Clinical guidelines for posterior restorations based on Coverage, Adhesion, Resistance, Esthetics, and Subgingival management

The CARES concept: Part I – partial adhesive restorations

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Abstract

Important changes have occurred over the last decades in the clinical application of the strategies for posterior restorations – from amalgam to composites in direct restorations and from traditional resistance form crowns to adhesive partial restorations such as onlays. Despite much evidence available for these advances, there are still very few established guidelines for common clinical questions: When does an indirect restoration present a clinical advantage over a direct one? When should one perform adhesive cusp coverage such as an onlay? When to implement resistance form designs in adhesive restorations? Which conditions create limitations for adhesion so that a resistance form preparation with a stiffer material such as a traditional crown might be more appropriate? In order to provide clinical guidelines, the present authors consider five parameters to support and clarify decisions – Coverage of cusps, Adhesion advantages and limitations, Resistance forms to be implemented, Esthetic concerns, and Subgingival management – the CARES concept. In Part I of this three-part review article, the focus is on clinical decisions for partial adhesive restorations regarding indications for direct versus indirect materials as well as the need for cusp coverage and/or resistance form preparations based on remaining tooth structure and esthetics.

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Introduction

Concepts involving minimal intervention, ethically balanced with the patient's esthetic requirements, seem to be the desired focus for an evidence-based practice of restorative dentistry. Restoring posterior teeth presents specific demands, inherently different from the demands of anterior teeth. Posterior teeth are a) anatomically and histologically distinct, and 2) withstand occlusal forces that are significantly higher and have different directions compared with anterior teeth. These two differences have an important impact on how to restore tooth structure in damaged posterior teeth.

The quantitative analysis of the remaining tooth structure regarding the decision between an adhesive versus a resistance form restoration is not well defined for posterior teeth. Moreover, when a posterior adhesive restoration is chosen, there are extensive recommendations in the literature regarding preparation designs for inlays, onlays, and overlays. The reasons for this variety are rather obvious – it is difficult to measure the progressive degree of tissue loss and the influence of different preparation designs in clinical studies. Clinical decisions, such as selective cusp coverage, the influence of tooth vitality, the extent of vertical reduction, and the amount of circumferential involvement of preparations, still lack clarification and consensus. Although it is difficult to provide straightforward and absolute protocols, it is important to formulate clinical guidelines, or at least thought processes, that are not only based on evidence but are also pragmatic in the sense that they should be clinically helpful – easy to understand and implement – to a vast majority of practitioners. In this context, the main objectives of the present article are to:

- Cover the specific and relevant biomechanics of posterior teeth.
- Present sequential degrees of tissue loss that can be related to clinical reality.
- Explain how each degree of tissue loss is related to a decision threshold regarding preparation design, according to available evidence.
- Provide simple-to-use directions for restorative strategies, from simple replacement of lost tissue to preventive cusp **c**overage, making use of **a**dhesion or **r**esistance solely or in combination, and trying to maintain natural **e**sthetics, whenever possible, as well as dealing with **s**ubgingival areas – the basis for the CARES concept.

Biomechanics of posterior vs anterior teeth

Anterior and posterior teeth differ in terms of their anatomy and histology. It is consensual that the posterior teeth protect the anterior ones by bearing more intense, vertical, compressive loads, and that the anterior teeth protect the posterior ones from tensile forces by guiding a disclusion mechanism in lateroprotrusive movements. Posterior teeth are wider, multi-rooted, have flatter cusps, and have a distinct distribution of dentin and enamel tissue at the dentinoenamel junction (DEJ). This complex histologic junction of a highly stiff and brittle material – enamel with an elastic tissue (dentin) – provides the tooth with the unique capacity to withstand loads in the posterior region. This structure is characterized as a less mineralized interface that gradually interrelates the two tissue types, with the capacity to undergo transitional deformation.[1] Although this area is present in all teeth, its surface area is more extensive in posterior teeth and has a specific design. It is important to understand this histologic interconnectivity – the convex enamel and concave dentin surfaces (resembling a sigmoid curve) – to establish more effective restorative strategies (Fig 1).[2]

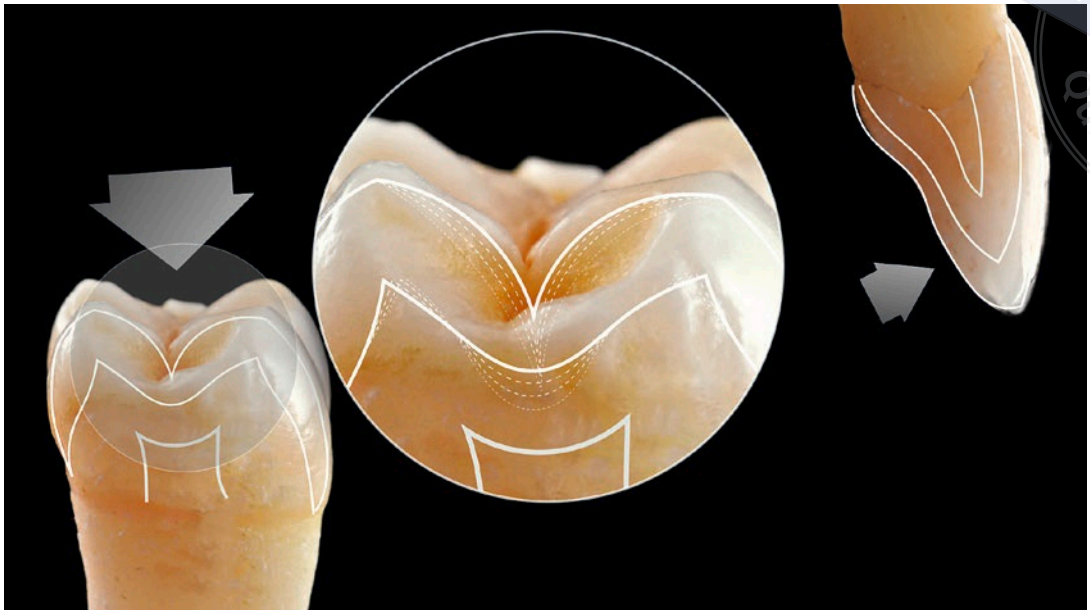

Fig 1 Posterior teeth have a more complex anatomy than anterior teeth. The dentinoenamel junction in posterior teeth has a unique stress-bearing configuration, making these teeth better adapted to withstand higher compressive loads. This specific feature of posterior teeth is difficult to replicate in restorative techniques.

Tissue loss and occlusal load resistance

The concept that tooth resistance is indirectly proportional to tissue loss, the fact that restorations are never lifelong and may need replacement, and the favorable clinical evidence of adhesive procedures support minimally invasive approaches. However, the relationship between tissue loss and resistance compromise does not follow the same proportional correlation in posterior and anterior teeth. For example, an endodontic access cavity associated with the loss of one palatal ridge in an anterior tooth may not pose a high fracture risk, and the need for a full-coverage strategy is debatable. However, there seems to be sufficient evidence for the need for a full-coverage restoration in an anterior tooth with palatal endodontic access and the loss of both marginal palatal ridges.[3] In vitro studies show that similar lesions in posterior teeth significantly benefit from partial or complete cusp coverage, with a preparation that usually needs to reach the dentin to ensure minimal restorative thickness, contrary to anterior teeth where enamel preparation can be minimized.[4] Posterior teeth also demand more resistant restorative materials than those required for anterior teeth. For example, layered feldspathic porcelain does not guarantee acceptable long-term results in cusp coverage restorations in posterior teeth, whereas it does in anterior teeth. In the posterior region, more resistant, reinforced glass-ceramics should be used as adhesive materials.[5]

