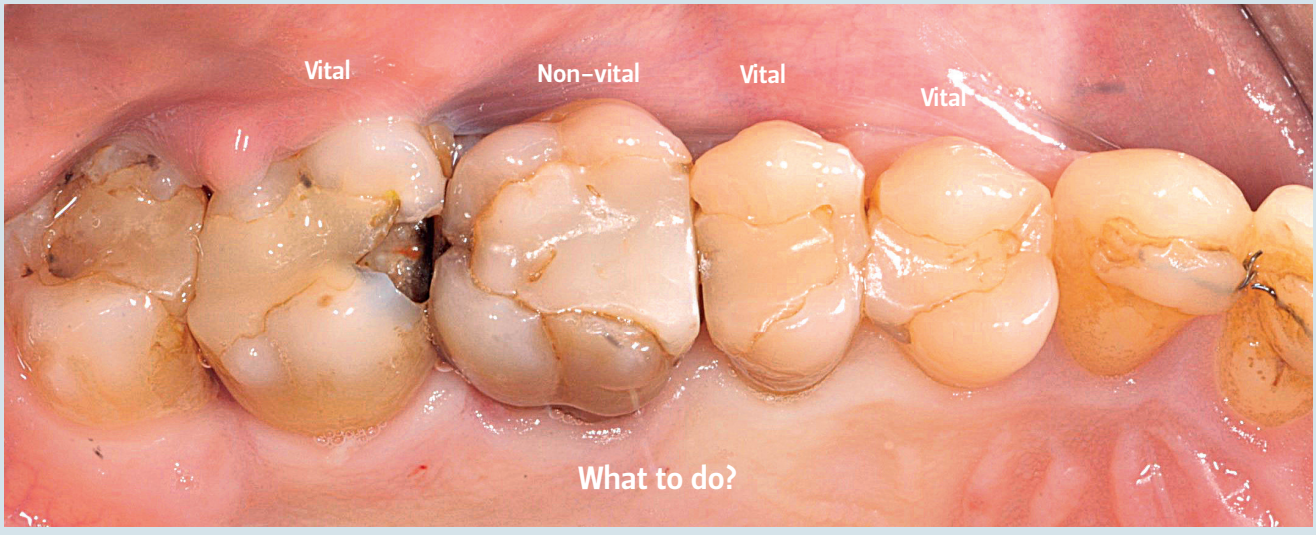
Partial tooth preparation

U. Campaner

Preparing a tooth for prosthetic purposes means removing biological tissues that will subsequently be reintegrated with a prosthesis. Dental tissues, in fact, cannot regenerate; therefore, once they are lost due to caries, trauma, or wear, they can be restored in their original shape and function only by using restoration materials.

Tooth preparation is an irreversible surgical procedure, and should therefore be carefully considered.

Deep knowledge and understanding of the various criteria to be followed are essential for making an adequate and satisfactory tooth preparation. Making an optimal tooth preparation is a daily challenge for dentists, who must inevitably find a compromise between biological needs, mechanical aspects, and aesthetic considerations. It is important to remember these principles in a synthetic manner because they are fundamental for making restorations. Although seemingly unrelated to the topic of this book, they represent the starting point that can affect the choice of the cementation method (1.1)



