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Accuracy of Amount of Tooth Preparation for Laminate Veneers Using Different CAD-Assisted Guides: A Narrative Review

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Abstract

The growing demand for highly esthetic and minimally invasive dental treatments has increased the popularity of laminate veneers as a conservative restorative option. Achieving the planned restorative outcome depends largely on accurate tooth preparation, as unnecessary reduction may compromise enamel preservation while insufficient reduction can affect the esthetic and functional results of the final restoration. Conventional freehand preparation techniques are highly operator-dependent and may result in variations in the amount of tooth structure removed. Recent advances in digital dentistry have led to the development of computer-aided design assisted preparation guides, which aim to improve preparation accuracy and enhance clinical predictability. This narrative review explores the current evidence regarding the accuracy of tooth preparation for laminate veneers using different guides. The available literature suggests that digital preparation guides can facilitate more controlled and uniform tooth reduction, allowing clinicians to better adhere to the planned restorative design while preserving healthy dental tissues. Their benefits appear particularly relevant in complex esthetic situations such as tooth discoloration, malalignment, diastema closure, and shape modification, where preparation requirements may vary considerably. Although different guide designs and digital workflows have demonstrated promising results, variations in study methodologies make direct comparisons challenging. Overall, preparation guides represent a valuable advancement in veneer restoration, offering improved precision and supporting conservative restorative principles. Nevertheless, further clinical research is required to validate laboratory findings and establish evidence-based recommendations for routine practice.

Keywords: Laminate veneers; Digital dentistry; CAD-assisted guides; Preparation accuracy; Minimally invasive dentistry.

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1. Introduction

Minimally invasive dentistry has remained a conservative approach for preserving tooth and periodontal structures with the least amount of tooth tissue removed or replaced through preventive and early-stage disease treatment techniques. Minimally invasive dentistry is not limited to caries treatment, but its principle can also be used in any general field of dentistry [1]. In esthetic dentistry, the concepts of minimally invasive cosmetic dentistry (MICD) and minimally invasive prosthetic procedure (MIPP) have been widely recognized, MICD involves a series of minimally invasive treatments to achieve a pleasing esthetic dental effect, MICD combines the functional and esthetic aspects to design minimally invasive treatments and do not compromise the esthetic, psychological, or physiology aspects of patients. MICD mainly emphasized on patients' benefits. Conventional treatment always focuses on the objective factors of minimally invasive dentistry, while MICD brought the attention to the subjective factors of patient psychology [2]. The concept of MIPP involves clinical procedure that focuses on the use of minimally invasive treatments to achieve a high standard of esthetic dental function and long-term success, the comprehensive concept of MIPP was especially appropriate for dental attrition with reduced occlusive height, which could be reconstructed with minimal reduction of the tooth tissue.

The core principle for both MICD and MIPP was maximum preservation of tooth tissue, which is also one of the earliest consensuses for the preparation of dental treatments in esthetic area [3]. Porcelain laminate veneers (PLVs) are a minimally invasive restoration with a long-term success rate. To achieve the best esthetics, biocompatibility and durability with PLVs, tooth structure, especially enamel, should be preserved during the tooth preparation process. However, controlling preparation depths for PLVs within fractions of millimeters is a challenge, several techniques have been advocated to achieve predictable and accurate veneer preparation [4]. In 1977, Preston proposed a "guided" tooth preparation, in which a rounded diamond bur was used to make depth grooves, followed by removal of the portions between the orientation grooves. Veneer preparation guided by calibrated burs has been shown to improve the quality of facial and incisal reduction [5]. However, this reduction is driven by the original tooth surface, and aggressive preparations may occur in some cases. In 1999, Magne introduced the use of silicone indices in guided tooth preparations, in this technique, silicone indices were made from a wax up to guide the veneer preparation [6].

Numerous studies have demonstrated that silicone indices help to isolate the targeted restorative space (TRS), which allows for minimally invasive tooth preparations [7-8]. Recently, studies have reported the application of a thermoplastic guide in tooth preparations. The thermoplastic guide promoted the visual evaluation of depth guiding dimple preparations and measurement of preparation depths through holes or slots made in guide; use of dimple technique showed a trend toward greater consistency in veneer preparation [8]. Surgical guides can be designed and fabricated digitally using different three-dimensional (3D) printing techniques, including stereolithography (SLA), inkjet printing, and selective laser melting. Various types of 3D printed tooth preparation guides have been designed for veneer preparation. Both 3D printed equal-thickness and nonequal-thickness TRS guides have been introduced to visualize TRS profile for veneer preparation. Gao et al introduced auto-stop SLA guides for simpler and more accurate veneer preparation [7]. Another study suggested that 3D printed guides could manage reduction depths in a more controlled and precise manner. In this study, artificial teeth were prepared to a uniform depth, but reduction depths are usually inconsistent in different regions in clinical practice [9].

