Clinical Parameters Influencing the Accuracy of 1- and 2-Stage Impressions: A Randomized Controlled Trial

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Purpose: The clinical success of fixed restorations is linked to the precise reproduction of the prepared teeth by dental impressions. The hypothesis under examination was that neither clinical parameters nor the impression technique influenced the reproduction of the finishing line during impression making. ***Materials and Methods:*** For 48 patients who needed a fixed restoration, a 1-stage putty-wash, 2-stage putty-wash, and monophase impression were made after preparation in a randomized order. Clinical parameters (Plaque Index, probing depth, bleeding on probing, Gingival Index, location of the finishing line, bleeding during impression taking, and blood at the impression) were recorded. Master casts were manufactured and optically digitized. Using the data of the 1-stage putty-wash impression as reference, the reproduction of the finishing line was measured 3-dimensionally. Linear models were used for statistical analysis. ***Results:*** The finishing line was reproduced most precisely by the 1-stage putty-wash technique. Variables with significant influence were the impression technique, blood at the impression, and probing depth. The 2-stage putty-wash impressions showed significantly reduced accuracy compared with the 1-stage impressions. ***Conclusion:*** Clinical parameters and the impression techniques determine the reproduction of the finishing line. The benefit of 2-stage putty-wash impressions with regard to a more complete rendering of subgingival finishing lines should be questioned in light of these results. *Int J Prosthodont 2008;21:322–327.*

Among other factors, the dental impression determines the fit of fixed restorations.[1–4] Imprecision during impression making is difficult to correct in subsequent manufacturing procedures for dental restorations and influences internal and marginal fit[3] as well as occlusal precision.[1,5,6] Thus, flaws of the impression often cause repetition of the impression and, in the worst case, remake of a restoration.

In the literature, threshold values, which indicate that a restoration must be redone, differ depending on whether in vitro studies[7,8] or clinical studies[6,9,10] are taken into consideration. Based on in vitro studies, 1-stage impressions showed predominantly superior accuracy compared to 2-stage impressions.[11–13] The marginal gap significantly influenced the severity of gingivitis in a retrospective study of crowns placed an average of 8.6 years ago. No correlation was found regarding marginal gap and probing depth.[10] The preparation line was pointed out as the weak spot of impression taking in a quantitative data analysis of patients participating in a randomized controlled trial. The impression technique and the location of the preparation line significantly influenced the precision.[5] A clinical trial investigating the influence of the design of the preparation (chamfer, 135-degree shoulder, and 90-degree shoulder) emphasized the relevance of clinical parameters.[6] To date, there is a lack of studies analyzing the influence of clinical aspects (eg, position of the finishing line, gingivitis, oral hygiene) and impression tech-

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Figs 1a and 1b **(a)** First very fine retraction cord placed below the finishing line. **(b)** Second nonsoaked retraction cord placed loosely onto the first cord.

niques on the precision of prepared teeth's impression. The specific aim of this randomized controlled trial was to test the null hypothesis that neither clinical parameters nor the impression techniques (1-step putty-wash, monophase, and 2-step putty-wash techniques) influence the reproduction of the finishing-line.

Materials and Methods

In this randomized controlled trial, a monophase, 1-step putty-wash, and 2-step putty-wash impression (MP, OS, and TS) were made of 48 patients each during therapy with single crowns or short-span fixed partial dentures. The procedure was tested in a pilot study with 9 additional patients. These data were not included in the study. Patients were included in the study if the teeth to be prepared showed probing depths ≤ 4 mm (Paro Audio-Probe, Esro) and tooth mobility ≤ Class II. Pregnant women, patients with severe general illnesses according to Kapur et al,[14] and patients with alcohol or drug addiction were excluded. After obtaining informed consent, a clinical examination (Plaque Index [PI] according to Silness and Loe,[15] probing depth [PD], bleeding on probing [BOP], and Gingival Index [GI] according to Loe and Silness[16]) was performed at least 1 appointment before preparation of the abutment teeth. A force control probe (Paro Audio-Probe, Esro) was used for periodontal measurements. The preparation was carried out by dental clinicians or by students in clinical training. PI, PD, BOP, GI, and the location of the finishing line were measured at 6 locations (sextants) before the impressions were made. During and after the impression making, further findings were gathered (bleeding during impression taking, blood at the impression). The order in which the impressions were made was assigned on a randomized basis for each patient using a randomization list with groups of 6 generated by the Department of Medical Informatics and Biometry. All impressions and clinical examinations were made by one of the authors (RGL). The investigator was trained by the head of the Department for Periodontology at the outset of the study. The impression materials used were polyvinyl siloxanes (PVS) for OS and TS and polyether for MP. The stock impression trays for the MP and OS techniques were stopped with silicone (Optosil, Heraeus-Kulzer). Retraction cords (size 0, Ultrapak, Ultradent) soaked with aluminum chloride (ORBAT, lege artis Pharma) were laid circularly if the finishing line was not at least 0.5 mm above the gingival margin (Fig 1a). In all cases, a second, nonsoaked retraction cord (size 1) was placed loosely onto the first (Fig 1b).

