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Original article

Freehand vs. depth-gauge rotary instruments for veneer preparation: A controlled randomized simulator study

M. Oliver Ahlers [a,b,*], Georg Cachovan [c,d], Holger A. Jakstat [e], Daniel Edelhoff [f], Jakob C. Roehl [g], Ursula Platzer [h]

[a] Department of Prosthetic Dentistry, Center for Dental and Oral Medicine, University Medical Center Hamburg-Eppendorf, Hamburg, Germany, [b] CMD-Center Hamburg-Eppendorf, Hamburg, Germany, [c] Oral Healthcare DACH, Philips GmbH, Hamburg, Germany, [d] Department of Periodontics, Preventive and Restorative Dentistry, University Medical Center Hamburg-Eppendorf, Hamburg, Germany, [e] Department of Prosthetic Dentistry and Dental Materials and Special Care, Center for Dental and Oral Medicine, University of Leipzig, Leipzig, Germany, [f] Department of Prosthetic Dentistry, University Hospital LMU Ludwig-Maximilians, Munich, Germany, [g] CMD-Center Hamburg-Eppendorf, Hamburg, Germany, [h] Department of Periodontics, Preventive and Restorative Dentistry, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

Abstract

Purpose: To investigate whether depth-gauge burs in veneer preparations influence preparation depth in a randomized, controlled, single-blinded trial and whether inexperienced operators can perform adequate veneer preparations.

Methods: Participants were 20 undergraduate dental students with no prior veneer preparation experience. The instruments used were the “Laminate Veneer System” (LVS), “Keramik-Veneers. de” (KVD), and a “Freehand” group (FH) for reference. All participants prepared three educational acrylic resin maxillae and three mandibular central incisors mounted in typodonts in patient simulators. The objectives were to achieve a preparation depth of 0.6 mm (tooth 11) and 0.4 mm (tooth 31). The sequences of the instruments used and prepared teeth were randomized. The measurements were performed using a laser triangulation coordinate-measuring machine. The data were stratified according to tooth location.

Results: The preparation depths of both depth-gauge-instrument-groups LVS and KVD achieved the objectives significantly better than did the instruments from the “Freehand” group ($P < 0.001$). The differences between the depth gauge groups were insignificant, although the maximum preparation depths were smaller in the KVD group. Regarding the prepared teeth, the preparation depths in the mandibular incisors were lower, and the differences were smaller.

Conclusions: The use of special depth-gauge burs for initial veneer preparation leads to significantly lower preparation depths than “Freehand” preparations. The tapered instruments resulted in a lower incidence of extreme preparation depths. The inexperienced operators performed veneer preparation remarkably well.

Keywords: Ceramic veneers, Tooth preparation, Preparation depth, Depth-gauge dental instruments

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1. Introduction

Ceramic or porcelain laminate veneers have been established as conservative treatment methods for restoring teeth affected by discoloration, surface defects, extended wear, fracture, malformation, or misalignment[1–3]. Reviews of clinical studies have confirmed the longevity of this type of restoration[4–7]. Furthermore, several factors have been determined to influence survival rates, including the restorative materials and adhesive techniques used[5,8], patient-related factors[9], and preparation design[6,10–15]. However, professional experience did not influence the outcome in earlier[9,16] and recent clinical trials[9,16].

Studies examining the influence of preparation design on ceramic veneer longevity have focused on the effect of preparation on marginal integrity[5,8,10,15,17,18] or fracture resistance[8,15,17,19–21]. These results are confirmed by long-term clinical studies covering large numbers of veneers, which indicated a significant effect of the preparations´ limitation to the enamel labial and at the margins on the longevity of the veneers[11,12,22].

In the following, new “second-generation” veneer preparation techniques were established to avoid unnecessary enamel loss by offering guidance based on silicone indexes generated from additive wax-ups[23]. One study investigated the preparation depths of this indexing technique[24], compared to classical “first-generation” veneer preparations, using depth marking instruments. The authors suggested that the use of a silicone index or depth-gauge burr should be considered when preparing teeth for ceramic veneers. A “third-generation veneer preparation technique evolved based on the placement of a mock-up and subsequent preparation of the mock-up and tooth structure[24]. Based on this evolution of preparation techniques, depth-gauge burs remain necessary for first- and third-generation preparation techniques, and there is no advantage in the use of a silicone index alone.

