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ORIGINAL RESEARCH

A COMPARATIVE EVALUATION OF THE ACCURACY OF TOOTH PREPARATION FOR VENEERS: CONVENTIONAL METHODS VERSUS DIGITALLY GUIDED TECHNIQUES - AN IN VITRO STUDY

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ABSTRACT

This in vitro study aimed to compare the accuracy of three different veneer preparation techniques: conventional freehand (CM), silicone reduction guides (ERG), and CAD/CAM 3D-printed guides (DG). Thirty maxillary central incisor typodont teeth were randomly assigned to three groups (n = 10 per group). A single experienced operator carried out all preparations to minimize operator variability. The CM group used calibrated depth-cut burs without any guide, the ERG group used silicone indices fabricated from diagnostic wax-ups, and the DG group used digitally designed and 3D-printed reduction guides. Pre-preparation and post-preparation scans were obtained and analyzed using Geomagic Control software to evaluate the mean absolute difference (MAD) and standard deviation (SD) of tooth reduction. The results revealed that the DG group exhibited the highest accuracy and precision in maintaining the planned reduction depth, followed by the ERG group. While the ERG technique provided improved control over freehand preparation, some deviations were observed due to the inherent flexibility and distortion of the silicone material. The CM group showed the least accuracy, with greater variability in reduction. Overall, the digitally guided method demonstrated superior control, precision, and conservation of tooth structure, highlighting its clinical advantage in aesthetic veneer preparations.

Keywords: Laminate veneers, 3D-printed guides, Tooth preparation accuracy, Computer Aided Designing/ Computer Aided Milling (CAD/CAM), Silicone index

INTRODUCTION

Laminate veneers are a conservative option for enhancing anterior tooth aesthetics. Since their introduction in 1983, they have gained popularity due to their strength, durability, minimal invasiveness, biocompatibility, and aesthetics.[1] Advances in ceramics and adhesive systems have made porcelain veneers predictable and minimally invasive.[2] Preserving tooth structure—especially enamel—is critical for bonding strength and pulp vitality. However, achieving accurate, conservative reduction remains a clinical challenge.[3] Over-preparation can damage enamel, while under-preparation may compromise fit or aesthetics.To improve precision, several techniques have emerged. In 1977, Preston introduced guided preparation with depth grooves using a rounded diamond bur.[4] While useful, it relies heavily on tooth anatomy and operator skill, risking over-reduction. In 1999, Magne introduced elastomeric guides (silicone indices) from diagnostic wax-ups for controlled depth.[5,6]

Studies like Gao et al. reported deviations of 0.12–0.16 mm with silicone guides—more accurate than freehand.[7] Still, silicone's flexibility may affect depth control.Digital advances now allow for CAD/CAM-designed 3D-printed guides via SLA, inkjet, or laser melting, offering greater precision, rigidity, and customization.[8,15] This in vitro study compared the accuracy of three veneer preparation techniques: conventional manual, elastomeric guide, and 3D-printed digital guide. The null hypothesis proposed no significant difference in accuracy among them.

MATERIALS AND METHODS

Thirty maxillary right central incisor typodont teeth (Nissin, Tokyo, Japan) were randomly assigned to three groups (n=10):

• **Conventional Manual Preparation (CM)**: Prepared using calibrated burs with visual depth judgment.(Figure1)

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Figure 1. Conventional manual preparation using depth cutter burs. B and C shows before and after images of manual preparation

• **Elastomeric Reduction Guide (ERG)**: Prepared using a silicone index for depth guidance at cervical, middle, and incisal thirds. (Figure 2)

Figure 2. A shows image of silicone index sectioned into cervical, middle and incisal thirds. B, C, D show images of preparation on each of the respective tooth surface (cervical,middle and incisal thirds) using silicone index as guide.

Digitally Guided (DG): Prepared using 3D-printed guides designed in CAD software (Nemosmile 3D) and printed with a Shining 3D printer. (Figures 3, 4)

