Modified Knife-Edgeless Subgingival Preparation: Tooth Preparation According To Biological Principles

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ABSTRACT

Background: *Fixed bridge and crown restorations are widely utilized in dental practice. The crown preparation procedure plays a crucial role in ensuring the long-term health of periodontal tissues. This study aims to explore the use of modified knife-edgeless subgingival preparation techniques and monolithic zirconia restorative materials as potential strategies for maintaining periodontal and esthetic appeal over an extended period.*

LiteratureReview: *Insufficient preparation can often lead to clinical challenges, such as bulky margins, impingement, or misfit margins, all of as they may impingement oral hygiene self-maintenance. Poor maintenance and the tendency for plaque accumulation can have detrimental effects on the periodontium. With advancements in material technology and manufacturing techniques, it is essential to critically assess the relevance of traditional chamfer and shoulder preparation methods in modern dental practice, particularly for restorations with a subgingival margin.*

Conclusion: *The knife-edgeless preparation technique combined with a monolithic zirconia crown may fulfill the clinical requirements for maintaining good periodontal health while achieving aesthetic appeal.*

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INTRODUCTION

Fixed crown and bridge restorations are commonly used as an alternative to dental implants, contributing to their widespread popularity in clinical practice. In Indonesia, dentists frequently choose fixed bridge and crown restorations as a cost-effective and successful method for managing cases of edentulism or restoring severely damaged tooth. The primary challenge in crown preparation lies in preserving periodontal health while ensuring the best possible aesthetic results.[1,2] The primary concern is optimal placement of the restoration margin to avoid any harm to periodontal health. From the periodontal standpoint, it is generally advised to keep the restoration margin supragingivally. This approach is thought to reduce disruption to the natural tooth's biological width, promoting healthier periodontal tissues and minimizing plaque buildup around the restoration margin.[3] Proponents of aesthetic dentistry, however, argue that placing the restoration margin subgingivally enhances both the aesthetic outcome and the longevity of the aesthetic outcomes. [4] This research aims to examine various preparation techniques and restorative materials to find optimal solutions for maintaining periodontal health and improving esthetics outcomes.

Over the four decades, bridges and crowns have typically been fabricated from a material called ceramo-metal, popularly known in Indonesia as Porcelain Fused to Metal (PFM). PFM offers several advantages, including outstanding durability and visually appealing aesthetic outcomes. However, a potential disadvantage is the appearance of a bluish pigmentation along the gingival margin of the restoration, caused by the metal layer used as a coping beneath the ceramo-metal material.[4] Recent advancements in technology have significantly improved material outcomes, particularly with the development of novel metal-free porcelain materials.[5] Lithium disilicate, widely recognized as eMax®, is among the most popular types of metal-free porcelain. Other alternatives to metal-free materials include composite resins, resin-porcelain hybrids like Enamic®, and zirconia, which can be categorized into single-layered or the more advanced multi-layered zirconia (renowned as 3D zirconia).[6,7] Each of these materials possesses distinct properties, including varying degrees of hardness, which determine their specific applications and limitations. Dental laboratories adopt various fabrication techniques, including analog, semi-digital, or fully digital systems. Clinical applications may also vary, as specific materials require specific parameter of tooth preparation technique and cementation methods to suit their unique properties.[8]

In general, crown preparation techniques can be divided into two main categories. The first category includes horizontal features, such as chamfers and shoulders, as well as their variations, like beveled and rounded forms. Preparation techniques that incorporate horizontal aspects are commonly used today, as crown materials such as ceramo-metal or lithium disilicate require these features to compensate the thickness of the restoration margin. The second category features only a vertical preparation called the knife-edge, a technique that is less commonly used today due to its historical association with metal crowns. [9]

Knife-edge preparations without horizontal preparation are unsuitable for ceramo-metal or all-porcelain restorations due to their margin thickness, which typically ranges from 0.8 to 1.0 mm. Ceramo-metal materials require sufficient thickness to effectively mask the metal color at the margin, whereas lithium disilicate materials are more vulnerable to fracture when the margins are too thin. Inadequate tooth preparation may lead to overly thick restoration margins, resulting in a bulky or over-contoured appearance at the cervical area.