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***Corresponding author:** M. Oliver Ahlers, Department of Prosthetic Dentistry, Center for Dental and Oral Medicine, University Medical Center Hamburg-Eppendorf, Falkenried 88, 20251 Hamburg, Germany.
E-mail address: Ahlers@UKE.de

Nevertheless, few authors have investigated the influence of preparation instruments on the ability of clinicians to prepare teeth with the desired shapes. Studies on master casts based on clinical impressions indicate that tooth preparation guidelines are often disregarded[2]; in many cases, the teeth are either over-or unprepared[3]. Nattress *et al*. examined back in 1995 the results from "freehand" preparations of maxillary central incisors for ceramic veneers without the use of dedicated depth gauge burs. The preparations were performed by experienced clinicians, aiming for a uniform reduction in labial thickness of 0.5 mm[1]. The study found significant differences in the preparation depth at different sites, with the least reduction in the mid-incisal region. The most extensive reduction was observed at the cervical and proximal margins, where the dentin areas were exposed in most teeth. This appears to be clinically relevant, as studies have indicated that dentin exposure at the margins of veneer preparations may lead to increased marginal (micro) leakage at the composite resin/dentin interface[25]. Cherukara *et al*. assessed the influence of different clinical techniques on the depth of veneer preparations and the incidence of dentin exposure[26–28]. In these studies, a single operator prepared the extracted maxillary central incisors using the dimple, depth groove, and freehand preparation methods, aiming for preparation depths between 0.4 and 0.6 mm. The results revealed considerable intraindividual variation. Brunton *et al*. compared the preparation depths achieved after initial preparations using depth-gauge burrs with freehand preparations and preparations guided by a silicone index[29]. Again, all preparations were performed *in vitro* by a single operator on the typodontic maxillary central incisors. As cited above, the authors determined that the results obtained after the initial preparation using conical depth-gauge burs were equivalent to those based on a silicon index. However, only one depth gauge instrument was used in this study.

Consequently, no evidence is available regarding the effects of cylindrical or conical depth markers. Furthermore, the available evidence relates solely to studies conducted by experienced individual investigators preparing handheld central maxillary incisors. Clinically, mandibular incisors are treated with veneers and are more challenging to access intraorally. Finally, not all practitioners who treat incisors with veneers are as experienced as the operators in the few available studies. Overall, the available evidence on the effect of preparation instruments on the quality of veneer preparations is scarce. This is surprising, as clinical studies have determined that adherence to the recommended preparation depth is critical for the longevity of ceramic veneers. Long-term survival strongly depends on all preparation margins placed in the enamel, with only limited dentin exposure[4,10–12].

Hence, the present study aimed to investigate the depth and consistency of veneer preparations in maxillary and mandibular incisors using different depth-gauge burs, preparation systems, and matching rotary instruments in a controlled setup that eliminated the influence of clinician bias and experience. The null hypothesis was that using different depth-gauge burrs to initiate veneer preparations would not result in any differences in the preparation depth.

2. Materials and Methods

2.1. Study design

This study was conducted as a controlled, randomized, single-blind simulator trial. **Figure 1** illustrates a CONSORT-compatible chart of the participant flow. Twenty undergraduate dental students prepared three educational acrylic resin teeth using one of two special veneer preparation instruments or prepared \`freehand\` using classic tapered rotary instruments. This study was approved by the ethics committee prior to its implementation. Due to the anonymization of students, the ethics committee formally decided that no ethics vote was required for this study.

2.2. Participants

The participants were 20 final-year undergraduate dental students from the University of Hamburg School of Dental Medicine in their final year. The participants had no prior experience with veneer preparation or placement. All students attended the same veneer preparation training. The detailed step-by-step instructions are provided below. The students voluntarily participated in the training and study. All results were recorded anonymously and thus rendered untraceable to individual students.

2.3. Preparation designs and instruments

The instructions for conservative veneer preparation were slightly modified from a previously published concept[30]. The method should allow for a ceramic thickness of 0.6 mm in the maxilla[31] and 0.3 to 0.4 mm in the mandible, as required for state-of-the-art ceramic materials[32]. Cutting of dentin should be avoided, particularly at the margins. The preparations should extend as far interproximal as possible to make the margins clean, and sharp internal line angles should be avoided as potential areas of stress concentration. Finally, the veneer insertion path should be free of undercuts. To achieve these goals, preparations began by cutting shallow orientation grooves using different depth markers provided for the depth marker groups LVS and KVD. In the "Freehand Group" (FH) the orientation grooves were prepared freehand using the smaller tapered diamond burs with the premise, to cut the teeth to approximately the required depths. In all the groups, this was followed by contouring of the preparation and smoothing of the surface using finishers provided by each set of rotary instruments.

Three sets of rotary instruments were used (**Table 1**).

1. FH ("Freehand"): comparable to Nattress *et al*.[1], the participants prepared freehand incisors using chamfered diamond burrs. The instruments were tapered, and the respective finishers were used (**Fig. 2A**).

2. LVS ("Laminate Veneer System)": the instruments of Set #4151 LVS (Laminate Veneer System, Brasseler USA) / CVS (Ceramic Veneer Set, Komet Dental, Germany)) have been described elsewhere[33,34]. The set includes two cylindrical depth-gauge burs (cutting depths: 0.3 and 0.5 mm), specially tapered two-grit diamond burs in two sizes (featuring a coarse grit for axial reduction and fine grit for incisal finishing), as well as various finishers for restorations margins after setting (**Fig. 2B**)[33].

