fig. 4).

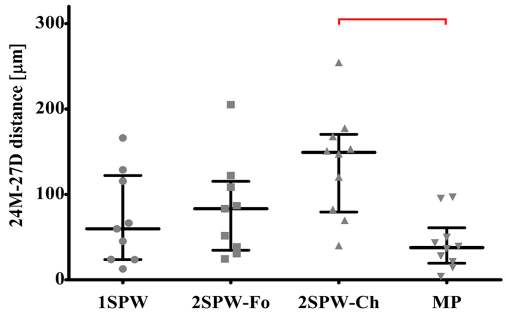

Figure 4. The average deviation for the medium distance. The red clasp indicates a significant difference ($p < 0.05$).

For the large distance between 21M and 27D, the trueness was as follows: the slightest deviation, 162.62 µm (SD: 68.24), was found for 1SPW. This was followed by MP 188.32 µm (SD: 48.48), 2SPW-Fo 286.14 µm (SD: 174.18), and finally 2SPW-Ch 348.85 µm (SD: 122.68). For the 2SPW-Ch technique, both 1SPW and MP proved significantly truer (Fig. 5).

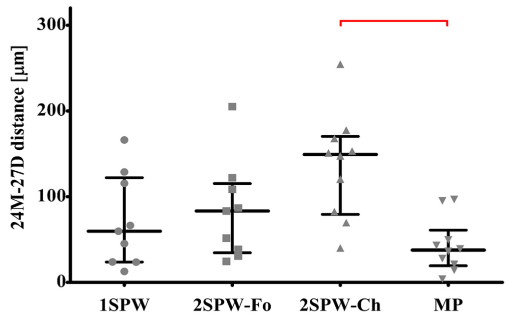

Figure 5. The average deviation for the long distance. The red clasp indicates a significant difference ($p < 0.05$).

4. DISCUSSION

Regarding the sampling trueness of the impressions, the strict deviation of 50 µm only fits the diameters of the stumps, and the medium distance measured between 24M and 27D with the MP impression technique [2]. The trueness of 1SPW with 2SPW-Fo techniques fell outside this range but is well within the most generally accepted trueness of 120 µm for both distances mentioned above [3]. The sampling trueness of the 2SPW-Ch technique shows a difference of more than 120 µm, even in the case of the stump diameter. The distance measured between the stumps increases even more with the increase of the examined length. Concerning long distance, the degree of deviation from the initial sample remained below 200 µm in the case of the 1SPW and the MP techniques, while for the 2SPW-Fo technique, it almost reached 300 µm. However, it does not make sense to use the 120 µm deviation for medium and long distances, since the distances examined are larger by orders of magnitude than for stump diameters. In this case, it is better to express the extent of the deviation in proportion to the distance examined (Table 1).

Table 1. The average deviation for the medium and long distances in percentage.

	1SPW	2SPW-Fo	2SPW-Ch	MP
medium distance	0.222%	0.259%	0.425%	0.133%
long distance	0.311%	0.548%	0.668%	0.360%

Thus, for all the examined distances, except for the largest studied length, the MP technique showed the slightest difference, followed by the 1SPW and the 2SPW-Fo methods, and in all cases, the 2SPW-Ch technique performed the worst. The first and second places were reversed for the largest distance examined.

Pastoret et al. found that the 1SPW technique performed best for short distances, while the MP technique performed best the long distances, but in both cases, the 2SPW-Fo technique remained below them [17]. Rudolph et al. and Luthardt et al. established the order 1SPW, MP, 2SPW with a spacer cap, while Dugal et al. found the 1SPW technique to be more accurate than the 2SPW with spacer cap [13,18,30]. According to Mann et al., the 2SPW-Fo impression technique is more accurate than the 2SPW-Ch technique [16]. These findings are all in accordance with the results published here.

Contrarily, Caputi et al. found a unique 3-phase impression technique to be the most accurate, followed by the 1SPW, and finally, the MP techniques [31]. The discrepancy may be that the MP technique was used with PVS and a stock tray instead of polyether and a custom tray. Nissan et al. found the latter to be the most accurate in both studies when comparing techniques using 1SPW, 2SPW-Fo, and 2SPW with a spacer cap [11,20]. The third technique, which was not examined in the present study, proved to be the most accurate. However, Nissan et al. did not succeed in detecting a significant difference between the 1SPW and the 2SPW-Fo techniques they examined, which coincides with the results presented here. In his study, Nissan used the same ISO 0, putty consistency impression material for all three techniques, which is not ideal for the 1SPW technique. This may be partially responsible for the different results. Jamshidi et al. found the 2SPW-Ch technique significantly more accurate than the 1SPW technique. However, in the one-step technique, the wash material was injected only on the stumps, they did not cover the kneadable base, and both techniques had the same ISO 0 consistency [12].