Observations from dental laboratories reveal that majority of dentists, often unintentionally, perform knife-edge preparations rather than the intended ideal chamfer or shoulder preparations.[10,11] Insufficient tooth preparation poses considerable challenges for dental laboratories when creating crown restorations, particularly in achieving a well-contoured PFM especially on its margin.

Knife-edge preparation may sometimes be necessary, particularly in cases of subgingival caries or periodontal damage affecting the tooth. Unlike chamfer or shoulder preparation, knife-edge preparation is relatively straightforward to perform. With regard to tissue preservation, this method minimizes tissue loss compared to chamfer or shoulder techniques by eliminating the need for horizontal extension during preparation.[12,13] In accordance with prior research, vertical preparation may be beneficial for adjusting the margin position and refining the emergence profile.

Determining the ideal location for the preparation margin has been a subject of debate for many years. The health of periodontal tissues and the risk of gingival recession have been central topics of scholarly discussion for years. A supragingival preparation margin is widely considered more beneficial for the overall health of periodontal tissues. Supragingivally located preparation margin is widely regarded as more advantageous for the overall health of periodontal tissues. The supragingival margin of the restoration allows for easier evaluation of the margin's tightness and fit, while also facilitating the removal of any residual cement. The accumulation of plaque at the restoration margin is easily noticeable, facilitating its removal and helping to reduce the risk of gingivitis.[14]

Nonetheless, in terms of aesthetics, it is undeniable that the aesthetic outcome is superior when the restoration margin is located subgingivally. Subgingival preparation enhances retention as it has a deeper position within the gums. The subgingival preparation may be beneficial in effectively harnessing the 'ferrule effect,' which aids in preventing tooth fractures caused by subgingival caries or those that have undergone root canal treatment.[15] A new perspective has emerged regarding equi-gingival restoration margins, suggesting that placing the restoration margin at the gingival level may compromise both periodontal health and esthetic outcomes.

The position of the restorative margin relative to the gingival level shows a strong correlation with periodontal complications. According to previous research, the occurrence of bleeding on probing (BOP) is significantly lower in patients with supragingival or equigingival margins compared to those with subgingival crowns.[4] A 12-month prospective, randomized, double-blind clinical trial was conducted to evaluate two subgingival preparation techniques: chamfer and knife-edge with a ceramo-zirconia crown or porcelain fused to zirconia (PFZ) crown. The results indicate that a subgingival chamfer preparation leads to less bleeding on probing and a reduced rate of recession compared to the subgingival knife-edge preparation.[16] This phenomenon arises from the similar fabrication techniques used for ceramo-

zirconia or porcelain-fused-to-zirconia (PFZ) restorations and porcelain-fused-to-metal (PFM) restorations. Both types require a specific thickness in the cervical area, which makes them unsuitable for knife-edge preparations.

Periodontal problems may arise when the biological width is violated, as this critical dimension is essential for maintaining the proper attachment of the junctional epithelium and connective tissue fibers to the tooth and gingiva.[17] The biological width is a crucial parameter in restorative dentistry for determining the placement of restoration margins below the gingival margin. It plays a vital role in preventing bacterial infiltration into the underlying periodontal tissues, despite its natural variations.[3]

Carranza's concept of periodontal treatment attributes that periodontal problems are frequently linked to inadequate periodontal maintenance.[18] The stages of periodontal treatment indicate that Phase IV, commonly referred to as the maintenance phase, plays a crucial role in ensuring the effectiveness and long-term success of treatment outcomes.[18] Supragingival margin restorations simplify maintenance and self-hygiene compared to subgingival margin restorations, as they are easier to clean and help prevent plaque buildup. Additionally, supragingival margins allow the dentist to visually assess the margin line and identify any misfit for correction.[19]

Other studies have reported that subgingival margin restorations are linked to poorer periodontal tissue health, as evidenced by increased bleeding on probing, higher plaque index, and deeper probing depths. Furthermore, no significant differences have been observed between all-porcelain and porcelain-fused-to-metal (PFM) materials in this regard. Key factors contributing to these periodontal issues include inaccurate or poorly fitted restoration margins, as well as bulky margin contours.[20]

The periodontal tissues are also influenced by the gingival biotype. Thick gingival biotypes are typically associated with better periodontal health. It is well-established that there is a correlation between biotype and the dimensions of the keratinized gingiva. Thick gingival biotypes typically feature a greater width of keratinized gingiva and a firmer gingival texture. The presence of a thick gingival biotype has been linked to a reduced incidence of periodontal disease.[21] Research findings suggest that there is no significant difference in the periodontal health of patients with thick gingival biotypes when comparing subgingival and supragingival restoration margins.