3. KVD ("Keramik-Veneers.de"): The instruments of Set #4388 (Komet Dental, Lemgo, Germany) included two tapered ellipsoid-ended depth-gauge burs (cutting depths:0.3 and 0.4 mm), matching tapered diamond instruments in two sizes and two matching finishers (**Fig. 2C**).

In addition to controlling the depth of preparation, no additional silicone indices were used to control the depth of preparation

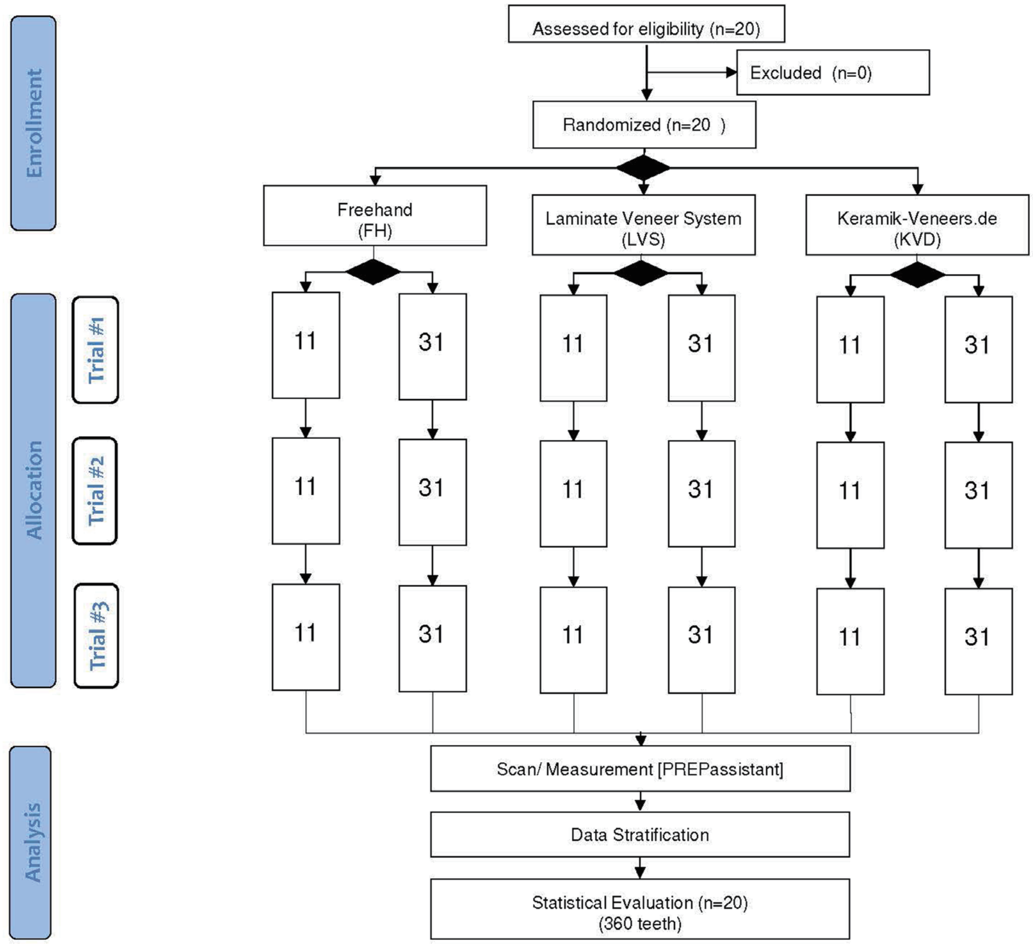

Fig. 1. Flow chart illustrating the setup of the investigation trial (black rhombus indicates randomizations)

Table 1. Description, composition, and manufacturers of the three different sets of rotary instruments employed in the study (all instruments by Komet Dental, Lemgo, Germany)

1. **FH ("Freehand")** tapered chamfered ended diamond burs only
868 tapered rounded diamond bur small size 012
868 tapered rounded diamond bur large size 016
8868 tapered rounded diamond finisher small size 012
8868 tapered rounded diamond finisher large size 016
2. **LVS "Laminate Veneer System"** Instruments from the Set No. 4151
834 cylindrical depth gauge bur "LVS-1" (depth gauge 0.3 mm) size 016
834 cylindrical depth gauge bur "LVS-2" (depth gauge 0.5 mm) size 021
6844 tapered two-grit diamond bur "LVS-3" (fine/coarse grit) size 014
6844 tapered two-grit diamond bur "LVS-4" (fine/coarse grit) size 016
3. **KVD "Keramik-Veneers.de"** Instruments from the Set No. 4388
868B depth gauge bur (depth gauge 0.3 mm) size 018
868B depth gauge bur (depth gauge 0.4 mm) size 020
868 tapered rounded diamond bur small size 012
868 tapered rounded diamond bur large size 016
8868 tapered rounded diamond finisher small size 012
8868 tapered rounded diamond finisher large size 016

to ensure that the results solely reflected the effect of the different rotatory instruments.