2. Methodology of the Review

This narrative review was conducted through a comprehensive literature search of peer-reviewed articles published up to 2026. Databases including PubMed, Scopus, and Google Scholar were queried using combinations of the following keywords: "Accuracy," "laminate veneers," "tooth preparation," "CAD-Assisted Guides," and "Digital Dentistry". Inclusion criteria comprised in vitro, clinical, and digital workflow studies evaluating tooth preparation for laminate veneers, the accuracy of tooth reduction, different CAD-assisted preparation guides, and their performance in various simulated clinical situations. Articles focusing on conventional preparation techniques, digital planning, guided preparation systems, and minimally invasive veneer preparation were also included. Studies unrelated to veneer preparation accuracy or lacking sufficient methodological details were excluded.

3. Laminate veneers

3.1. Definition and terminology

A veneer is a thin restoration bonded to the external surface of a tooth to enhance function and esthetics. Veneers might be fabricated directly with composite resin or indirectly using ceramics. Laminate veneers particularly refer to thin indirect restorations, most commonly ceramics, bonded mainly to enamel with minimal tooth preparation. The concept of lamination underscores reliance on adhesive bonding rather than mechanical retention. From a biomimetic perspective, laminate veneers are designed to replicate the mechanical and optical behavior of natural enamel while preserving maximum tooth structure [10].

3.2. Indications for Laminate Veneers

Laminate veneers are indicated when esthetic improvement can be attained without compromising tooth structural integrity or vitality, common indications include intrinsic discolorations such as enamel hypoplasia, and discoloration of non-vital teeth resistant to bleaching. Veneers also widely used to correct rotations, malalignment, diastemas, peg-shaped teeth, and discrepancies in tooth size and shape [11]. Additionally, veneers can restore chipped or fractured anterior teeth and manage mild developmental anomalies such as amelogenesis imperfecta. In carefully selected cases, veneers assist in re-establishing anterior guidance and improving functional harmony [12].

3.3. Classification of Laminate Veneers

Material composition, degree of preparation, and manufacturing method can all be used to classify laminate veneers. Veneers are divided into ceramic and composite resin systems based on the materials used, while composite veneers are more affordable and require less intraoral repair, ceramic veneers are chosen for their greater translucency, color stability, and wear resistance [13]. Veneers can be classified as no-preparation, minimal-preparation, or conventional-preparation restorations based on the degree of preparation. The location of the teeth, the need for color change, and the amount of restorative space available all influence the choice. CAD/CAM-based digital workflows and traditional laboratory processing are examples of fabrication approaches. A balance between mechanical performance, biological preservation, and aesthetic needs is reflected in each categorization [13].

3.4. Veneers preparation

Coachman et al proposed a classification to describe techniques of veneer preparation; the first generation involves preparation of facial and incisal edge using calibrated burs, this method aims to reduce tooth structure consistently but can lead to aggressive preparation due to not considering the enamel wear or final restoration's position [14]. Second generation uses a diagnostic wax up using silicone index to guide incisal and labial reduction, the second-generation veneer preparation method involves creating the necessary space by considering the proposed restoration material and future anatomy of the restoration [15]. The third-generation technique, Gürel's aesthetic pre-evaluative temporary technique, involves placing a temporary mock-up fabricated through a diagnostic wax-up over teeth, this allows for more conservative and faster preparation but has limitations such as subtractive cases necessitating pre-reduction and parts dislodging before final veneer application [16]. To ensure consistent and accurate veneer preparation, a range of methods have been recommended [4]. Preston described a "guided" tooth preparation method in 1977 that involved creating depth grooves with a rounded diamond bur and then removing the spaces between the orientation grooves (Fig 1). It has been demonstrated that using calibrated burs to guide veneer preparation improves the quality of incisal and face reduction [5]. However, the original tooth surface is what drives this reduction, and in certain situations, extensive preparations may take place [17]. Silicone indices were first used in guided tooth preparations by Magne [6] in 1999 using this method, the veneer preparation was guided by silicone indices created from a waxup. Silicone indices have been shown in numerous investigations to aid in isolating the targeted restorative space (TRS), which permits minimally invasive tooth preparations [7]. The use of a thermoplastic guide in dental preparations has been documented in recent research [18], the thermoplastic guide improves the visual evaluation of depth guiding dimple preparations and the measurement of preparation depths through slots made in the guide; the use of the dimple technique showed a trend toward greater consistency in veneer preparation [19].