The advancement of digital technology has enabled the development of multicolor multilayer zirconia blocks, which are capable of producing monolithic zirconia restorations. This eliminates the need for a porcelain layer, as seen in porcelain-fused-to-zirconia (PFZ) restorations. Unlike traditional zirconia copings, these blocks do not require porcelain layering along the margins and can feature margins as thin as 0.3 mm, as they have internal color that matches the natural tooth color. A general principle in materials science is that materials tend to break as their thickness decreases.[22] It has also been observed that thinner objects are more susceptible to accelerated wear during their service life. However, unlike lithium disilicate, which cannot be fabricated with a 0.3 mm margin, zirconia can maintain its structural integrity even at this reduced thickness. [23] While a very thin margin may not be suitable for the occlusal area, it works well for the cervical area, which does not experience occlusal load.

DISCUSSION

The process of tooth preparation for prosthetic crowns is invasive, leading to the irreversible removal of hard tooth tissue. When preparing a tooth with a vital pulp, there is potential for adverse effects, such as irritation, inflammation, or necrosis, which may necessitate further endodontic intervention. Preparation techniques can be categorized into two main types, primarily distinguished by the horizontal preparation approach. The first category includes horizontal preparations, such as chamfers, shoulders, and their respective variations. Many authors argue that there is no significant difference between shoulder (90°) and chamfer (45°) preparations. A chamfer preparation is generally recommended for restorations with porcelain-fused-to-metal (PFM) crowns or porcelain-fused-to-zirconia (PFZ). For restorations made from all-porcelain materials, such as lithium disilicate or non-zirconia porcelain, a substantial shoulder is advised to ensure the durability and stability of the restoration, especially when thicker margins are required.

The second category of preparations pertains specifically to vertical preparations. Shoulderless preparations, in particular, are characterized by the absence of horizontal preparation, resulting in no distinct shoulder or bevel. As mentioned earlier, the shoulderless dental crown preparation—also known as knife-edge preparation—has been variably referred to based on the inclination of the restoration wall. Common terms include feather edge, knife edge, and chisel edge. There is consensus among authors that vertical preparations represent a conservative technique, helping to preserve tooth structure while effectively preventing the formation of marginal gaps. However, the use of shoulderless preparations has largely been discontinued due to the need for horizontal preparation in dental laboratory technology, which allows for better accommodation of restoration margin thickness, particularly when using PFM, PFZ, or lithium disilicate restorations.

The modified knife-edgeless or vertical-edgeless preparation technique, originally introduced by Vick Pollard and Rex Ingraham, is being discussed. This technique, which later became known as the Biologically Oriented Preparation Technique (BOPT), has been further developed and refined by researchers such as Di Febo, Carnevale, and Ignazio Loi. It is also referred as rotating gingival curettage. The primary objectives of this technique are: 1) positioning the preparation subgingivally, ensuring it extends beneath the gingival margin, 2) establishing a tight seal along the preparation margin from the coronal aspect to the finish area, and 3) reshaping the emergence profile by creating a new prosthetic edge that aligns with the gingival edge, known as the prosthetic cemento-enamel junction (PCEJ). This approach provides limited flexibility in determining the final preparation margin because the margin forms a narrow band rather than a single line, extending from the CEJ to the gingival margin. The technique emphasizes creating a narrow band at the preparation-end area margin rather than a distinct and sharply-defined preparation margin. Consequently, the distance between the margin depth and the free gingival margin varies, depending on the extent of the biological width.

The tendency of dentists to inadvertently use the knife-edge technique, combined with its relative ease to perform, makes it worthwhile to explore this modified, knife-edgeless approach. Rather than creating a distinct line, the knife-edgeless technique involves preparing a narrow area at the preparation's end. This technique is originally known as Vertical Edgeless Preparation (VEP). It involves eliminating the CEJ (Cemento-Enamel Junction) margin, which in turn will create a new junction and emergence

profile. Extensive efforts in prosthodontics and restorative dentistry have been directed toward developing optimal and effective tooth preparation techniques. These techniques emphasize factors such as emergence profiles, precise marginal fit, and the preservation and refinement of enamel and dentin, as outlined in Table 1.