For the OS technique, the impression tray was filled with a medium-body PVS (Dimension Penta H, 3M ESPE), and simultaneously, the prepared teeth followed by the occlusal surfaces of the unprepared teeth were syringed with a light-body PVS (Dimension Garant L, 3M ESPE). For the MP technique, the prepared teeth and then the occlusal surfaces of the unprepared teeth were syringed, and the tray was filled with the polyether impression material at the same time (Impregum Penta, 3M ESPE). For the primary impression of the TS technique, the tray was filled with a heavy-body PVS (Dimension Penta H Quick, 3M ESPE) and seated immediately into the mouth. Septa and undercuts were removed, and drains were cut in to improve the material flow of the low-viscosity material. For secondary impressions, the primary impression was first filled with a light-body PVS (Dimension Garant L Quick, 3M ESPE), except for the prepared teeth, which were subsequently syringed with light-body impression material. The tray was seated immediately and pressed

Fig 2 One-step impression made with stock tray that was stopped with silicone.

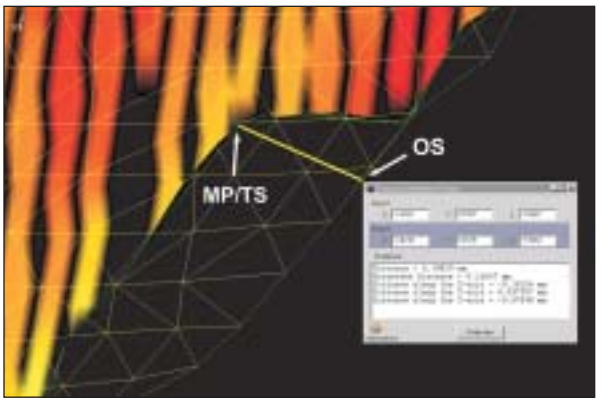


Fig 3 Detail of the aligned data sets of 1 prepared tooth showing 1 of 6 measuring locations. The yellow line indicates the distance between the automatically generated finishing lines of either monophase or 2-stage impressions (yellow to red color-coded digital representation of the tooth gained) compared to 1-stage impressions (green triangular mesh digital representation of the tooth gained).

against the teeth. Impressions were removed 6 minutes after the start of mixing (Fig 2). None of the impressions were repeated, regardless of their clinical quality.

The master casts were manufactured following a standardized protocol according to the Zeiser process 4 hours after impression making with type IV improved stone (batch: 21105043 apricot, Esthetic-rock, Dentona). The master casts were measured with a high-resolution optical digitalization system (ODKM97, IVB; measurement uncertainty as given by manufacturer: ≤ 8 µm) within 24 to 48 hours after preparation. First, the socket with only the die representing the prepared tooth was digitized. After adding the dies of the neighboring teeth to the socket, it was digitized once more. The resulting data sets were processed by a visualization and handling software (ARGUS, Fraunhofer Institute for Applied Optics and Precision Mechanics) and a design and analysis software (Surfacer, Imageware).[5,17] The reproduction of the finishing line was chosen as the primary outcome measure. To calculate the 3-dimensional deviations between the finishing lines gathered from the 3 impressions, boundary curves of each finishing line were generated automatically (Surfacer).[5] For each patient, the data sets of MP and TS were aligned to the data set of reference OS (best-fit registration feature of Surfacer). An exact alignment is mandatory for the analysis of the impression accuracy. The precision of the alignment was evaluated by calculating the root mean square of the deviations (RMS error).