Materials for posterior partial adhesive restorations

Some review studies show significantly higher long-term survival for ceramics compared with composites. A recent review and meta-analysis suggested a survival rate for partial ceramic and composite restorations of about 90% at 5 years.[6] The 10-year survival rate for ceramic restorations seems to be around 85%,[6] but this rate probably drops

to 80%[7] in composites. Nonetheless, most reviews state that there are still not enough well-conducted studies to clearly prove the clinical superiority of ceramics.[6]

Composite resins can provide acceptable long-term clinical behavior[8] at a lower cost than ceramics and are easily available to most dental professionals. Their use is very appealing in posterior teeth since they can be used directly in a noninvasive or minimally invasive approach and are easier to repair, making them appropriate for younger patients and for testing occlusal changes in more extensive rehabilitations. They also provide less abrasion on the opposing teeth compared with ceramics.[9] Within the use of composite resins, indirect restorations allow a better anatomy/contact point, the material shrinkage is limited to the cement gap, and better physical properties are provided due to the improved conversion of polymerization.[10] Nevertheless, there are no significant differences concerning the survival of direct versus indirect composite resins in the medium to long term.[11] The main concern with composite materials with an organic matrix is the loss of physical and optical properties due to hydrolysis in the oral environment. However, they are easily fabricated chairside through CAD/CAM technology. CAD/CAM allows the use of composite resin blocks with improved physical properties,[12] but it is still unknown whether they provide significant advantages regarding organic degradation over traditional resins in long-term oral function.

If a ceramic material is chosen, monolithic leucite-reinforced or lithium disilicate glass matrix ceramics seem to be the safest option when adhesion is performed due to their high fracture resistance within the etchable ceramics group. They are also versatile as they can be pressed or CAD/CAM milled and easily stained for adequate esthetics for posterior teeth. Both materials have acceptable behavior in clinical studies, but lithium disilicate will likely have better long-term performance in more challenging situations due to its higher intrinsic flexural strength.[5]

Adhesive cementation can be carried out with light-cured resin cement or heated composite with proper treatment of the restoration interface (dentin, enamel, dentin sealing resin coat or composite buildup) and proper surface conditioning of the restoration. Heated composite may provide some advantages compared with resin cement as a luting agent such as easier removal and better biomechanical properties. However, there is still no evidence to prove that they provide clinical advantages in the long term compared with resin cement.[13]

Coverage, Adhesion, and Resistance

Based on the above clinical factors, it is important to try to apply a rational thought process that provides helpful, logical, and simplified guidelines to implement when making choices for restorations. In order to do this, an analysis of sequential degrees of tissue loss is considered below as well as the clinical implications. In order to clarify the insights, the different aspects of the CARES concept – **c**overage, **a**dhesion, **r**etention, **e**sthetics, and **s**ubgingival management – are presented in parallel.

How much residual functional tissue is maintainable?

To correctly analyze tissue loss, 'maintainable functional tissue' must be defined. The first requirement is that it should be supported underneath by healthy noncarious tissue. Even though there is some evidence of tissue remineralization when sealed from the oral environment, from a prosthodontic perspective this is not advisable. It is also not

Table 1 Structural factors and clinical context to consider when deciding on preventive cusp coverage

STRUCTURAL FACTORS	Central cavity depth	Interaxial dentin	• The most decisive factor seems to be the combination of cavity depth versus wall thickness • Cavities deeper than 4 mm (as in ETT) will significantly benefit from cusp coverage if remaining walls have 3 mm or less • In shallow cavities (up to 3 mm), the walls need to be less than 1–2 mm for coverage indication • These are thought processes rather than strict guidelines and clinical context may have an influence
	Buccal and lingual walls		
	Marginal ridges and contact points	• Its preservation or inclusion in the preparation depends on the possibility of assuring a minimum of sound tooth structure of 1 mm and a minimum of occlusal thickness depending on the restorative material and substrate • Clinical context is also decisive regarding preserving or including the contact point in the restoration	
	Enamel cracks	• Coverage of the cusps affected by cracks seems to be advisable	
	Cervical lesions	• If axial preparation is needed for resistance or esthetics, cervical lesions should be included; otherwise, they can be effectively restored with direct composite	
CLINICAL CONTEXT	Occlusal load	• Clinical signs of excessive occlusal load are decisive factors that increase the need for cusp coverage and the inclusion of marginal ridges/contact points in the restoration	
	Carious risk	• Increased caries risk will favor decisions to include more marginal ridges/contact points to minimize the need for future restorative revision and repair due to interproximal secondary caries	
	Erosive risk	• Clinical history and signs of increased erosive risk will lead to the inclusion of more dental surfaces in the restoration in the areas more exposed to the erosive agent	

clear whether restorative materials can effectively substitute dentin under unsupported enamel.[14] Moreover, there are technical challenges in successfully removing carious tissue from underneath occlusal enamel. Once unsupported tissue is removed, the second requisite is a minimal wall thickness that must be maintained, the measurement of which is not clear in the literature. Most authors recommend a minimum wall thickness of between 1 and 2 mm in order for a posterior tooth to be directly restored without cusp coverage. Therefore, it is recommended that unsupported tissue be removed and thin walls be vertically reduced until a minimum wall thickness of 1 mm is achieved.[15]

Replacement of lost tissue or preventive cusp reduction?

A pivotal decision to make is when preventive reduction for adhesive coverage is appropriate or when to perform adhesive replacement limited to lost tissue since this will lead to completely different restorative approaches. This decision will depend mostly on structural factors and the clinical context such as functional load.

Structural factors to be considered (Table 1):

- Central cavity depth, including the endodontic access cavity, if present (pulp chamber roof loss).

- Buccal and lingual walls.
- Interproximal marginal ridges and contact point.
- Enamel cracks.
- Cervical lesions.

As demonstrated in several in vitro studies, these factors act interdependently in their contribution to overall fracture risk, making clinical decisions difficult. First, it is important to distinguish classical in vitro studies on cusp coverage before adhesive procedures (amalgam, gold, and other cast metals) from contemporary studies that should now be considered, where adhesive technology is used with resins and ceramics. The interaxial dentin in the tooth center (dentin around and above the pulp chamber) has been consistently established to be the most important factor in posterior tooth resistance. The amount of interaxial dentin can be expressed as a conjunction of the cavity depth and peripheral dentin loss. Therefore, interaxial dentin loss depends on the cavity depth (including endodontic access cavity) as well as the remaining wall thicknesses. The more the interaxial dentin loss, the more likely the remaining walls will be prone to residual stresses and fracture.[16] Although several authors have proposed guidelines for the minimal wall thickness threshold in order to decide whether cusp coverage should be performed, there is not enough scientific clarity on this.

In vitro studies suggest that cavity depth is significantly more important than buccolingual wall thickness.[17] For example, in vitro studies show that molars with MOD cavities with up to 3-mm depth do not seem to have significantly increased fracture risk, even with walls as thin as 0.5 mm. Once the occlusal preparation depth reaches 5 mm, as in deep cavities of vital teeth or in endodontically treated teeth (ETT) where the pulp chamber becomes part of the occlusal cavity, the risk of fracture is high, even with 3.5-mm–thick walls.[17] On the other hand, a simple endodontic access cavity, and consequently a preparation deeper than 5 mm, without any other associated structural loss, does not cause a significant reduction in tooth stiffness. However, if the access cavity is associated with the loss of marginal ridges and contact points, the tooth is structurally compromised.[18] Therefore, there is an interdependent relationship that needs to be considered between cavity depth, remaining wall thickness, and marginal ridge/contact point involvement.