Table 1. Advantages and Disadvantages of Subgingival Crown Preparation with Different Techniques

	Horizontal Preparation	***Knife –edge* preparation**	***Modified Knife- Edgeless* Preparation**
Periodontal health impact	Maybe deleterious	Less deleterious	Less deleterious
Restoration margin thickness	0.8-1.00 mm	0.3 mm	0.3 mm
Restoration margin line	Clear and sharply defined margin line	Clear and sharply defined margin line	Narrow band are without distinct margin line
Difficulty of preparation	Relatively high	straightforward	Straightforward
Emergency profile	Frequently violated	Rarely changed	Newly formed as a result of rotary curettage.
Recommended restoration	PFM, PFZ, Zirconia, Metal, Lithium disilicate	Metal	Metal dan monolithic Zirconia
Risk of overhanging bulky margin, and margin gap	Low if in accordance with the correct strict preparation protocol and excellent dental laboratories	Relatively low if use metal restoration	Relatively low if use metal restoration or monolithic zirconia
Restoration margin position relative to gingival line and periodontal health	Supragingival: Good periodontal index	Supragingival: Good periodontal index	Supragingival: Good periodontal index
	Subgingival: Low periodontal index if there is any misfit, gap, overhanging or bulky margin restoration	Subgingival: Periodontal index is good while using recommended restoration	Subgingival: Periodontal index is good while using the metal or monolithic zirconia
Preparation and restoration-impression taking time interval	Direct	Direct	6 weeks; waiting for healing and newly-formed biological width.

Multiple studies have shown that the quality of periodontal tissue health remains consistent, regardless of whether subgingival or supragingival restoration margins were chosen, as long as the protocol was strictly followed and executed precisely. Periodontal problems typically arise due to misfit between the restoration margin and the preparation-end line. Insufficient tooth preparation when using PFM restorations, porcelain-fused-to-zirconia (PFZ), or lithium disilicate may result in bulky or overcontoured margins, as these types of restorations require thicker margins. However, there is limited

evidence in the existing literature that establishes a clear correlation between periodontal tissue health, the specific location of restoration margins, and the type of restoration (e.g., PFM or zirconia).

The excessive contouring observed at the margins of PFM crowns is primarily due to the need for porcelain layering to mask the metal color. The metal coping requires a minimum margin thickness of 0.25-0.30 mm, while the opaque layer needs a thickness of 0.1 mm, and the porcelain layer itself requires 0.5-0.6 mm. The standard margin thickness for PFM restorations ranges from 0.8 to 1.0 mm. A thickness of 1.0 mm is required when using lithium disilicate material to avoid material breakage. In cases of knife-edge preparation or inadequate preparation, the margin may result in bulky or overhanging areas, creating an exaggerated convexity in the buccal contour. A study by Paniz[16] compared two subgingival preparation techniques —chamfer and knife-edge approaches— along with ceramo-zirconia restorations. The research found that knife-edge preparation may have a detrimental effect on periodontal health in these cases. A similar study by Jameel A.[19] found that the periodontal tissue health in subgingival preparations was superior for metal crowns compared to PFM crowns. Based on these findings, it can be assumed that applying porcelain coatings over PFM or PFZ restorations results in thicker restoration margins, which, in turn, necessitate horizontal preparation techniques, such as chamfers or shoulders, to accommodate the increased margin thickness.

Studies have investigated crowns made of monolithic zirconia with a 0.3 mm thick margin, similar to the knife-edge margin used in metal crowns, to assess their ability to withstand occlusal forces. This particular study focused on how zirconia margins endure the forces exerted during chewing.[26] Furthermore, other research indicates that knife-edge preparations exhibit a fracture resistance of 1202 N, which is higher than the typical range of chewing forces, approximately 800-1000 N. [27]

This knife-edgeless preparation is typically used in crown lengthening procedures to improve gingival contour. This technique can also be applied to teeth without any periodontal tissue damage. This technique does not provide a clear and distinct preparation end margin. This preparation technique places its margin on a band-like area rather than a clear and distinct preparation line. This transition results in the formation of a new anatomical feature, known as the Prosthetic Cemento-Enamel Junction (PCEJ).