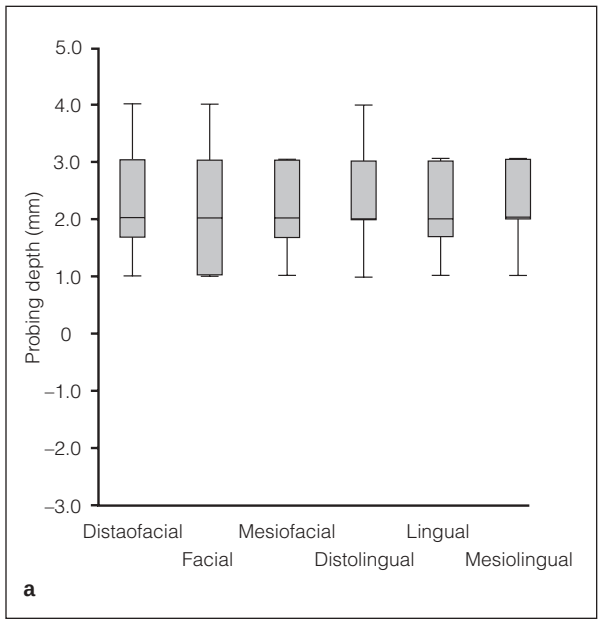
For each of the sextants (ie, 6 measuring locations surrounding the prepared tooth), the largest deviations between the finishing lines of MP and TS compared to OS were measured centripetally to the prepared tooth (Fig 3). By definition, positive values indicated a more complete reproduction of the finishing line by the reference impressions, and negative values indicated a more complete reproduction of the finishing line by either MP or TS.

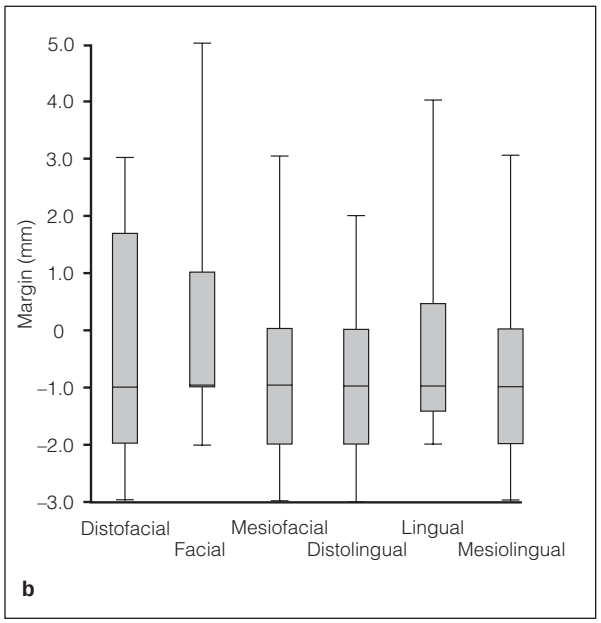
Linear models were used for statistical analysis. Scientifically optimal models were developed by stepwise reduction. Compound symmetry was assumed for the covariances between the observed values for 1 patient (ie, all values were seen as intraindividually correlated). All average value comparisons were based on Tukey-adjusted contrasts with a global significance level of .05. The assumed approximate normal distribution of the target variables could be assumed from a theoretical consideration of the methodology. The calculations were made with the SAS procedure MIXED (SAS).

Results

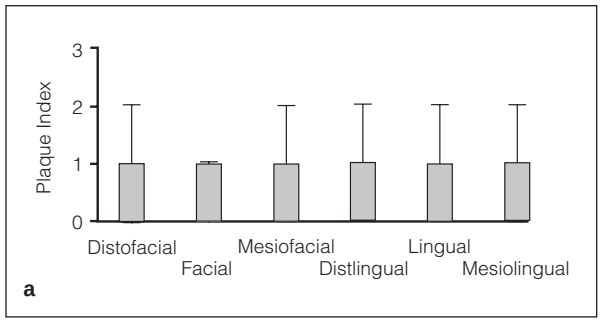
Forty MP, 42 OS, and 41 TS impressions that were taken mainly from prepared molars (followed by premolars) were evaluated. The impressions of 6 patients could not be evaluated because of insufficient quality of the OS's digital data used as reference. The clinical examination showed a median PD of 2 mm (Figs 4a and 4b), median PI of 0 (Fig 5), and median GI of 1, independent of the sextant (Figs 5a and 5b). The median position of the finishing line was located 1 mm below the gingival margin. The average RMS error was 14 µm with the MP technique and 17 µm with the TS technique and showed no significant differences.