2.4. *Typodont teeth and patient simulators*

Educational acrylic Typodo teeth were selected (KaVo Dental, Biberach, Germany) and encoded prior to preparation. The codes were recorded in tabular form, with tables available only to the supervisor. The teeth were mounted on compatible typodonts fixed in patient simulators (Frasaco, Tettnang, Germany). The typodonts and simulators were the properties of the School of Dentistry's undergraduate program. The prepared teeth included a right maxillary central incisor (tooth 11, FDI) and a left mandibular central incisor (tooth 31, FDI). Each of the 20 participants prepared three maxillary and three mandibular central incisors using three sets of rotary instruments. A total of 360 typodontic acrylic teeth were prepared in a simulated clinical setting.

2.5. *Randomization and Measurement*

The sequence of the prepared teeth (maxillary or mandibular teeth first) was randomized, as was the sequence of the instruments employed (**Fig. 1**). If participants regarded the preparation as unsuccessful and requested a replacement for repeating a task, no other teeth were provided.

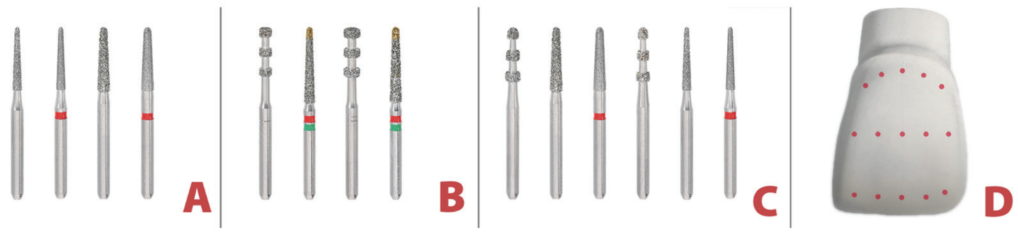

Fig. 2. Rotary Instruments of the groups "Freehand"–a part of Set 4388 (A); "Laminate Veneer System" - Set 4151 (B); "Keramik-Veneers.de" Set 4388 (C); and an Illustration of preparation design indicating 15 sites where preparation depths were recorded on central *maxillary* incisors. Recordings on *mandibular* incisors were made accordingly (D).

The teeth were measured before and after preparation using a coordinate measuring machine (CMM) based on laser triangulation (PREPassistant; KaVo Dental, Biberach, Germany) to assess the preparations. According to the manufacturer, the system's measurement accuracy is 20 µm. The preparation depths were recorded at 15 locations, including nine locations previously suggested in a preliminary expert study by Nattress *et al.*[1].

• Vertically at 1 mm from the incisal and cervical margins and in the middle

• Horizontally 1 mm from the mesial and distal finishing edges and in the center (midline)

• Halfway between the mesial and distal locations and the middle (**Fig. 2D**).

Altogether, this resulted in 5,400 depth measurements. The encoding of the teeth and tables was not available to the staff during the measurements. Consequently, the evaluators were blinded and could not attribute the prepared teeth to individual participants, or the specific instrument used in the preparation sequence. Only after the measurements were obtained were the data regarding the anonymous operators, instruments used, and location of the measuring spot unveiled.

In the following evaluation, the results were initially analyzed for each of the three groups: FH, LVS, and KVD (Section 3.1). The results were subsequently analyzed for the prepared teeth (Section 3.2) and measuring sites, both vertical (Section 3.3) and horizontal (Section 3.4). Of the five horizontal measurement sites, only three were evaluated to limit the amount of available information. Data from the sites halfway between the mesial and distal locations and the middle were not assessed, reducing the number of measurement sites from 15 to nine.

2.6. Statistical evaluation

For statistical evaluation, the data were analyzed using SigmaStat 3.5, a statistical software application (Systat, San Jose, CA, USA), initially using the Shapiro-Wilk normality test, followed by Student's t-test, if applicable, or the Mann-Whitney-U-test/Wilcoxon rank sum test.