3.5. Digital Workflow in Laminate Veneer

Veneer planning and implementation have been transformed by digital dentistry. Before teeth are prepared, suggested results can be seen thanks to digital smile design, which enhances patient-clinician communication and treatment acceptability. With less chairside and lab time, CAD/CAM solutions enable precise and effective production. The accuracy and repeatability of restorations are improved by digital impressions and virtual articulation. Despite technological progress, digital tools should complement rather than replace sound clinical principles. Predictable success still depends on precise diagnosis, cautious planning, and careful bonding [20].

4. CAD-Assisted Guides

Various 3D-printed tooth reduction guides have recently been developed, primarily to facilitate the creation of depth grooves that assist in subsequent tooth reduction, with advancements in digital dentistry, the concern of achieving an inaccurate tooth reduction depth in conventional veneer preparation can be effectively addressed through computer-assisted veneer preparation. Various 3D-printed tooth reduction guides have recently been established, primarily to facilitate the creation of depth grooves that assist in subsequent tooth reduction (Fig 2). Figueira et al. designed a simple guide with open window access, but its limited control over bur movement resulted in greater variability in tooth preparation depth [21]. Tinoco et al. suggested a cross-shaped guide that creates vertical and horizontal grooves at the mid labial surface of the tooth; however, its reliance on subsequent freehand PLV preparation may result in inconsistent tooth reduction depths [22].Gao et al. designed a more complex guide with multiple depth-guiding holes on the labial surface and incisal edge, used in combination with a calibrated bur with depth scales; despite this guide improvement, a deviation up to 0.3 mm was still reported [7]. In addition to the guide designs, the accuracy of these guides is also affected by the type of printing technology used. Nevertheless, usually used printing methods in tooth reduction guide fabrication including Stereolithography (SLA), Digital Light Processing (DLP), and multi-jet printing (MJP), Liquid Crystal Display (LCD), technology demonstrate a precision range b/w 25.4 µm and 62.0 µm[8], which falls within clinically acceptable limits [23] (Table 1).

5. Influence of Different Clinical Situations on Veneer Preparation

The concept of a universal preparation design for laminate veneers has gradually been replaced by a more customized approach that considers the patient's specific esthetic and anatomical needs. The amount and location of tooth reduction are influenced by several factors, including tooth position, color, morphology, and the intended restorative outcome. Consequently, preparation guides generated through digital workflows have become increasingly valuable, as they allow treatment planning to be tailored to each clinical situation rather than relying on standardized reduction protocols. In patients with well-aligned anterior teeth and favorable tooth proportions, laminate veneers can often be accomplished with minimal reduction, under these circumstances, the primary objective is to create adequate space for the restorative material while preserving as much enamel as possible. Digital planning facilitates visualization of the final restoration before any irreversible procedure is performed, enabling clinicians to identify areas where preparation may be reduced or completely avoided [24]. When veneers are used to mask intrinsic discoloration, restorative challenge becomes greater.

Darkened teeth often require increased material thickness to achieve an acceptable optical result, especially when highly translucent ceramics are selected. In these cases, preparation depth is governed not only by the need to accommodate the veneer material, but also by the optical requirements needed to obscure underlying substrate. Guided preparation systems may help strike a more controlled balance between esthetics and tissue preservation [25]. Tooth malalignment presents another challenge frequently encountered during veneer preparation, labial reduction guidelines differ considerably between protruded and retruded teeth. Whereas prominent teeth often require selective reduction to improve the final alignment, retruded teeth may benefit from an additive restorative approach with little or no preparation [26]. Digital diagnostic procedures provide a three-dimensional assessment of these discrepancies and allow preparation to be directed only toward areas that interfere with the proposed restorative contours. Similarly, patients seeking closure of anterior diastemas often require modifications in tooth width rather than significant changes in facial contour. Since restorative material is added primarily to the proximal surfaces, aggressive facial reduction is usually unnecessary.