The presence of enamel cracks (incomplete fractures without noticeable separation) is another factor to consider regarding the decision about cusp coverage,[19] since they can progress into the dentin. Transillumination can be very helpful to identify these cracks. Cracks that might demand a restorative approach will cause a defined light blockage in a transillumination analysis. Craze lines, on the other hand, are physiologic findings on enamel and are not considered to be biomechanically susceptible zones; they will provide a continuous light passage in a transillumination analysis.[19] If the examination reveals that cracks are present, most authors recommend that the respective cusps be covered because the risk of propagation and fracture seems high. However, what is not clear is whether the preparation should continue to completely remove the asymptomatic cracks, in case they extend further than the required space for the restorative material.[20]

Cervical lesions can affect stress distribution and resistance, but composite resin restorations can effectively reestablish biomechanical characteristics to values similar to unrestored teeth.[21] Therefore, the presence of cervical lesions may not be a decisive factor for cusp coverage if composite resin restorations are to be performed. However, in case additional axial

preparation is considered in order to increase resistance, or for esthetic reasons as discussed below, then the cervical margin will have to extend to the cervical lesion. Nevertheless, the etiology of the lesion needs to be addressed (abrasion, abfraction, erosion, and periodontal recession) for adequate prevention or treatment. This frequently involves improving local soft tissue conditions, identifying and controlling brushing (abrasion), dietary habits (erosion), and occlusal management.

The functional load is an important factor for making decisions about cusp coverage. A tooth more posteriorly positioned in the mouth, the presence of bruxism, and the absence of protective anterior guidance during excursions will potentially promote higher loads. Bruxism is known to be associated with higher prevalence of mechanical technical complications in prosthodontic treatments.[22] The presence of erosion is also a modifying factor that can reduce enamel thickness. If left untreated, not only can it deteriorate the remaining dental tissue but it can also damage restorative materials that contain organic components such as composite resins.[23] These factors will make a decision in favor of coverage more likely, even in teeth with less structural loss.

Notwithstanding how interdependently these factors may act, mistakes in clinical decisions may compromise tooth survival, with high biologic and financial costs – for example, where an irreparable fracture could have been prevented if some or all of the remaining cusps had been correctly covered. Therefore, it is important to present clinical guidelines that constitute a balance between minimally invasive procedures and protective strategies in cases with significant fracture risk. In order to do this, quantification of the remaining structure needs to be considered, based on available in vitro and clinical evidence.

When should a simple adhesive replacement of lost tissue be performed, without cusp coverage?

As stated above, posterior teeth with sufficient interaxial dentin – central occlusal cavity up to 4 mm (ie, vital teeth, without an endodontic access cavity), buccal or lingual wall thickness of at least 1 mm, absence of cracks or other signs of heavy mechanical and chemical stresses – do not seem to need preventive cusp coverage[17] (Figs 2 and 3). A direct adhesive restoration limited to lost tissue seems the most reasonable treatment to perform. Any additional tooth preparation should be limited to beveling enamel margins for adhesive optimization. Even though 1 mm is being considered as the minimum thickness (for up to 4-mm–deep central cavities), to avoid cusp coverage, judgment of the clinical context such as high occlusal loads, enamel cracks or erosive action may ligitimize a decision to cover the cusps in these cases, even with 2-mm–thick walls. With shallow central cavities up to 4-mm deep, and a remaining wall thickness of 1 to 2 mm, the use of an indirect restoration without cusp coverage (an inlay) may not provide significant advantages over a direct composite restoration as it creates a more invasive preparation at a higher cost without a clear clinical advantage.[24] Since the restorative volume is reduced in these shallow cavities, the polymerization depth is effective, shrinkage and stress on the remaining walls is potentially lower, and an effective contact point is clinically predictable (Fig 3).[25] Although these numerical recommendations can be helpful, they should be seen more as an evidence-based thought process; a flexible clinical guideline rather than a strict decision tree.

When should preventive reduction for adhesive cusp coverage be performed?

When the cavity depth is 5 mm or more – as is the case of ETT or deep cavities in vital

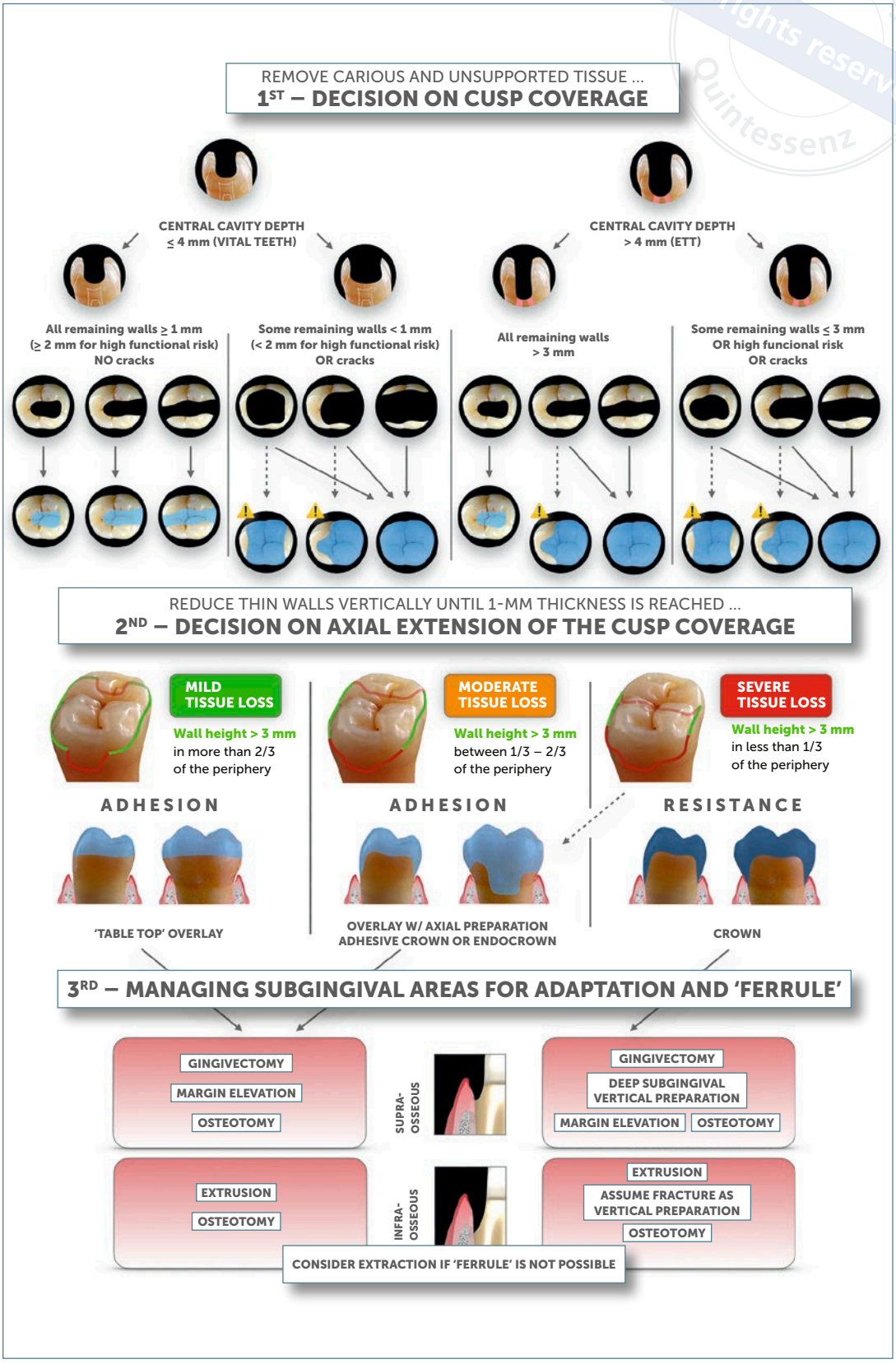

Fig 2 Decision chart for posterior teeth for cusp coverage, axial extension, and subgingival management.