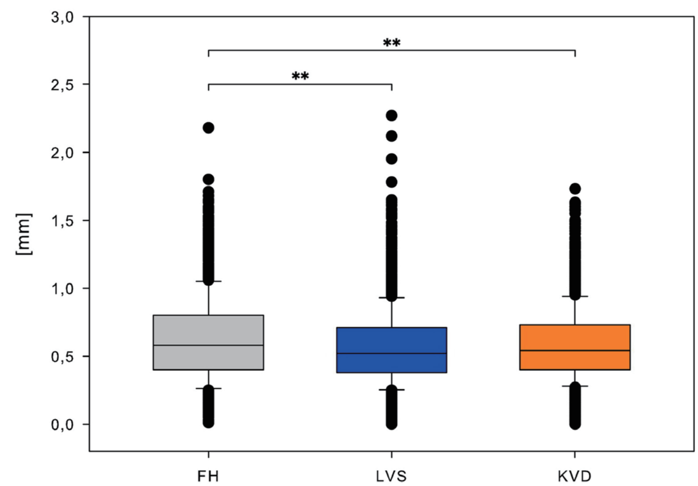

Fig. 3. Comparison of preparation depths of three groups on all teeth in all sites. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

3. Results

3.1. Results by instrument groups

The results of this study are presented in **Figure 3**. The differences in medians between the freehand reference group FH and the *depth-gauge* bur groups LVS and KVD were significant ($P < 0.001$). The difference in the median values between the two depth-gauge burr groups, LVS and KVD, was not large enough to exclude the possibility that the variation was due to random sampling ($P = 0.067$). However, the maximum preparation depths in the FH group (2.18 mm) and in the LVS group (2.27 mm) exceeded those in the KVD group (1.73 mm) to a clinically relevant extent.

3.2. Group results by tooth

The results for all *maxillary* incisors followed the same distribution as the general results (**Fig. 4 and Table 2**). Again, the difference in median values between the reference group FH and the depth gauge groups LVS and KVD was significant ($P < 0.001$). In contrast, the difference between the two depth gauge groups (LVS and KVD) was not significant ($P = 0.888$). In comparison, the depth results for all *mandibular* incisors were lower. The distribution of results was different, showing significant variations in the median values between FH vs. LVS ($P = 0.002$) and LVS vs. KVD ($P = 0.003$). As for the instrument groups in total, the maxima of maxillary and mandibular incisors

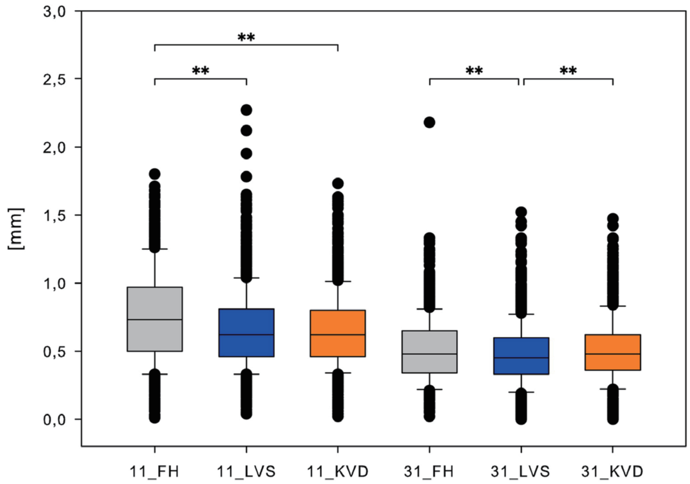

Fig. 4. Comparison of preparation depths for maxillary, mandibular incisors in all sites. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

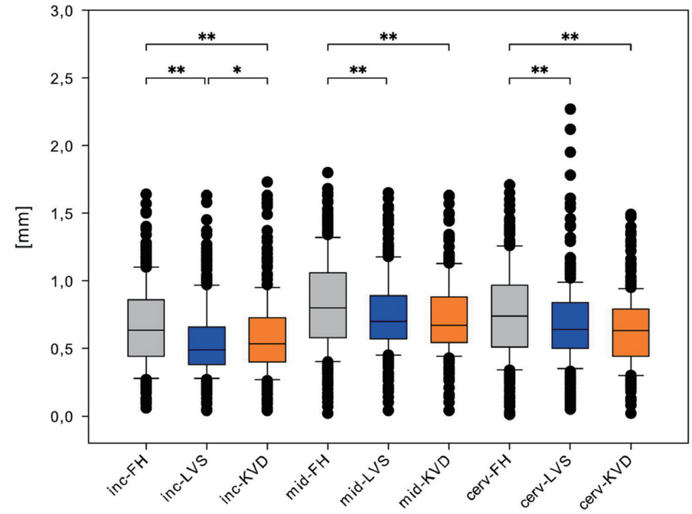

Fig. 5. Preparation depths for maxillary incisors in vertical stratification with separate measures for incisal, middle, and cervical sites. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

Table 2. Means and median preparation depths regarding the teeth prepared (FDI No. 11 and 31) and subdivided into the groups Freehand (FH), Laminate Veneer System (LVS), and Keramik-Veneers.de. (KVD) [mm]; aims were 0.6 (tooth #11) and 0.4 (tooth #31), respectively.