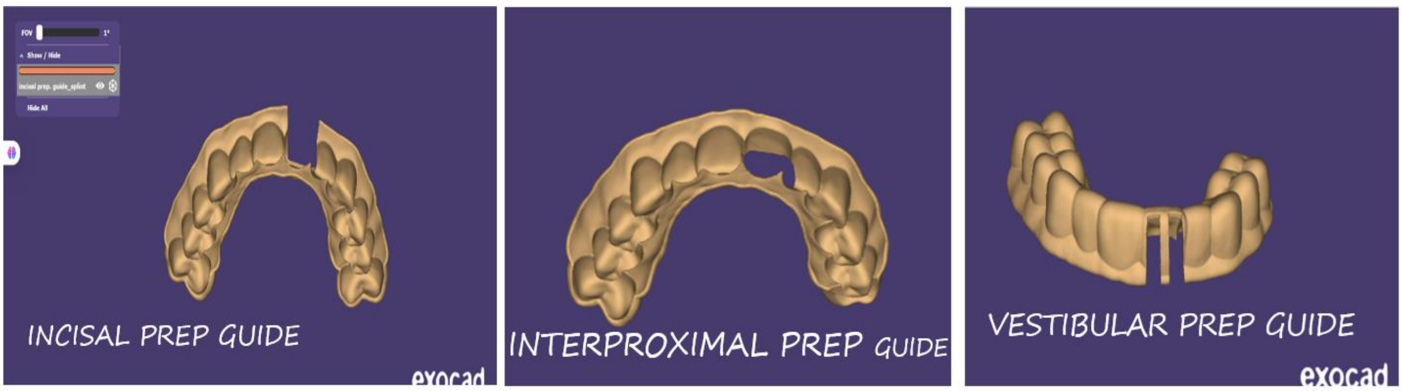

Figure 3. Image showing the 3D designs of each preparation guide (using Nemosmile 3D software)

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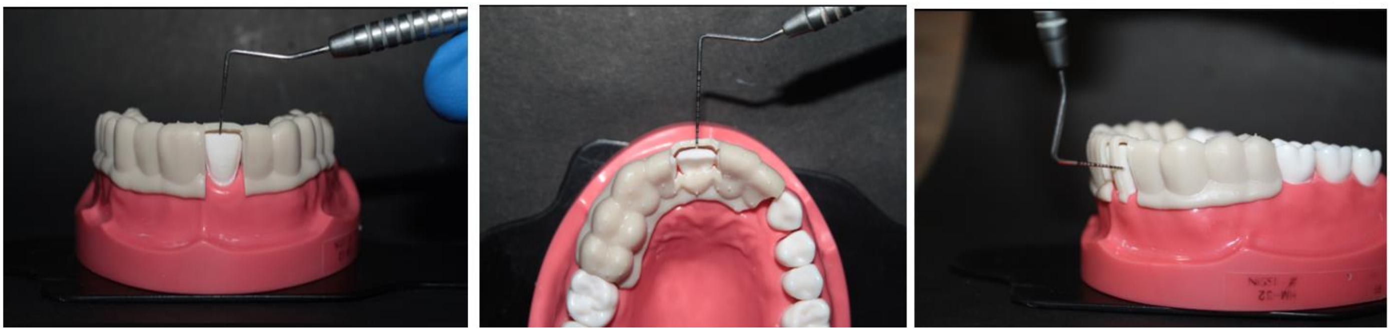

Figure 4. Guided preparation using 3D printed guides

A standard typodont was scanned with a Shining 3D lab scanner, and the STL file was used as a reference for depth comparison. Preparations were done by a single operator.

Accuracy was measured by mean absolute difference (MAD), and precision by standard deviation (SD). Statistical analysis used SPSS v.26 (IBM, Armonk, NY) with ANOVA and Bonferroni tests for intergroup comparisons.

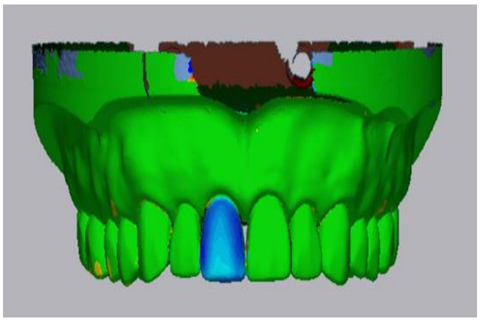

Figure 5. Post-preparation, samples were scanned and analyzed using Geomagic Control X (2017.0.1; 3D Systems, Rock Hill, SC) for deviation.

Table 1. Comparison of the mean deviation (mm) and standard deviation (SD) in veneer preparations (V=veneer sample) across different groups: Digitally Guided (DG), Conventional Manual (CM), and Elastomeric Reduction Guide (ERG).