Digital preparation guides can assist in maintaining this conservative philosophy by limiting preparation to regions that directly affect veneer seating and emergence profile. Developmental anomalies including peg-shaped lateral incisors, microdontia, and localized enamel defects are particularly suitable for additive restorative strategies. In such cases, the restorative volume is created mainly through ceramic addition rather than tooth reduction. Preservation of enamel is especially important because adhesive bonding to enamel remains more predictable and durable than bonding to dentin. Consequently, careful preoperative planning plays a crucial role in minimizing unnecessary preparation [27]. The literature strongly supports the use of additive restorative strategies for cases requiring significant contour modification, aligning with the principles described for developmental anomalies. Contemporary veneer philosophy emphasizes that bonding to enamel has been shown to provide reliable results, and thus conservative tooth reduction is key to the success of ceramic bonded veneers [28]. The "less is more" approach in minimally invasive dentistry recognizes that reduced tooth preparation means enhanced adhesion and clinical longevity.

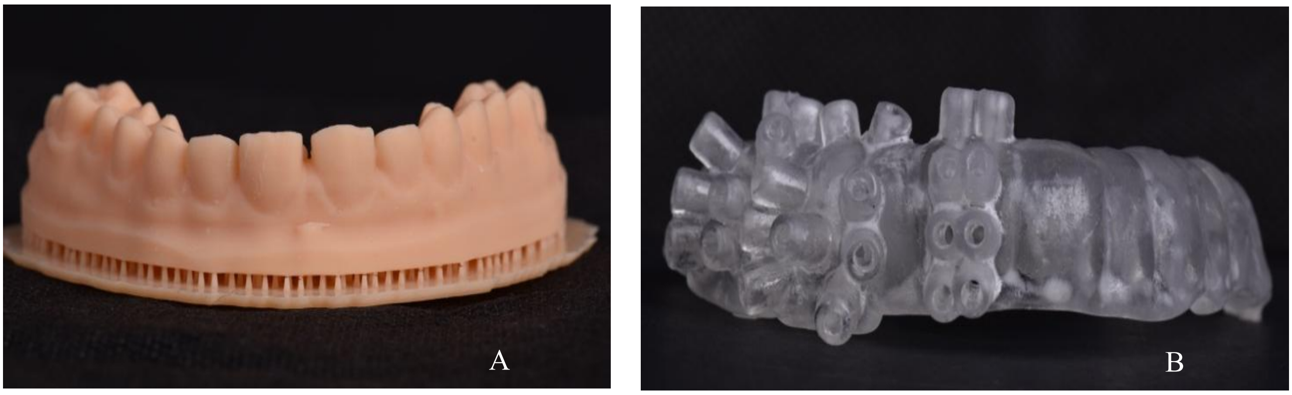

Fig 1. Pre-operative 3D printed model (A), 3D printed preparation guide (B)

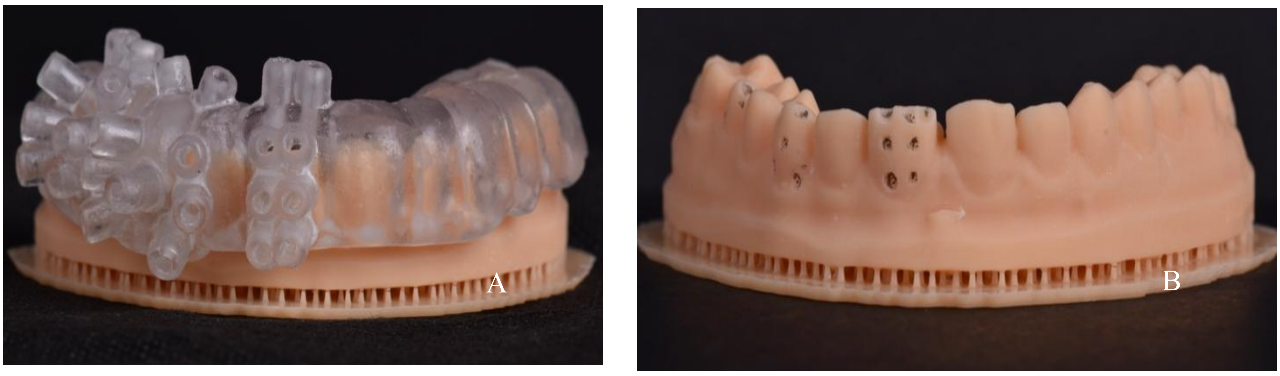

Fig 2. 3D printed preparation guide on model after preparing the depth grooves (A), 3D printed model with pencil markings of the areas to be removed (B)

Table 1. Comparison of 3D Printing Technologies Used for CAD-Assisted Veneer Preparation