Prepared tooth	11			31		
	FH	**LVS**	**KVD**	**FH**	**LVS**	**KVD**
Mean	0.75	0.66	0.65	0.58	0.47	0.5
Median	0.73	0.62	0.62	0.48	0.45	0.48
Std. Dev.	0.34	0.3	0.28	0.24	0.24	0.24

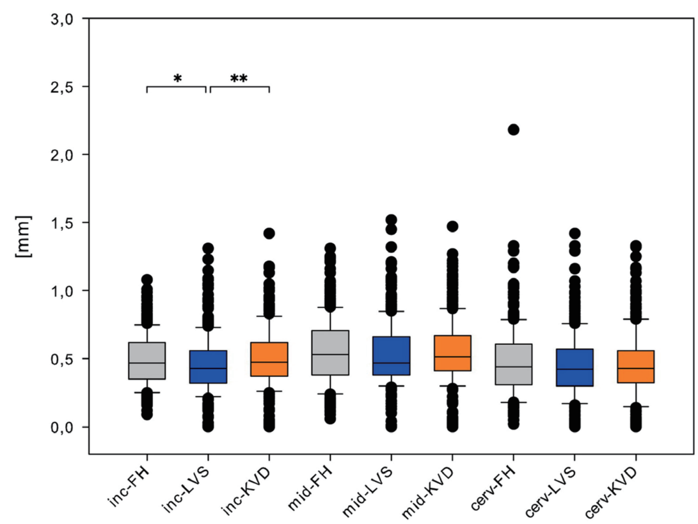

Fig. 6. Preparation depths for mandibular incisors in vertical stratification with separate measures for incisal, middle, and cervical site. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

were lowest in group KVD (1.73 mm in maxillary incisors and 1.47 mm in mandibular incisors).

3.3. Results by group and by the tooth in vertical relation

Figure 5 shows the depth results for *maxillary* incisors in the vertical stratification measured incisally, mid-section, and cervically. The medians differed significantly between the FH, LVS, and KVD groups at all sites. In contrast, the differences in the medians between the two depth-gauge burr groups, LVS and KVD, were insignificant except in the incisal region. Notably, the maximum cervical values were considerably higher in the LVS group (2.27 mm) than those in the FH (1.71 mm) and KVD (1.49 mm) groups.

Figure 6 shows the depth results for *mandibular* incisors in the vertical stratification. Only the incisal region showed significant differences in median values between the FH and LVS groups and between the LVS and KVD groups. Again, an extreme depth was observed in the FH group (2.18 mm).

3.4. Results by group and by the tooth in horizontal separation

Figure 7 shows the depth results for all *maxillary* incisors in the horizontal stratification measured between the mesial and distal edges. The difference in the medians between the FH and LVS groups was also significant ($P < 0.001$), as was the difference between the FH and KVD mesial and middle groups. No significant difference was observed in the distal aspect ($P = 0.518$).

Figure 8 illustrates the individual results for all *mandibular* incisors during horizontal stratification. Again, the differences in medians were significant between groups FH and LVS for the mesial ($P = 0.004$) and distal ($P = 0.019$) edges, as well as between groups FH and KVD ($P = 0.020$ and $P = 0.028$, respectively), whereas no significant difference was observed for the center only (FH and LVS as well as FH and KVD, both $P = 0.962$).

4. Discussion

In general, the results of this study indicate that preparation depths in the two groups using depth-gauge diamond burs (LVS and KVD) were significantly less invasive than preparation depths in the freehand technique group (FH). Therefore, the null hypothesis was rejected.

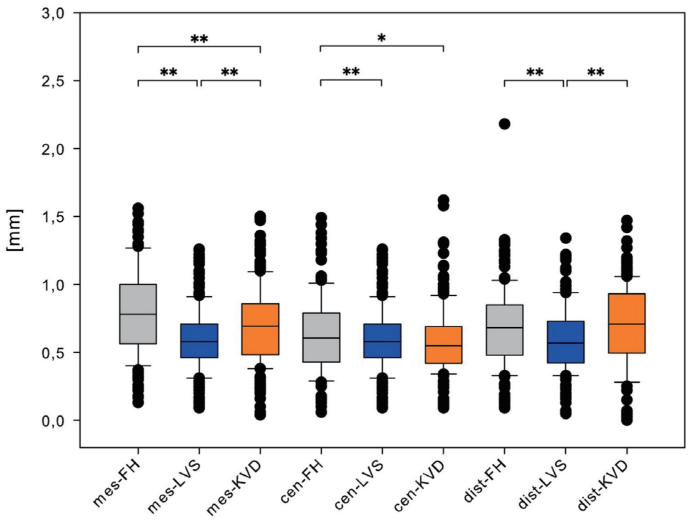

Fig. 7. Preparation depths for maxillary incisors in horizontal separation with separate measures for the mesial, center, and distal sites. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