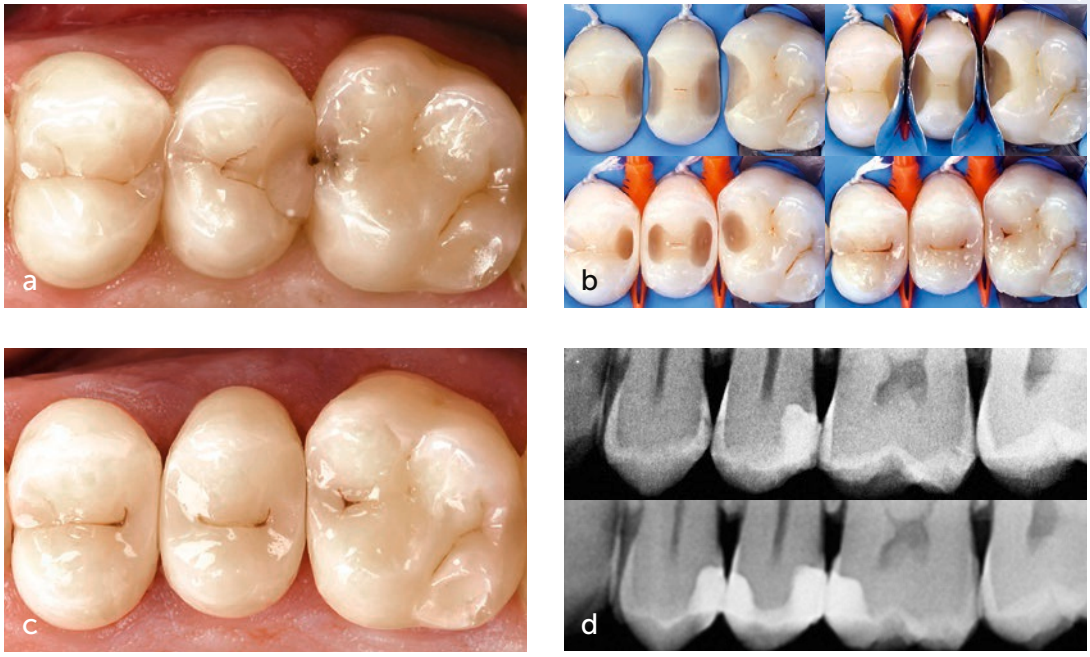

Fig 3 (a) Initial situation with caries on premolars and first molar. (b) Removal of carious tissue, removal of unsupported enamel, absent or shallow central cavities with remaining walls thicker than 1 mm – therefore, a direct adhesive restoration was performed. (c) Result at 3 years. (d) Radiographs of initial situation (top) and at the 3-year follow-up (bottom).

teeth – and is associated with marginal ridge loss, then cusp coverage needs to be considered, even for teeth with remaining walls of 3-mm thickness. In these deeper cavities, the volume of interaxial dentin loss is significantly higher, and more stress is present in the preserved walls (Fig 2).[17]

It is worth mentioning the suggestion of some authors to use fiber or short fiber-reinforced direct composites in large cavities as a possible alternative to more complex indirect restorative treatment. The idea behind this is that the improved biomechanical and physical properties of these direct materials may reduce the need for cusp coverage in large cavities, including ETT, as is shown in some in vitro studies.[26] However, other in vitro studies show that fiber-reinforced composites cannot replace the need for cusp coverage.[27]

Selective or complete cusp coverage?

It is generally accepted that indirect posterior restorations can be classified as inlays (no cusp is covered), onlays (at least one cusp covered), and overlays (all cusps are covered). The choice for maintaining some cusps (onlay restoration) or covering all cusps (overlay restoration) depends, again, on structural and functional factors (Fig 2). There can be structural factors indicating a need for coverage in the mesial cusps (deeper cavity, thinner walls or ridge loss in the mesial area) but not in the distal area. Tissue preservation would be the obvious advantage of maintaining some cusps, but there are some disadvantages, depending on the situation. In patients with a high caries risk, the interproximal area that has been preserved may develop a lesion in the future. A revision treatment might be simple if

the previous restoration is a resin since a predictable adhesive repair protocol can be performed.[28] If the previous restoration is a ceramic, some difficulties regarding repairs can be expected. Even though bonding of ceramics with a thin luting resin agent shows excellent long-term behavior, in the present authors' experience, repairing ceramic fractures with higher volumes of composite resin does not seem to produce the same predictable clinical results, probably due to different elastic moduli. An additional perspective is that tooth–restoration interfaces on the occlusal surface in teeth that are highly susceptible to deflective forces may also present a weak point for margin degradation.[28] Therefore, before deciding to preserve some cusps, the clinician should consider the age, carious and functional risk of the patient, and management of secondary caries or fractures.

How much vertical reduction is needed for cusp coverage?

Studies suggest between 1 to 2 mm as the minimum vertical reduction for cusp coverage, depending on material choice. CAD/CAM composite resin and lithium disilicate-reinforced glass-ceramics seem to need less reduction (around 1 mm),[29] while CAD/CAM feldspathic and leucite-reinforced glass-ceramics need more occlusal volume (closer to 2 mm; Fig 4).[30] When the enamel is preserved on the occlusal surface, such as in cases with a raised vertical dimension where occlusal reduction is not needed, the material thickness can be reduced due to the higher stiffness of the substrate.[29]

Occlusal preparation design for cusp coverage

Cases of complete cusp coverage, where no additional axial preparation is performed, have been referred to in the literature as overlay 'table tops' or 'occlusal veneers.'[31] In these cases, where most of the remaining wall height is more coronal to the tooth equator, there seems to be no biomechanical reasons for additional axial preparation, as explained later in this article. This design is also possible when there are no esthetic demands to cover a buccal wall in a discolored tooth, for example.[15] The occlusal reduction should be concave following the natural concavity of the posterior occlusal surfaces (Fig 4). This anatomical preparation has been shown to be significantly beneficial as it ensures adequate thickness in the central sulcus.[32] Although no further axial preparation is needed, there are still a few possibilities regarding the peripheral finishing line on this type of preparation. A simple 90-degree butt joint would be the simplest margin to perform. However, preparing the enamel parallel to its prisms is not ideal. Bonding strength to a surface that is parallel to enamel prisms can be half of what can be achieved in surfaces that are perpendicular.[32] Therefore, the proposition by some authors to use a light chamfer or a bevel at the margin may have benefits in terms of marginal integrity and the maximal enamel surface for adhesion (Fig 4).[33] Yet, it is most difficult with these conservative margins to optically hide a transition of the restorative interface. In esthetic situations, such as in the case of maxillary premolars, a different approach might be needed, as discussed later in this article.

When should marginal ridges and the contact point be included?

A common question is when to include the marginal ridge and/or the contact point in the restoration. A lost marginal ridge will obviously be included if a decision is made to cover its adjacent cusps. The doubt usually arises when a decision is made to cover the cusps adjacent to a marginal ridge that is intact with its contact point. In most cases, it is recommended to include it in the restoration, especially when the remaining