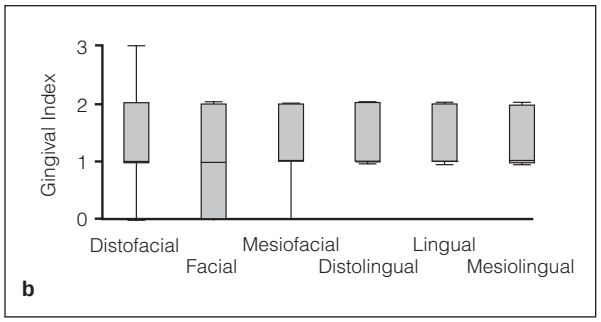
The finishing line was reproduced more completely by OS than by MP and TS, as shown by the positive medians of the measured differences. Maximum and minimum values as well as the 10th and 90th percentiles are shown in Figs 6a and 6b. Comparing the medians calculated for the facial and lingual sextants, only slight differences between OS and MP (facial: 31 µm;





Figs 4a and 4b Boxplots for probing depth **(a)** and location of finishing line below the gingival margin **(b)**. Medians, minima, maxima, and 10th and 90th percentiles are shown.





Figs 5a and 5b Boxplots for Plaque Index **(a)** and Gingiva Index **(b)**. Medians, minima, maxima, and 10th and 90th percentiles are shown.

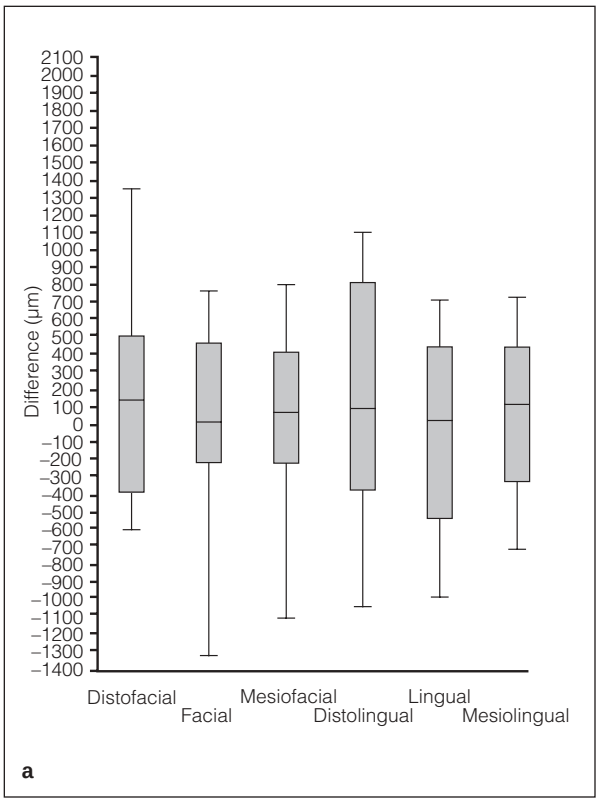
lingual: 14 µm) were found. Except for the distofacial sextant, MP reproduced the finishing line more completely than TS. The largest deviation of the median was determined for the distolingual surface when the TS technique was used (difference = 189 µm).

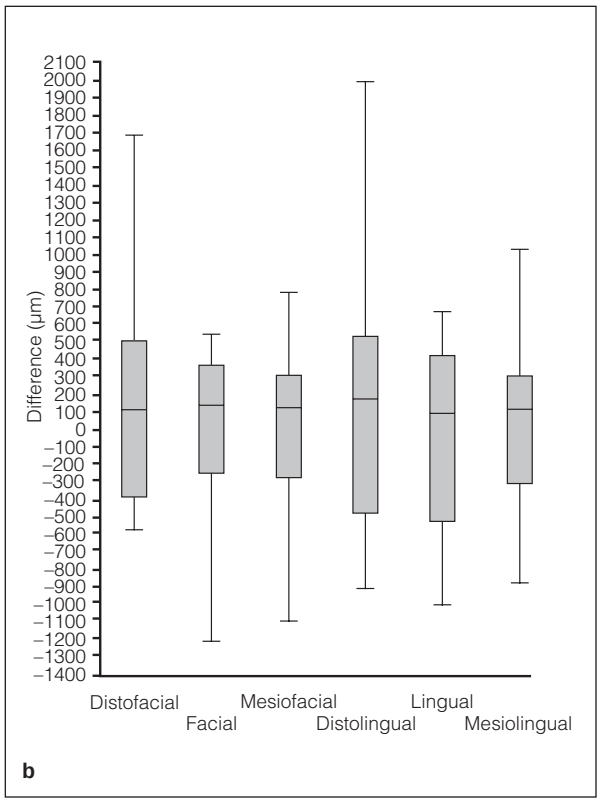
The reproduction of the finishing line was significantly influenced by the impression technique ($P = .0248$), blood at the impression around the prepared tooth ($P = .0349$), and the PD in the sextant ($P = .0358$) (Table 1). In contrast to the reproduction of the finishing line, which was negatively influenced by inflammation of the gingiva, a lesser PD was not connected to a better reproduction of the finishing line. The MP technique reproduced the finishing line significantly more completely than the TS technique (Table 2). Generally, impressions made second or third reproduced the finishing line more completely. The finishing lines were reproduced less completely by MP and TS at distal surfaces as well as at sextants with inflamed gingiva (Table 2).