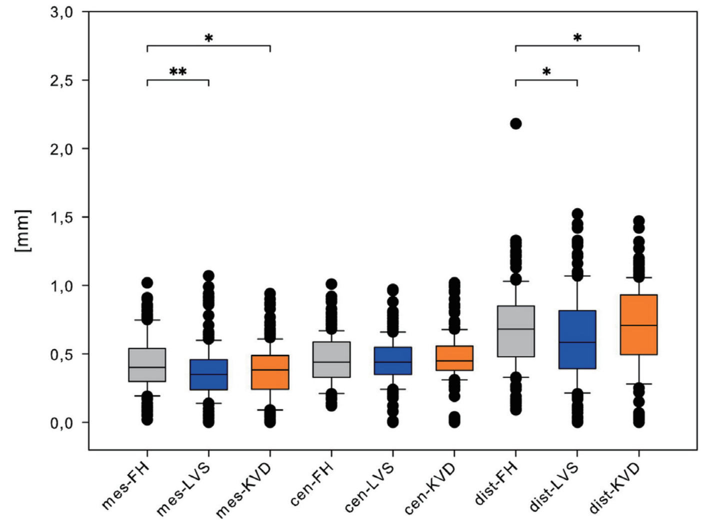

Fig. 8. Preparation depths for mandibular incisors in horizontal separation with separate measures for the mesial, center, and distal sites. FH: Freehand, LVS: Laminate Veneer System, KVD: Keramik-Veneers.de.

The present study's design was the first regarding the number and experience of operators, preparation in a patient simulator, preparation of maxillary and mandibular teeth, instruments employed, and multiple randomizations. While other studies have employed a general practitioner[29] or dentists who were experienced in the preparation of veneers[1], the operators in this study were inexperienced, without prior training in veneer preparation[1]. Accordingly, the operators' prior experience or personal preferences did not influence the results. Furthermore, this study employed 20 operators, unlike earlier studies that used only one[26–29] or two[1] operators. A larger number of operators ensures that the results most likely apply to other dentists.

Earlier studies used natural teeth[1] or typodontic teeth mounted on typodonts[26–29], thus allowing unrestricted access to the teeth. In addition, in this study, typodonts with typodontic teeth in place were mounted on patient simulators, allowing for a greater probability that the results could be compared to patients' clinical treatments. However, consideration must be given to the fact that the prepared teeth were only polymer teeth and not actual clinical teeth of patients. This does not allow us to determine whether dentin was exposed during preparation and must be regarded as a limitation of this study. The *prepared teeth* in this investigation included the maxillary central incisors. This appears adequate, as earlier studies indicated that these teeth were the most frequently treated in clinical practice, accounting for almost 50% of the veneers prepared[2,3]. Accordingly, smaller teeth were prepared for veneer restoration. This is not surprising, as extended veneer restorations preserve more tooth structure than full crowns do[35]. Therefore, it is necessary to investigate whether the results of preparations of *maxillary* central incisors are also applicable to smaller *mandibular* incisors. To the best of our knowledge, this is the first study on this topic.

The selection of rotary instruments investigated in this study was unique. The instruments employed for the freehand technique were not parallel-sided but *tapered*. Unlike earlier studies[1], this allowed for a better comparison, as the contouring instruments in both depth gauge groups were tapered. To evenly distribute the influence of individual human talent on the preparation results, *all* operators used *all* sets of instruments, one set after the other. Furthermore, the instruments' sequence and the prepared teeth were randomized to exclude confounding factors. Thus, neither the preparation set, nor the prepared tooth (11 or 31) could be chosen according to the subjects' preference but were determined by random allocation. This avoids gains from experience from using one set of instruments influencing the results of successive groups. Finally, to balance the effect of the experience gained in the preparations, the sequence in which the *maxillary* and *mandibular* teeth were prepared was randomly assigned.

These results confirm earlier studies showing that inexperienced operators can perform sufficient veneer preparations. In the expert study from 1995, the preparation instruction was to produce a circumferential reduction maximum of 0.5 mm by freehand preparation, resulting in the overall mean of the reported values of 0.62 mm[1]. In our study, with a preparation instruction for maxillary incisors of a maximum of 0.6 mm, the medians and means of the freehand group were approximately 0.1 mm larger than in the depth-gauge groups (**Table 2**). Moreover, the medians of the two depth-gauge groups (each 0.62 mm) were very close to the required preparation depth (0.6 mm) despite the limited experience of the participants.

Regarding the results for the mandibular incisors alone, the recorded depths were lower, and the standard deviations were considerably smaller. As for the absolute depths, means and medians in all groups exceeded the depth of 0.4 mm, which was required from the operators. However, the mean and median values remained below 0.5 mm, as recommended in earlier preparation studies[1], except for the means in the freehand group (FH). This indicates that inexperienced operators generally can prepare teeth as required in a simulated clinical setting.