The procedure begins with an assessment of the sulcus depth to determine the location of the epithelial attachment. A long, thin bur is then used to remove any undercuts located coronal to the epithelial attachment. At the same time, the bur removes a thin layer of epithelial tissue within the gingival sulcus, a process commonly referred to as rotating gingival curettage or gingitage. This intervention induces fresh hemorrhage and exfoliation of a thin epithelial layer within the gingival sulcus. This preparation procedure completely removes the cervical enamel junction (CEJ) or any previously established horizontal preparation margins. The provisional crown plays a crucial role in shaping the new emergence profile for the final restoration. To establish a new biological width, the margin of the temporary crown should be positioned subgingivally, approximately 0.5–1 mm below the sulcus.

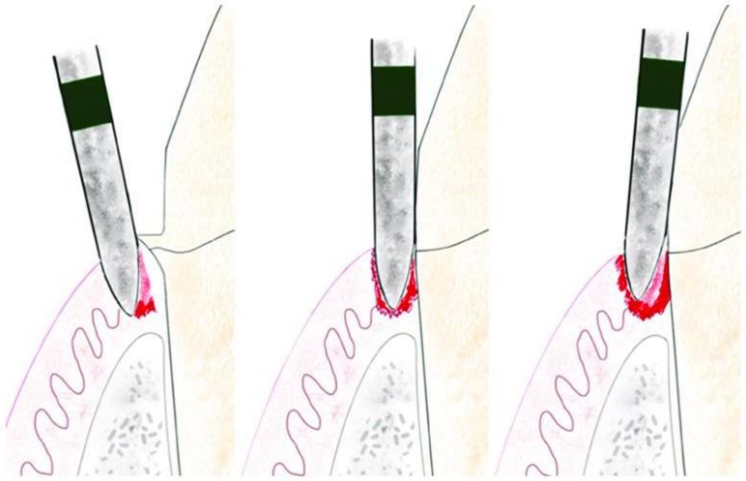

Figure 1. Illustration of a knife-edgeless preparation technique.
A. The initial stage of the knife-edgeless preparation begins with the use of a long, thin, flame-shaped diamond bur (dimensions: diameter 1.2 mm, length 10 mm) held at an angle of 10–15° relative to the tooth axis to remove undercuts. This preparation extends from the cemento-enamel junction (CEJ) to the junctional epithelium.
B. In the second step, the bur is positioned beneath the gingival margin, parallel to the tooth axis (0° angle), to remove the existing margin and create a defined 'finishing area' for the preparation endpoint.
C. In the final step, the bur is positioned at a slightly convergent angle relative to the incisal edge (approximately 6°) to create an appropriate axial preparation wall for the crown.[33]

This procedure can be widely applied, particularly in cases where the width of the keratinized gingiva is insufficient, biological width correction is required, gingival contour modification is needed, or teeth present with subgingival cavities. Bleeding during gingival preparation, a process known as gingitage, has been observed to positively influence the thickness and stability of the gingival margin. Furthermore, this approach may create a new biological width, leading to the formation of a newly established periodontal cemento-enamel junction (PCEJ).

Figure 2. The position of the restoration margin is determined by the depth of the gingival sulcus; however, it is crucial to emphasize that this process must not interfere with the epithelial attachment. The innermost portion of the model, once exposed, will be marked with a blue line, indicating the location of the junctional epithelium. The red line represents the gingival margin. The area between the red and blue lines is commonly referred to as the 'finishing area'. The margin of the temporary crown should be placed within this finishing area, and the definitive crown will be positioned in the same location after the new biological width is established, typically within 6 months.[34]

The prosthetic phase begins with the creation of a provisional crown, which provides a good emergence profile and a well-fitting margin at the finishing area. This area allows the crown to be pressed slightly deeper, ensuring a secure fit margin. Research has shown that misfit margins, impingement, and discrepancies or gaps between the restoration and the margin can lead to plaque accumulation, which adversely affects periodontal tissues and may cause secondary caries.