Technology	Typical Accuracy	Advantages	Limitations
SLA (Stereolithography)	High (≈25–50 µm)	Excellent accuracy; smooth surface finish; widely validated	Longer printing time and resin post-processing required
DLP (Digital Light Processing)	High (≈35–50 µm)	Fast printing; good dimensional accuracy	Possible pixelation depending on projector resolution
LCD (Liquid Crystal Display)	Moderate–High (≈35–62 µm)	Cost-effective; rapid production	Lower light uniformity and material durability
MJP (Multi-Jet Printing)	Very high (≈16–32 µm)	Excellent detail and surface quality	High equipment and material cost

Table 2. Common Methods Used to Assess the Accuracy of Tooth Preparation

Technique	Principle	Advantages	Limitations
STL Superimposition	Compares preoperative and postoperative STL files	Highly accurate and produces color maps	Requires specialized software
Micro- CT	Produces high-resolution 3D images to measure tooth reduction	Highly accurate and non-destructive	High cost
3D Optical Scanning (Intraoral or Laboratory Scanner)	Digitally captures the prepared tooth surface for dimensional analysis	Fast and non-invasive	Accuracy depends on scanner and operator

This philosophy is particularly relevant in cases where the dental element will receive a veneer that will modify its final contour, such as conoid teeth and diastemas, as described by A. Farias-Neto et al., 2019 [29]. More extensive modifications may be required in patients undergoing comprehensive smile enhancement. Alterations in tooth length, width, axial inclination, or symmetry often necessitate complex restorative planning. Digital workflows incorporating virtual smile design and three-dimensional reduction guides provide clinicians with a practical method for transferring the proposed design accurately to the clinical setting [21]. This may improve consistency between the intended and achieved preparation dimensions while reducing operator-dependent variability. Taken together, these observations suggest that preparation requirements should be determined by the restorative objectives of each individual case rather than by predetermined reduction values. The integration of CAD-assisted guides into veneer therapy has strengthened this patient-specific approach, enabling clinicians to achieve greater precision while adhering to the principles of minimally invasive dentistry[4].

6. Accuracy

Accurate tooth preparation is essential for PLVs to achieve optimal esthetic results and reliable bonding strength. With innovations in digital technology, the issue of attaining inaccurate tooth reduction depth in conventional veneer preparation can be effectively addressed through computer-assisted veneer preparation. Among all the techniques evaluated, the conventional free hand technique was the least accurate, possibly due to its high dependency on the operator's freehand skills. These findings are consistent with previous studies [9, 19]. Notably, when comparing different preparation sites, labial reduction demonstrated slightly better accuracy, being approximately 0.1 mm more precise than incisal and cervical margin preparations, likely due to the use of a wheel-shaped depth gauge bur. This finding is supported by Ahlers et al., who highlighted the significance of using a depth gauge bur in achieving more controlled depths during initial veneer preparation [30]. The Surgical Guide technique, which uses a silicone index for guidance, showed limited improvement in accuracy, except the incisal reduction. Among various 3D-printed guide designs, the commonly used is cross shaped 3D printed guide (3D_C) due to its simplicity. Although 3D_C significantly improved accuracy at the incisal half of the labial reduction and the cervical margins compared to the Free Hand technique, its overall trueness was lower than that of 3D_S, likely due to the need for freehand finishing [23] (Table 2).

7. Conclusion

The integration of CAD-assisted preparation guides into veneer treatment protocols has significantly improved the precision and predictability of tooth preparation. Compared with conventional freehand techniques, digitally guided approaches provide more consistent tooth reduction, enhance enamel preservation, and support minimally invasive restorative principles. The effectiveness of these guides varies according to their design and the specific clinical situation being treated. Despite encouraging evidence, current literature remains predominantly laboratory-based, highlighting the need for long-term clinical investigations. Future research should focus on standardizing digital preparation protocols and assessing their influence on clinical outcomes, restoration longevity, and patient satisfaction.

Author contributions

Mai Mohamed Abdelfattah, Doaa Taha Sayed Taha, and Marwa Mohamed Wahsh contributed to the review work. Data collection methodology performed by Mai Mohamed Abdelfattah and Doaa Taha Sayed Taha. The first draft of the manuscript was written by Mai Mohamed Abdelfattah and Doaa Taha Sayed Taha. Mai Mohamed Abdelfattah, Doaa Taha Sayed Taha, and Marwa Mohamed Wahsh commented on previous versions of the manuscript. Mai Mohamed Abdelfattah, Doaa Taha Sayed Taha, and Marwa Mohamed Wahsh read and approved the final manuscript.

Declaration of conflict of interest

The authors declare no conflict of interest

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