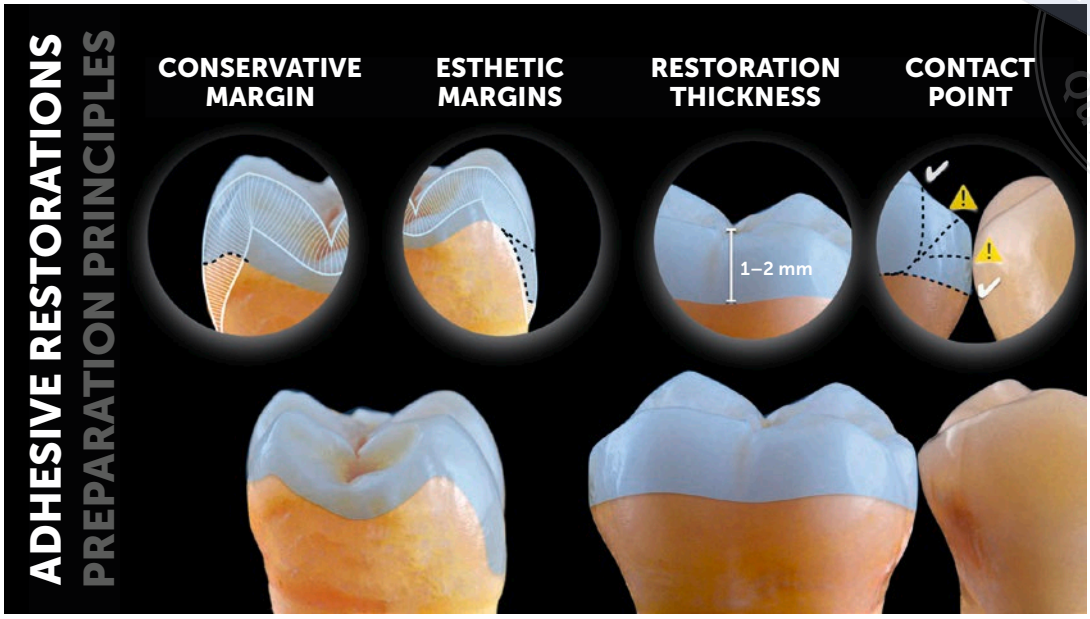

Fig 4 Indirect adhesive restoration preparation principles.

marginal ridge is less than 1-mm thick (absence of DEJ), presents cracks or the interface will be in an opposing occlusal contact (Figs 2 and 4). Inclusion of the contact point also depends on its vertical location in the interproximal area. In younger patients, there can be enough space to ensure a minimum of 1.5 mm for restorative thickness, which can include the marginal ridge in the restoration but still not reach the contact point. However, in worn teeth, the contact point is usually more occlusal, and in order to ensure a minimal restorative thickness, the contact point needs to be included in the preparation. Deciding to preserve a marginal ridge and/or contact point can pose the same risks as when some cusps are preserved – secondary caries, restorative fracture or marginal ridge fracture due to thin volumes.

When should retentive designs be added to 'occlusal veneer' or 'table top' overlays?

When to perform an 'occlusal veneer' or 'table top' only? When to further prepare? How to provide more volume to the restoration in order to restore more extensive structural damage? Not only are these common decision points, they also frame the issue in a simple, logical, and clinically relevant context. The easy answer is that these decisions are related to the remaining tooth structure, namely the enamel. The difficulty, however, is how to relate the structural loss to a specific preparation design.

It is accepted that restorations cannot rely solely on micromechanical adhesion, especially if enamel is absent since adhesion to dentin is not predictable in the long

term.[34] The more the remaining walls are compromised vertically, the less enamel is present, and a higher vectorial result in horizontal loads is induced in the adhesive interface. An extreme example would be a completely flat preparation at the gingival level that would be likely to fail due to two factors: a) The high vertical restoration volume would subject the bonding interface to a more intense tensile load; and b) The reduced enamel thickness in the gingival area would result in less predictable bonding. Therefore, it is logical to establish a minimal height of the remaining walls, below which the restoration must rely not only on adhesion (the 'table top') but also on grasping, splinting or somehow introducing additional mechanisms of resistance. However, there are no studies that objectively address this decision, only expert recommendations. In the literature to date, the decision to go from a 'table top' to a 'veneerlay'/'vonlay' (overlay with additional buccal coverage) is justified by either the esthetic need to cover the visible buccal surface or by a subjective recommendation regarding more 'extensive' damage.

In order to overcome the lack of clarity regarding this decision, the present authors propose the use of a grading division for the minimal peripheral height that will dictate clinical decisions. It is important to note that this evaluation is performed after caries removal and the clearance of unsupported enamel as well as after the vertical reduction of thin walls until a minimum of 1-mm thickness is reached, as stated earlier. A reasonable and practical evaluation threshold for wall height can be around the equator. Although it has some variability, it is located roughly around half the clinical crown, 2 to 3 mm coronal to the cementoenamel junction in posterior teeth in the buccal and lingual areas. This criterion can be important for the predictability of adhesive retention to enamel and, consequently, impact on the clinical decision. Apically to this area, the enamel thickness starts to significantly reduce below 1 mm (Fig 2).[35] With this reference in mind, but knowing that this should be seen more as a thought process than a strict guideline, the present authors can suggest three grades that will have a clinical impact on the restorative decision, based on the amount of remaining wall height per tooth periphery:

- *Mild tissue loss:* Remaining walls with enamel above half the height of the clinical crown (> 3 mm) in more than two thirds of the tooth's periphery.
- *Moderate tissue loss:* Remaining walls with enamel above half the height of the clinical crown (> 3 mm) between one third and two thirds of the tooth's periphery.
- *Severe tissue loss:* Remaining walls with enamel above half the height of the clinical crown (> 3 mm) in less than one third of the tooth's periphery.

In cases with mild tissue loss, the restorative technique can be a simple cusp coverage according to the criteria stated above, without any additional design – a 'table top' or 'occlusal veneer.' There is still a large peripheral enamel extension above the equator line, thicker than 1 mm. Adhesion will provide the restoration with the micromechanical stability to prevent it from dislodging along the insertion path (retention) or another oblique path (resistance; Fig 5).

Cases with moderate tissue loss have less surrounding vertical structure and enamel thickness for adhesion, and the present authors believe that these situations demand an additional adhesive area and/or complementary resistance measures. These measures can include (Fig 2):

1. Axial preparation (shoulder/chamfer/long bevel) of the walls, allowing the restoration to partially or completely brace the tooth structure – also referred to as a