SAMPLE NO.	DG		CM		ERG	
	MEAN DEVIATION (mm)	Standard Deviation (SD)	MEAN DEVIATION (mm)	Standard Deviation (SD)	MEAN DEVIATION (mm)	Standard Deviation (SD)
V1	-0.0151	0.147	-0.0095	0.2192	-0.0168	0.1839
V2	-0.0148	0.1621	0.0001	0.1433	-0.0119	0.1368
V3	-0.0131	0.1475	-0.0031	0.2043	-0.0108	0.1574
V4	-0.0113	0.1394	-0.001	0.1482	-0.0168	0.1839
V5	-0.0112	0.146	-0.001	0.1447	-0.0032	0.152
V6	-0.0110	0.1495	-0.0100	0.2293	-0.0170	0.1876
V7	-0.0107	0.1601	-0.0012	0.1462	-0.0120	0.1370
V8	-0.0109	0.1377	-0.0032	0.2052	-0.0109	0.1588
V9	-0.0111	0.1487	-0.0011	0.1489	-0.0167	0.1852
V10	-0.0112	0.151	-0.0010	0.1449	-0.0033	0.151

Table 2. Statistical comparison of mean deviation (mm) and standard deviation (SD) for laminate veneer preparation across three methods: Digitally Guided (DG), Conventional Manual (CM), and Elastomeric Reduction Guide (ERG). P-values indicate statistical significance.

Group	Mean Deviation	Standard Deviation	p-Value
DG	-0.0131 mm	0.1484	0.004*
CM	-0.0029 mm	0.17194	
ERG	-0.0119 mm	0.1628	

Table 3. Intergroup Comparison of Mean Differences. Statistically significant differences (p < 0.05) are noted with asterisks.

Comparison	Mean Difference	p-Value
DG vs CM	-0.1020	0.00*
DG vs ERG	-0.0012	1.00
CM vs ERG	-0.0090	0.01*

Mean deviation and standard deviation (SD) for veneer preparations were evaluated across three groups: Digitally Guided (DG), Conventional Manual (CM), and Elastomeric Reduction Guide (ERG) (Table 1). DG showed the lowest mean deviations (-0.0151 to -0.0107 mm) and lowest SDs (0.1377–0.1621), indicating superior accuracy and consistency. A significant difference in mean deviation was found among groups ($p = 0.004$) (Table 2). DG had a significantly lower mean deviation (-0.0131 mm, SD = 0.1484) than CM (-0.0029 mm, SD = 0.1719). ERG showed similar accuracy to DG (-0.0119 mm, SD = 0.1628), but with slightly more variability. Intergroup analysis showed significant differences between DG and CM (mean difference = -0.1020, $p = 0.00$), and CM and ERG (mean difference = -0.0090, $p = 0.01$), but not between DG and ERG (mean difference = -0.0012, $p = 1.00$) (Table 3). DG proved most accurate and consistent; CM showed the greatest variability; ERG was comparable to DG with minor deviations.

DISCUSSION

The null hypothesis was rejected, as significant differences in veneer preparation accuracy were found among the three techniques. Digitally guided preparation showed the highest accuracy and consistency, minimizing enamel removal and providing precise depth control. These findings align with Ahmed et al. (2024) and Silva et al. (2022), who highlighted the precision and reduced operator variability of digital workflows [9,10]. The elastomeric guide method was more accurate than conventional manual preparation but limited by material flexibility and manual fabrication. Gao et al. reported silicone guide accuracy of 0.12–0.16 mm versus 0.05 mm for 3D-printed guides, emphasizing digital superiority [7]. Despite offering depth control, elastomeric flexibility may cause minor deviations. Manual preparation had the lowest accuracy and highest variability, supporting Ahlers et al. (2023), who noted increased over-preparation risk with freehand techniques [11]. Though DG and ERG had similar mean deviations, DG showed significantly less variation, confirming its superior precision. Digital guides also offer clinical advantages like pre-treatment visualization, better patient communication, and integration with Digital Smile Design (Coachman et al., 2019) [12]. All techniques produced deviations within clinically acceptable limits, affirming their usability. However, digital adoption is limited by cost, access, and the CAD/CAM learning curve (KeunBaDa Son et al., 2019) [13]. Neimar et al. (2024) also noted that 3D-printed guides improve efficiency by reducing chairside time [14,15]. This study supports incorporating digital tools for more accurate, predictable veneer preparation while acknowledging the continued relevance of conventional methods in resource-limited settings. Future studies should explore long-term outcomes, performance across tooth types, and cost-effectiveness to guide clinical decisions.

CONCLUSION

Guided veneer preparation improves accuracy, fit, and restoration longevity. Digitally guided preparation was most precise, followed by elastomeric guides; conventional manual preparation was least accurate. Future studies should explore long-term outcomes, performance across tooth types and designs, and cost-effectiveness to support evidence-based practice.

DECLARATIONS

Competing interest

The authors declare that there are no competing interest.

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Ethical Approval

“Not applicable”

Consent for publication

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Competing interests

The authors declare no competing interests.

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