In the most relevant literature, the simultaneous techniques proved to be more accurate, i.e., less difference can be expected when using them than in the case of separate time impression techniques, except for some less commonly used, individually modified two-step techniques [17,30]. In almost all studies examining two-step techniques, using the 2SPW-Fo technique or 2SPW with spacer cap gave better results than the 2SPW-Ch method [11,16]. All this is in line with the results presented here.

However, there is no consensus on which simultaneous technique provides greater trueness: MP or 1SPW? One important reason for the discrepancy may be that the combinations of impression material and impression tray recommended primarily for the 1SPW and MP techniques were not appropriately used in all studies [11,12,31]. As is well known, the 1SPW impression technique is primarily based on ISO 1 consistency (and not ISO 0, as in several of the studies cited), and a stock tray is recommended. In contrast, for the MP technique, the use of ISO 2 medium consistency material and a custom tray gives the best result [18]. In the latter case, polyether impression material has an advantage over PVS due to its thixotropic effect.

According to our study results, it can be said that the one-step impression techniques performed better. This may be due to the deformation during the replacement of the impression for the second time.

Additionally, the hydraulic distortion, and finally the imperfect connection between the two different consistencies at the two-step impression techniques may account for the better performance of one-step techniques.

Within the limitations of this study, it can be concluded that better clinical results can be achieved using one-step impression techniques, either MP or 1SPW, while preparing fixed prostheses. In the case of using the two-step putty-wash technique, the decompression with only escape channels might be insufficient, leading to hydraulic distortion and inaccurately sitting fixed prosthesis in the end. However, it is essential to note that besides the MP and the 1SPW impression techniques, even the 2SPW-Fo method provides adequate results at the stump level, only 2SPW-Ch proved to be insufficient this level.

5. CONCLUSION

Within the limitations of this study, the hypothesis was confirmed: it was proved that the MP and the 1SPW, i.e., the simultaneous techniques, showed significantly better trueness among the examined precision impression techniques. In contrast, the 2SPW-Ch technique proved to be the most inaccurate at all diameters and distances.

CONFLICT OF INTEREST

The authors have no financial interest in any of the companies whose products are used in this study.

AUTHOR CONTRIBUTIONS

BJ, **SZK**, **MJ** and **JB**: concept. **SZK**, **BV**, **GJK**: protocol. **BJ**, **SZK**, **MJ**, **BV**, **GJK**: data gathered and analyzed. **PH**, **JB**: interpretated and critically revised the manuscript. All authors read and approved the final manuscript.

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Bálint JÁSZ
DMD, Clinical Doctor
Department of Prosthodontics, Faculty of Dentistry
Semmelweis University, Budapest, Hungary

CV

Dr. Bálint Jász, DMD, graduated from the Faculty of Dentistry, Semmelweis University, Budapest, Hungary in 2019. The title of his thesis was: Comparative evaluation of precisional impression techniques. He is currently attending the residency program in Prosthodontics at the Department of Prosthodontics, Faculty of Dentistry, Semmelweis University, Budapest, Hungary. He has been participating in the Digital Dentistry Working Groups since 2017. He has been researching conventional impressions since 2018.

Questions

1. Monophase impression are correctly made with impression material of the following consistency:

❑a. ISO-0;
❑b. ISO-1;
❑c. ISO-2;
❑d. ISO-3.

2. PMMA is ideal for master cast material because:

❑a. It does not affect the setting of impression materials;
❑b. It has a nice color;
❑c. It is sufficiently flexible;
❑d. It hardens heat.

3. In our study, the distances between the following teeth were evaluated:

❑a. “Small distance”: between 24 distal and 27 mesial points;
❑b. “Extra long distance”: between 14 mesial and 27 distal points;
❑c. “Medium distance”: between 24 mesial and 27 distal points;
❑d. “Horizontal distance”: between 14 mesial and 24 mesial points.

4. On the large distance the most true impression technique in our study is:

❑a. One-step putty-wash technique;
❑b. Monophasic technique;
❑c. Two-step putty-wash technique with spacer foil;
❑d. Two-step putty-wash technique with escape chanel.