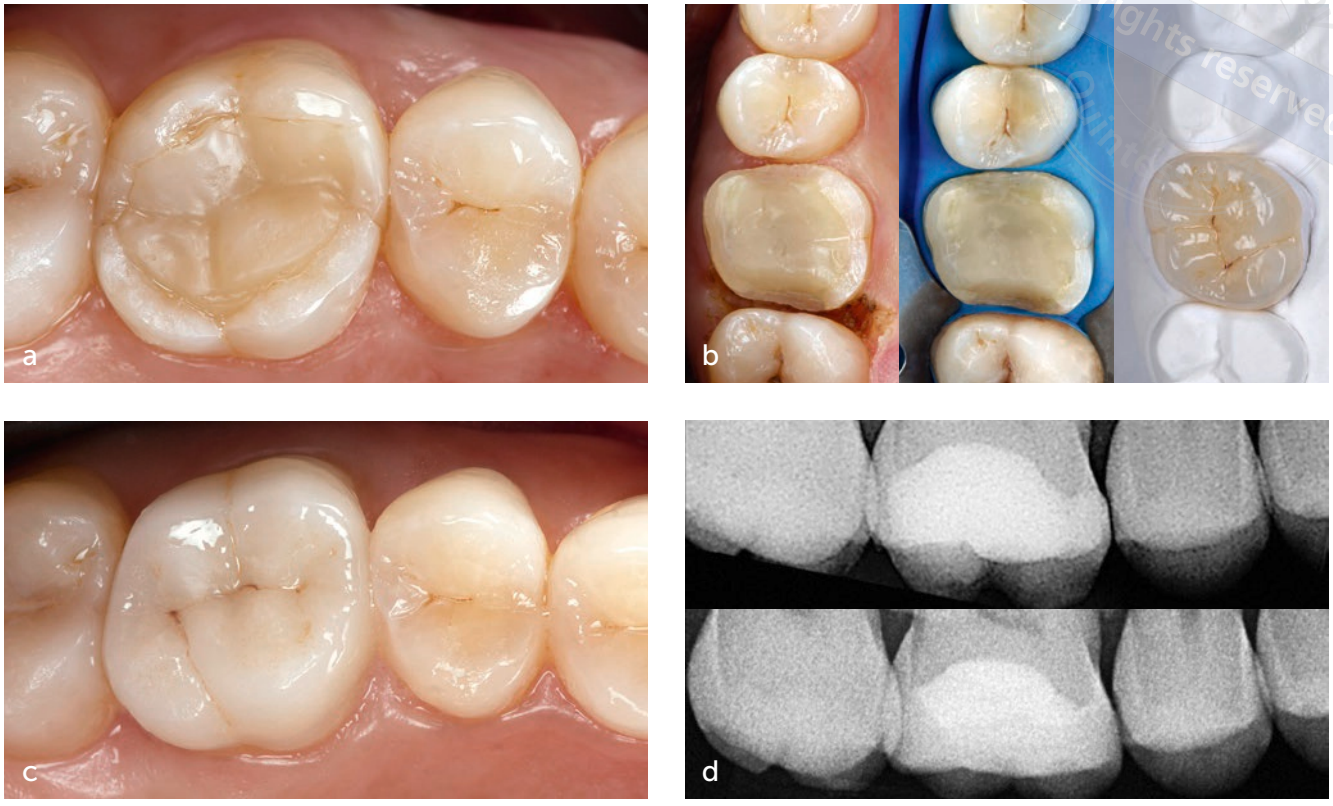

Fig 5 (a) Initial situation of a vital maxillary right first molar showing clinical signs of infiltration on the restoration margin. The central cavity was 3-mm deep, with remaining walls of < 1 mm in some areas. The history and clinical examination revealed signs of centric bruxism, and there were visible cracks in the interproximal walls. A full cusp coverage restoration was planned. (b) The previous restoration was redone and a gingivectomy was performed under rubber dam isolation on the subgingival area for better marginal finishing. Adequate remaining walls in more than two thirds of the periphery were present; therefore, a simple 'table top' indirect restoration was indicated without the need for additional preparation for retention. Contact points were included in the preparation/restoration since the existing enamel cracks were removed. A conservative margin was selected as it was a less visible molar and no discoloration was present. A CAD/CAM-milled and stained lithium disilicate 'table top' was fabricated. (c) Restoration after bonding. (d) Initial (top) and 3-year postoperative (bottom) radiographs.

'long wrap overlay' or a full contour 'adhesive crown,' respectively.
2. The use of the pulp chamber in cases of endodontically treated teeth – an endocrown.
3. Both of the above – an endocrown with peripheral axial preparation.

The use of posts does not seem to provide benefits in partial adhesive posterior restorations when cusp coverage is performed since enough remaining structure is usually still present.[36] The amount of remaining tooth structure to which a restoration can bond or engage around ('ferrule' effect) seems to be more important than the use of a post.[37] Therefore, posts may eventually be more indicated for build-up reconstructions prior to full-contour resistance form crowns, where more extensive tissue losses compromise tooth flexural strength. However, no fundamentalist doctrines for or against the use of posts have been clearly supported by scientific evidence. In borderline cases,

even in adhesive restorations, the clinician may decide that the buildup needs additional retention/resistance, and a post may be used according to certain considerations (discussed in Parts II and III of this article series).

In cases of severe tissue loss, endocrowns can be considered. However, when adhesion is not predictable, resistance-form preparations for full-contour crowns (discussed in Part II of this article series) may have a better prognosis.

Which resistance measures can be added to partial adhesive restorations? Peripheral axial preparation or using the pulp chamber (endocrown)?

Peripheral axial preparation for additional adhesive area and resistance

Shoulders and chamfers as a form of peripheral axial preparation have been associated with higher long-term survival of onlays.[38] A marginal design in silica-based ceramic materials demands particular attention since these materials are more prone to marginal chipping than composite resins.[39] However, as discussed initially, lithium disilicate seems to be the most reasonable ceramic material to consider for posterior adhesive restorations since thinner preparation designs have been providing good clinical results. The shoulder may provide a safer marginal design biomechanically than a bevel,[40] and 1 mm can be considered the minimum thickness for the material in the axial area.[41] Since thickness of enamel drops below 1 mm apically to the equator level,[35] a common doubt exists: a) Should the axial preparation be limited to enamel and compromise ceramic thickness, especially below the equator level?; or b) Should the ceramic thickness be maintained, irrespective of the loss of some of the enamel area? The thickness of monolithic ceramics can be reduced in the occlusal area if enamel is present. However, when an axial preparation is added to the occlusal reduction – a so-called 'vonlay' or 'veneerlay' or a full adhesive 'crown' – the material is subject to different tensile forces. For monolithic ceramics in the posterior area, the literature seems to favor keeping the ceramic thickness adequate and allowing some preparation into the dentin in the axial areas,[41] while trying to maintain some enamel at least in the margins when the preparation needs to extend below the equator for structural or esthetic reasons. Therefore, cervical lesions should be covered by the ceramic restoration, ensuring that a previous direct composite is performed to reduce lesion depth, preventing undercuts and unnecessary tooth preparation. However, in premolar teeth, especially in restorations mainly for esthetic reasons, it seems reasonable for the preparation to remain in the enamel, using the same strategy as for veneers in anterior teeth.

Another important consideration is that the buccal or lingual axial preparation margin should extend into the interproximal zones to gradually connect to the finishing line in that area whenever marginal ridges have been reduced, so that the contact point is included within the restoration (Fig 6).

Endocrown – use of the pulp chamber for additional adhesive area and resistance

While in the case of an onlay or overlay the pulp chamber is previously restored with a direct restoration, the 'endocrown' uses the pulp chamber for additional adhesive area and resistance of the indirect restoration itself (Figs 2, 7, and 8). Recent reviews reveal high long-term success rates of endocrowns, comparable with post and crown restorations for molars and premolars.[42] Although promising, this modality needs to be considered carefully due to the limited number of available clinical studies. It is not clear whether adding a peripheral axial 'ferrule'