Discussion

The OS technique was chosen as the reference because of its superior in vitro results. Three-dimensional analysis processes are based on the comparison of digital data.[5,17–19] The high-precision alignment of the data sets of different objects to be compared is mandatory to achieve reliable results. The RMS error is an assessment of the quality of alignment.[20] The results found for the alignment of the digital data of MP and TS to the data sets of OS only slightly exceeded the threshold value of 10 µm, thus representing excellent alignment precision as stated by Peters et al.[19]

The automatic generation of boundary curves from the digital data ensures that the curves are actually representing the finishing line. During the cast preparation, small plaster pearls or apparent defects in the area of the finishing line were removed and blackened to prevent digital data collection of these flaws.[5] While in





Figs 6a and 6b Comparison of the differences between the finishing line reproduced by the 1-step putty-wash impressions (reference) and the monophase **(a)** or 2-step putty-wash impressions **(b)**.

Table 1 Results of the Linear Regression Analysis for Reproduction of the Finishing Line for the Model with Optimum Fit

Factor/covariable	Adjusted *P* value
Impression technique	.0248
Repetition of the impression (period)	.3696
Sextant	.0951
Blood at the impression around the prepared tooth	.0349
Probing depths at the prepared tooth	.0358
Gingival Index at the prepared tooth	.0646

Table 2 Effects of Different Factors and Covariables on Reproduction of the Finishing Line (µm)*

Factor	Estimated least squared means
Impression technique	
Two-step putty-wash	26.54
Monophase	–54.53
Period	
First impression	24.35
Second impression	–27.06
Third impression	–39.28
Locus	
Distolingual	54.41
Distofacial	20.89
Mesiolingual	–3.13
Mesiofacial	–8.77
Lingual	–92.23
Facial	–55.15
Blood at the impression	
Yes	82.27
No	–110.30

*Negative values indicate a more complete reproduction of the finishing line.

daily clinical practice most of these impressions would have to be repeated, they were included in the evaluation since the study's goal was to determine the precision and reliability of the impression techniques. Conventional methods used to determine the marginal quality are limited at the proximal areas of restorations where the largest deviations were found.[10] Procedures qualified for 3-dimensional analysis can overcome such restrictions.

The null hypothesis that the reproduction of the finishing line does not vary depending on the impression techniques and clinical parameters was rejected. Using individualized metal stock trays and the double retraction cord technique, the finishing line was reproduced more completely by the OS technique at all sextants compared to the MP and TS technique. These results support the Guidelines of the British Society for Restorative Dentistry,[11–13] which prefer 1-stage techniques to 2-stage techniques. The first retraction cord, which remained in situ in the majority of cases, limited the flow of light body impression material into the sulcus using the the TS technique. Condensation silicones recommended for TS technique[21] were not taken into account in this trial because of the lack of storage stability and handling disadvantages of these materials, which would have resulted in limited comparability of the results.

When judging an impression clinically, blood at the surface of the abutment teeth is a reliable predictor for an incomplete reproduction of the finishing line. A higher PD is a significant predictor for a more complete reproduction of the finishing line, whereas gingivitis at the abutment teeth results in a tendency for a less complete reproduction of the finishing line. Since lower PD is linked to gingival health, these findings appear to be contradicting. A possible explanation for this effect is a lack of connection of the long epithelial attachment after periodontal treatment compared to healthy gingiva showing low PD. This agrees with the clinical experience that making impressions of young patients with healthy gingiva and a subgingival preparation line can be a challenging task.

Conclusion

Within the limitations of the study, it can be concluded that the finishing line is best reproduced by the 1-step putty-wash technique, followed by the monophase technique and the 2-step putty-wash technique. Blood at the impression at abutment teeth is a predictor of a poorer reproduction of the finishing line. Clinical parameters and the impression techniques determine the reproduction of the finishing line. The benefit of 2-stage putty-wash impressions with regard to a more complete rendering of subgingival finishing lines should be questioned in the light of this study's results.

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