Unlike traditional preparation with well-defined restoration margins, an imprecise margin may lead to a gap in the restoration margin (see figure 3A). It is true that, if all conditions are ideal—such as optimal

preparation, accurate impression taking, and precise crown fabrication—the margin fit will be achieved, regardless of the type of preparation. However, achieving ideal preparation and an accurate impression can be challenging, and misfits are inevitable, even with optimal dental laboratory work. This new preparation technique may mitigate errors by allowing the crown to fit slightly deeply, ensuring the margin remains within the finishing area and compensating for mistakes made by either the dentist or the dental laboratory. [14]

During the crown fabrication process, particularly in the digital era, there is typically a cement gap ranging from 0.06 to 0.08 mm, with no gap in the cervical area (approximately 1 mm) from the margin (see figure 3B). This cement gap allows the crown to settle slightly deeper onto the preparation without a distinct preparation line. However, if a clear preparation line is present, especially in horizontal preparations, a situation may arise where one side reaches the preparation end line while the other does not. This misfit can result in a margin gap, potentially leading to periodontal issues in the future (see figure 3A).

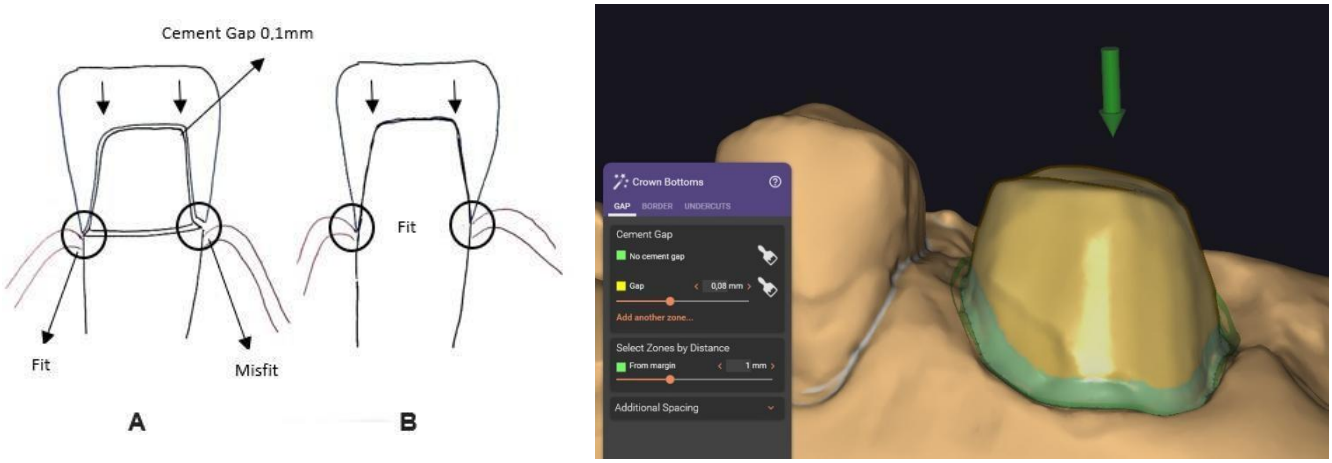

Figure 3. (A) An inaccurate margin (misfit) prevents the crown from being inserted further onto the tooth with horizontal preparation and a distinct margin, as one side reaches the preparation end line while the other does not. This is a situation that sometimes occurs in everyday practice.
(B) A digitally fabricated crown, where a 0.08 mm cement gap is applied to the occlusal area, allowing the crown to settle slightly deeper onto a knife-edgeless preparation without a distinct preparation line.

The knife-edgeless preparation technique offers favorable aesthetic outcomes; however, it is important to note that this method must not be used for restorations involving ceramo-metal or ceramo-zirconia materials, nor for all-porcelain restorations that require a thick margin. The knife-edgeless approach is particularly well-suited for monolithic zirconia restorations or metal restorations without any porcelain coating on the margin area. Recent advancements in dental materials have expanded possibilities for highly effective restorations, especially with the introduction of multilayer zirconia. These zirconia blocks, known as 3D zirconia blocks, feature up to seven internal color layers, each with varying hardness levels. This innovative material is considered a potential solution for reducing premature wear of opposing teeth, as its lower hardness in the incisal area makes it less abrasive compared to conventional zirconia.

The main disadvantage of this preparation is the need for a tissue healing period of up to six weeks before proceeding with the final restoration. Additionally, using a bur that penetrates too deeply

may harm the biological width, which should be carefully considered.

CONCLUSION

The risk of periodontal tissue damage in subgingival preparations can be reduced by employing a modified knife-edgeless technique. These new zirconia materials can achieve a thickness comparable to metal, while also offering internal color that meets aesthetic requirements. This narrative study should be validated through a controlled-clinical trial in the future to establish its relevance in clinical practice.

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