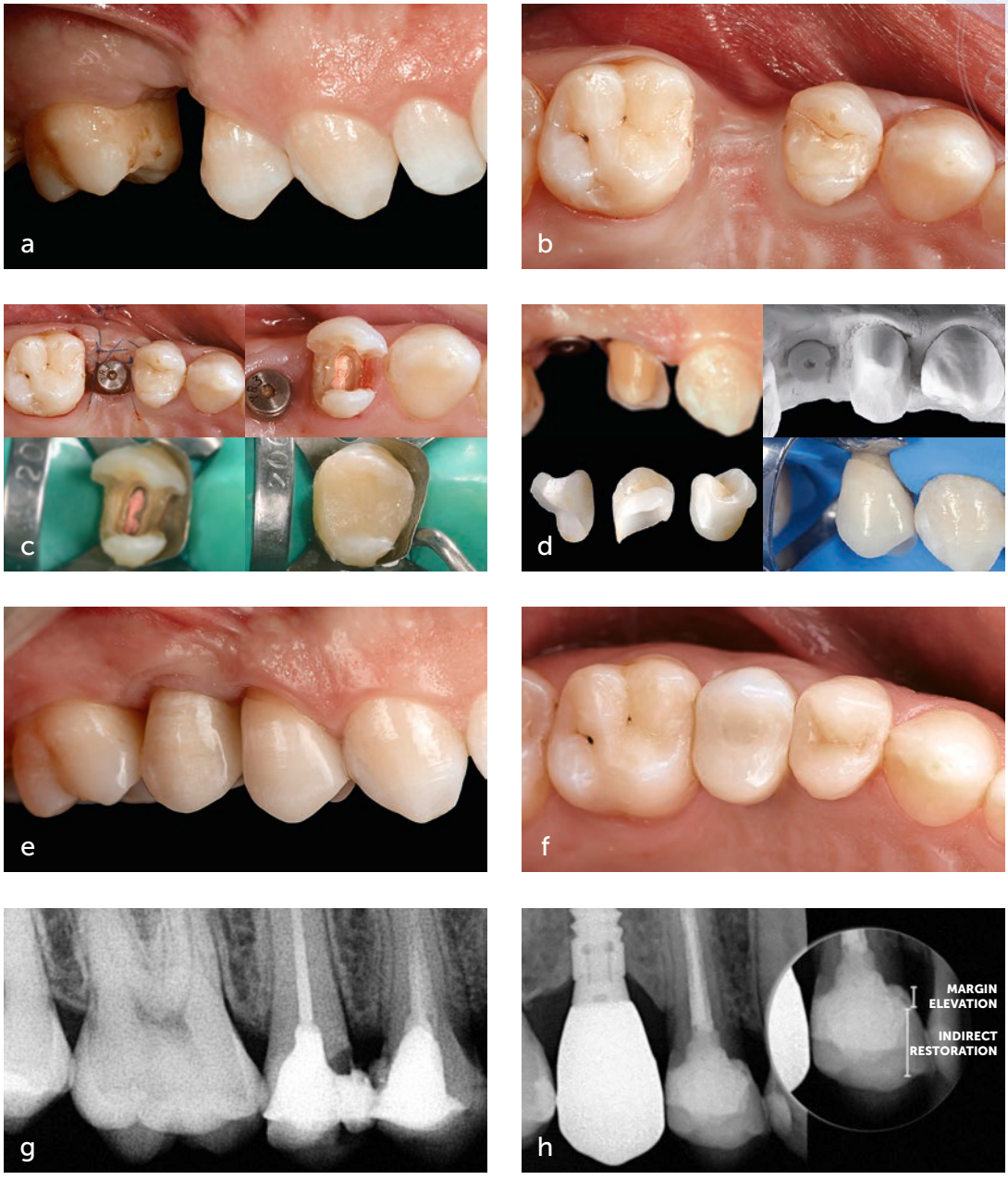

Fig 6 (a) Initial situation: buccal view. (b) Initial situation: occlusal view. (c) Implant placement and soft tissue graft to increase buccal volume on tooth 15. Removal of existing restoration and evaluation of remaining vertical walls above the equator and its presence in between one and two thirds of the periphery on tooth 14. An adhesive indirect restoration with peripheral axial preparation was selected. A previous direct restoration was performed to elevate the future interproximal margins and core buildup. (d) Final preparation for the adhesive restoration, creating axial preparation for esthetics, additional retention, and adequate margin elevation for a correct emergence profile and contact point of the restoration with the adjacent teeth. An indirect monolithic lithium disilicate restoration was bonded. (e) 7-year follow-up: buccal view showing minimally stained ceramic margin. (f) 7-year follow-up: occlusal view showing normal signs of wear on tooth 14 (with monolithic lithium disilicate), probably less wear than that shown on the monolithic zirconia implant crown on tooth 15. (g) Initial radiograph. (h) Final radiograph at the 7-year follow-up showing the tooth structure, margin elevation, and ceramic restoration interfaces with apparent stability. The mesial contact point of the implant has been lost due the mesial migration of the teeth with age, which is a well-known phenomenon.

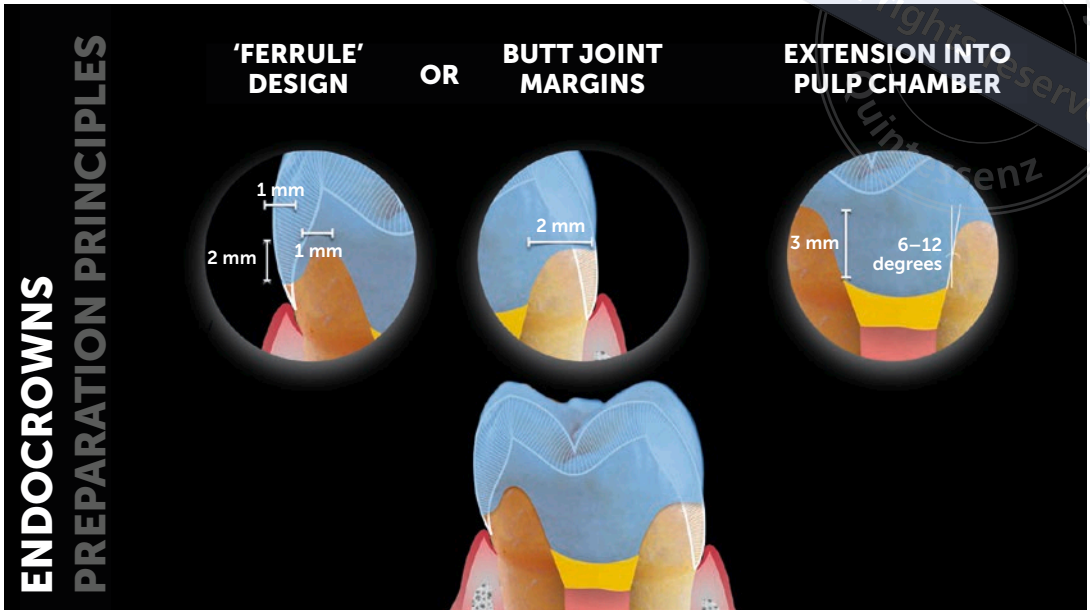

Fig 7 Preparation principles for endocrowns.

Fig 8 CAD/CAM-milled lithium disilicate endocrown with peripheral axial shoulder preparation as seen in the mirror reflection of the intaglio surface.

design to an endocrown preparation provides significant advantages since conflicting studies exist in the literature.[43] However, there is some evidence that premolars benefit from a 'ferrule' design more than molars.[44] Additional recommendations from a recent review include an extension of around 3 mm into the pulp chamber with a divergence of 6 to 12 degrees, and a cervical marginal width with a minimum of 2 mm with a flat or slightly beveled margin.[42] The height of endocrowns can easily reach 8 mm (the normal crown height of posterior teeth) or more. Even though an effective curing depth of up to 8 mm has been achieved in some in vitro studies with more translucent ceramics,[45] for higher distances or whenever the opacity is questionable it seems advisable to use a dual-cure resin cement.[45]

Previous buildup and dentin sealing

Directly restoring the cavity after removing damaged, unsupported tissue before the preparation has several advantages. Smooth surfaces can be created and retentive areas filled, avoiding undercuts and the unnecessary preparation of tooth structure to create convergent walls for insertion. Unless an endocrown has been chosen for the restoration, the pulp chamber is completely filled with a direct composite resin – the buildup (Fig 6).

Freshly cut dentin should be simultaneously sealed with an adhesive system with a high inorganic load or, ideally, the addition

of composite resin (flowable or packable). This will prevent dentin contamination and hypersensitivity during temporization and dissipate the polymerization tension of the adhesive interface while bonding, thus increasing immediate dentin bond strength, compared with adhering the restoration directly onto the dentin without previous sealing.[46] Besides a few in vitro studies, data are lacking regarding long-term clinical advantages of dentin sealing, except that it seems to increase long-term restoration survival when the dentin occupies more than 50% of the surface for anterior veneers.[47]

When should the transition be made from an adhesive restoration to a resistance-form crown in the clinical decision?

Using the same pragmatic logic of remaining vertical height per tooth periphery, in cases of severe tissue loss – remaining walls above half the tooth's height (> 3 mm), in less than one third of the tooth's periphery – the amount of enamel available for adhesion is significantly limited. As previously stated, there are promising clinical data concerning the long-term performance of adhesive endocrowns in cases with a limited amount of peripheral enamel. Given the good clinical results, even in cases without a 'ferrule' design, endocrowns can be considered in teeth with severe tissue loss; for example, when all the walls are less than 3 mm while still supragingival, exhibiting a thin but fully present enamel layer throughout the periphery. Although there have been promising studies for the clinical performance of endocrowns, a traditional high-strength restorative material with a resistance-form preparation (crown) still has important long-term scientific support that justifies its use in severely damaged teeth. When adhesion is not reliable (limited or absent enamel), it is the crown engagement, grasping or embrasure in the tooth structure (creating a 'ferrule' design) that is mainly responsible for the restoration resistance.[48] These types of resistance form preparations, traditionally referred to as 'crowns,' are fully discussed in Part II of this article series.