Regarding *vertical differentiation*, the cervical depth was the greatest in the initial expert study from 1995[1]. Contrary to this, in our investigation, the greatest preparation depths for the maxillary incisors occurred in the middle. This indicates that cervical overpreparation was avoided in our study. Regarding the instruments employed, preparation depths for the FH group were significantly greater at all sites than those for both depth gauge groups (LVS and KVD) (**Figs. 5 and 6**).

The same initial expert study reported depths that differed substantially between the mesial, central, and distal regions for horizontal differentiation[1]. Here, the results for the maxillary incisors in the center closely matched the required depths, whereas the mesial and distal preparation depths exceeded the required depths (**Figs. 7 and 8**). However, this was only applied to the FH and KVD groups and not to the LVS group. This was surprising because the cutting depth of the LVS-1 instrument used for the maxillary incisors exceeded that of the comparable KVD instrument, and the diameter of the LVS instruments exceeded that of the other instruments. Hence, a comparatively greater preparation depth could be expected for the LVS group based on the geometry of the LVS depth gauge instruments. In the mandibular incisor preparation, the distal depths were greater than the central and mesial depths. This finding was applied to all instruments, so there might be a common reason – presumably, access to the distal aspect of tooth 31 is the most difficult to prepare.

In addition to the *relative* preparation depth, the *absolute* penetration depth is crucial for dentin exposure. Another group previously described the problem as being connected to extreme individual overpreparation[26]. This occurred only in the FH and LVS groups in the present study.

The question remains whether the personal skills of the operators can explain this or whether the individual differences may also be related to noncompliance with the protocol, as determined in other studies[16].

Because of these few extreme overpreparations, which are clinically undesirable and cause concern, the question remains whether the results per participant within each group improved between preparations. Further research will provide information on the number of veneer dentists who should prepare a simulator before introducing the technique into clinical practice. In a comprehensive *in vitro* study in 2020, Blunck *et al.* referred to invasive preparation forms, which can be considered extreme overpreparations. According to the authors' results, this does not inherently increase fracture risk[15]. Based on their results, extreme overpreparations with both 50% and 100% exposed dentin did not lead to an increased risk of fracture or impaired marginal quality if the thickness of the restorations was increased considerably to compensate. However, this is not clinically desirable because it is associated with aesthetic impairment. Hence, in clinical practice, extreme overpreparation inevitably leads to clinically unacceptable or unsatisfactory aesthetic results.

This background also strengthens the results of this study, which suggests the use of depth-gauge instruments, followed by additional color markings in the depth grooves[34], and the subsequent use of matching contouring and finishing instruments to ensure that the planned depth of preparation is attained and maintained. In the current study, the reported results were based solely on the use of a combination of pre-preparation using diamond burs in the Freehand Group or depth cutters in the LVS and KVD groups, subsequent color markings to the bottom of the grooves, and conservation of remnants of the color marking during subsequent preparation and finishing.

Therefore, the results are as applicable to classical (first-generation) veneer preparations as third-generation preparation techniques, including mock-ups placed on prepared teeth. This is important because pre-preparation with depth indicators does not guarantee safe preparation in situations characterized by severe tooth wear. Therefore, a combination of mock-up recontouring of treated teeth and successive initial preparation with depth markers was developed to permit substance removal control, even in severe tooth wear cases. In addition, while the mean preparation depths reached using cylindrical and tapered depth gauge instruments did not differ significantly, extreme preparation depths occurred less frequently when using tapered depth gauge instruments, indicating an advantage in terms of safety. Therefore, it appears that combining the initial use of tapered depth gauge instruments with rounded tips and the subsequent use of tapered diamond burs in the KVD group provides more safety against unwanted extreme overpreparation and might thus be preferable, at least for inexperienced operators.

Future studies should investigate the safety provided by color markings applied to control the depth of the preparations to ensure that the preparations remain minimally invasive.

5. Conclusions

1. The use of depth-gauge burs at the onset of veneer preparation resulted in significantly decreased preparation depths compared with freehand preparations, reducing the risk of unwanted dentin exposure.

2. Using depth-gauge burs (LVS, KVD) led to a smaller distribution of preparation depths in clinically relevant areas, especially for all maxillary incisors, compared to freehand preparation (FH).

3. The preparation depths obtained using the two depth gauges and their respective contouring and finishing instruments were not significantly different. However, the maximum preparation depth was less invasive with the use of tapered depth-gauge burs and instruments.

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Authors [a] and [f] received an honorarium developing other rotary instruments. Students and faculty members involved in the study did so without payment from any manufacturers or institutional grants. Author [c] is an employee of Philips GmbH.

Ethics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments. The study was approved by the ethics committee of the Hamburg Medical Council prior to its implementation. Due to the anonymization of students, the ethics committee formally decided that no ethics vote was required for this study. Subjects gave informed consent to the work.

Conflicts of interest

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

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