Esthetics

Posterior teeth are less visible and are therefore less of an esthetic concern. However, this is not true for all patients, as some have higher esthetic expectations and may not accept or understand an esthetic compromise in favor of tissue conservation. For this reason, in order to manage these expectations, it is important that clear explanations and good communication is developed before the start of treatment.

Esthetics in posterior teeth can involve: a) Blending of the optical properties of partial restorations between the restored and preserved areas within a tooth in more visibly exposed buccal/occlusal areas; and b) Blending of the optical properties between the restored and adjacent teeth.

Regarding optical integration in partial restorations, what needs to be considered is that, in vital teeth, a successful immediate optical blending of the restorative material with the remaining structure will probably be maintained in the long term. However, uncovered areas in nonvital teeth are very likely to become progressively discolored with time.[49] While some patients may accept this color contrast and understand the conservative advantage, others may be dissatisfied, even in areas that seem less exposed during smile. Moreover, the preparation depth/restorative thickness needs to be addressed in case of discoloration. Heavier discolorations may need a preparation that goes into the dentin and might demand a subgingival margin. This can eventually change the conservative/adhesive restorative decision that was exclusively based on

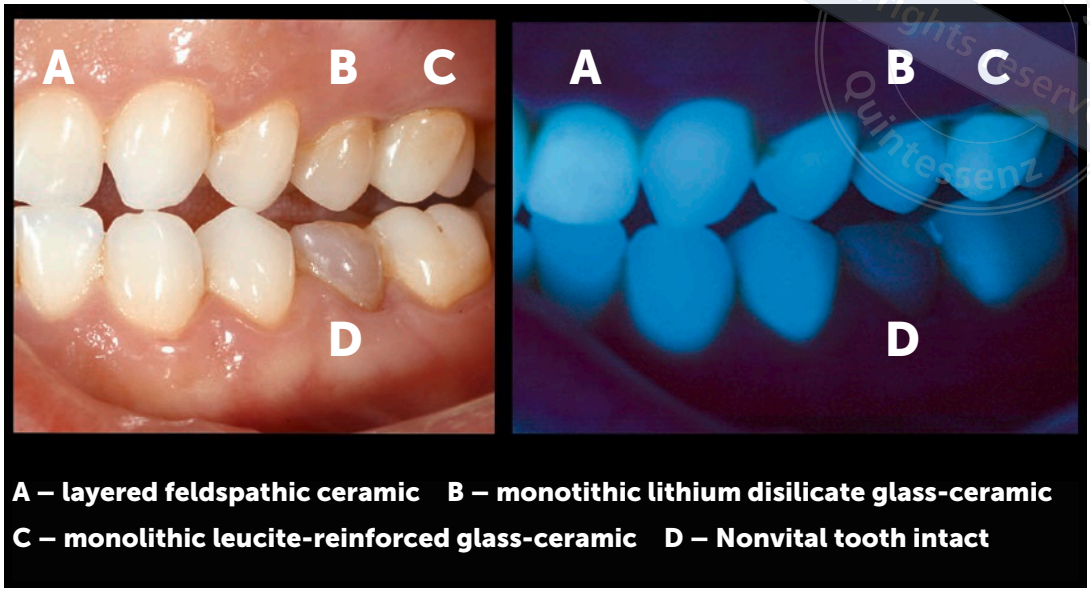

Fig 9 Fluorescence behavior of different ceramics: natural vital and nonvital teeth. The lithium disilicate on tooth 25 has almost no fluorescent behavior, even though the composite used to bond it can express some of it through the restoration. Non-fluorescent materials provide a less natural result, especially in different light conditions.

remaining tooth structure into a more resistance form approach as enamel is removed. Therefore, options should be discussed with a patient to find a balance between a conservative approach and esthetic satisfaction (Figs 4 and 6).

In terms of optical integration with adjacent teeth, especially relevant in maxillary premolars, it is important to realize that the use of monolithic ceramics is far from being as predictable regarding the match with natural teeth as layered ceramics. However, monolithic multilayered blocks can be helpful to mimic different translucencies within the restoration. Monolithic restorations that are stained or minimally layered in nonfunctional areas need to be mastered in order to create optical illusions of depth, translucency, and value/brightness, especially if the adjacent teeth are natural and the patient is young. In heavily discolored teeth, the need to hide the substrate may require a preparation depth of more than 1 mm, removing remaining enamel and reducing bonding performance.[47] For this reason, these situations may also demand additional resistance form measures – or even the decision for a full-contour resistance form preparation – and for the adhesive option to be discarded. Internal bleaching can also be performed, analyzing risks and potential benefits, always considering that color stability in the long term is not predictable.[47]

Fluorescence is a critical but often neglected part of the optical result that will provide better metameric behavior (less variability in different light conditions) and will result in less shadowed cervical areas, especially in dark substrates. It can increase value/brightness without affecting translucency, especially important to nonvital teeth that lose fluorescence properties. Lithium disilicate and zirconia, for example, have a very low fluorescence and brightness/value compared with natural vital teeth (Fig 9).[50] For these reasons, implementation of

fluorescence is particularly important in dark teeth through the use of proper ceramic ingots and fluorescent glaze or by layering fluorescent feldspathic porcelain.

Subgingival areas

As shown in Figure 2, once decisions have been made regarding, firstly, the need for coverage, and secondly, the choice of an adhesive partial restoration, the subgingival areas can be addressed. For mild to moderate tissue loss to be restored with partial adhesive restorations, possible approaches to manage these areas are soft or hard tissue removal (gingivectomy or osteotomy) or margin elevation or a combination of both. Extrusion can additionally be considered. Strategies and indications for subgingival management will be thoroughly discussed in Part III of this article series.

Conclusions for partial adhesive restorations within the CARES concept

Posterior teeth differ from anterior teeth by having a distinct anatomy and a more complex histologic distribution of the DEJ, enabling them to sustain higher loads. Clear guidelines are important to enable clinicians to treat these cases with minimally invasive approaches and preparation strategies, such as cusp coverage, that prevent irreparable fractures, especially in more compromised endodontically treated teeth. A few considerations are of paramount importance to better understand and clarify the CARES concept and to provide simplified and easy-to-implement clinical suggestions:

Coverage and Adhesion:

- Interaxial dentin (central cavity depth and remaining wall thickness) seems to be the most reliable parameter found in the literature to decide to simply replace lost tissue (mainly adhesive) or perform preventive cusp coverage reduction (adhesive cusp coverage grasp).
- Cusp coverage extension options need to consider the thickness of the restorative material and the possible involvement of marginal ridges and interproximal contacts as well as the advantages and limitations for each patient (carious and functional risk).
- Sealing of dentin with a preliminary direct resin coat or composite buildup will improve bonding effectiveness, allow a smoother surface, and allow less invasive preparation designs.

Resistance:

- In addition to adhesive occlusal cusp coverage, some resistance mechanisms may need to be incorporated such as further axial reduction or the use of the pulp chamber or both. This axial reduction will influence the grasping of walls and maximize the enamel surface for bonding.
- The exact criteria for additional resistance measures are not clear, but it is reasonable to use the relative amount of the height of the remaining walls in the tooth periphery as a parameter for this decision.

Esthetics:

- Esthetics, even in posterior teeth, may influence the preparation design and depth to be more cervical in order to include the buccal surface and its transition to the interproximal areas.

Subgingival management:

- Once the decision is made to provide a partial adhesive restoration, tissue removal, the elevation of subgingival areas or extrusion are possible strategies to facilitate impressions and bonding procedures in accessible margins, as will be discussed in Part III of this article series.

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