1.1 Fundamental principles for prosthetic preparation

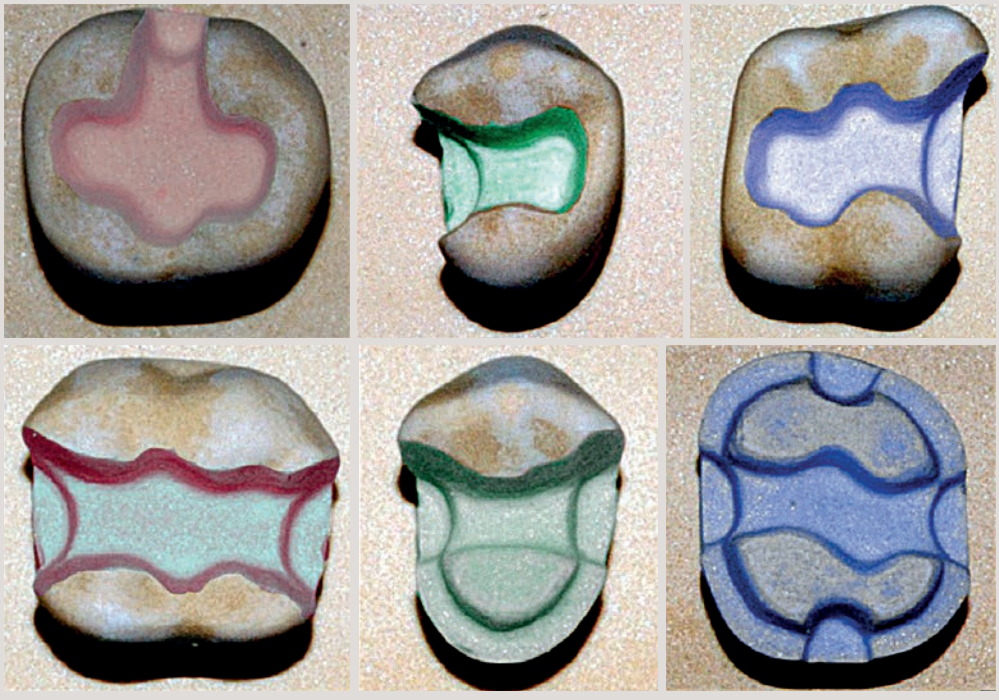
Principles	Meaning	Suggestions
BIOLOGICAL	Protection for pulp vitality (if preparations on vital teeth are performed)	· The greatest preservation possible of the residual sound tooth structure has biologic, mechanical, aesthetic, and psychological advantages.[1] The preparation technique for jacket crowns allows for adequate crown retention preservation of pulp vitality · **Excessive temperature**, **chemical irritants**, or **microorganisms** can cause **irreversible pulpitis**, particularly if they act upon newly sectioned dentinal tubules · **Magne** in his work[2] suggested **immediate dentin hybridization** after its preparation via bonding (according to the procedures for appropriate dentin adhesion). The aim is to immediately seal dentinal tubules · **Pulp vitality** is also **maintained** via the **correct use of** diamond or tungsten carbide **abrasive burs**
	Protection of adjacent teeth	· The **damaged enamel layers** are more **prone to plaque retention** and consequently more susceptible to caries · A thin and tapered diamond burr can be passed through the interproximal contact area, leaving a small "lip" or "fin" of enamel tissue to be removed subsequently using manual tools. This eliminates the need for excessive tooth reduction as well as the risk of angling the bur in undesirable directions · It is possible to use **matrices** or thin **steel matrices** blocked by wooden wedges, to apply as a protection for interproximal surfaces
	Protection of superficial and deep periodontal tissues	· Various studies have supported the use of **supragingival** or **juxtagingival finishing lines**, whenever possible, to preserve periodontal health · Schätzle et al. argued that **subgingival margins** are problematic and should be avoided whenever possible[3] · A **subgingival margin** frequently results in a **gingival inflammatory response**,[4] which might go from mild subclinical inflammation to severe inflammation with more noticeable signs such as swelling, redness, pain, bleeding, fragile tissues, and sometimes bone resorption
MECHANICAL	The shape of the prep must guarantee retention, stability, resistance and adequate marginal seal of the prosthetic restoration	· **Retention** is the **capacity to resist removal** based on the **insertion axis** of the single or multiple restoration (vertical forces)[5] · **Stability** is the capacity to **prevent displacement** due to **horizontal or oblique chewing loads** · **Resistance** refers to the **thickness** that **restoration materials** must have to reduce the risk of fracture, thus affecting the **axial and occlusal reduction** in the prepared element · **Marginal seal precision** is the interface between prosthetic restoration and apical limit of the tooth preparation (be it a finishing line or area)
AESTHETIC	They represent a balance between functional needs and requirements, different material properties and patient expectations	· **Communication** is **key** for the patient to understand the treatment options and is equally crucial to dentists to comprehend patient's expectations. **Digital dentistry** enables this process by allowing **simulations** that can be shared with the patient. · Furthermore, the digital flow allows creating a **mock-up** with which patients can make sure that the aesthetic result is up to their expectations. They may ask for changes or small modifications to be made prior to the final restoration fabrication.

General criteria for the functional and aesthetic recovery of a damaged tooth

The abovementioned daily challenge also applies to dental technicians who produce dental prostheses with the required characteristics. The success of the tooth preparation and the fabrication (by the technician) of a dental prosthesis is closely linked to the final phase performed by the clinician, i.e., cementation, which is the creation of a stable and lasting bond between the tooth and the prosthesis.

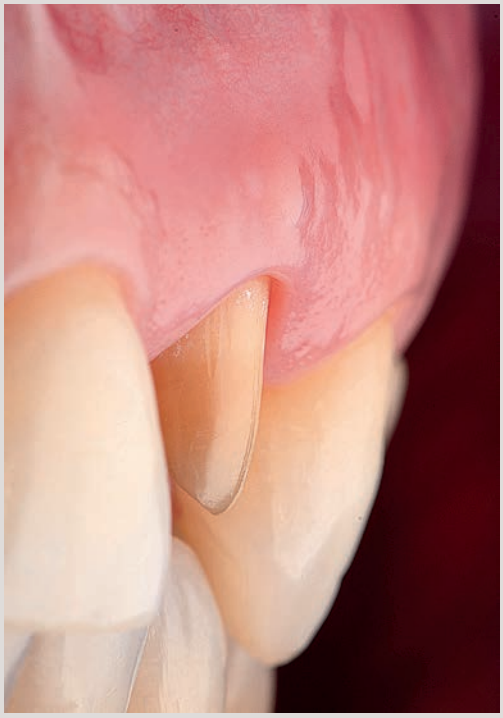
To address the topic of cementation, one must be aware of all the substrates to be interconnected and of the products that can bind them to the surrounding biological structures in a nearly irreversible manner. This concise definition hides a long series of elements that should be carefully considered. It is necessary to consider the mechanical and physical characteristics, the precise structure of the tooth concerned, and the prosthetic artifact; to achieve the intended purposes, it is necessary to carefully analyze the chemical composition and chemical reaction behind each product used to create an adhesive cementation. To this one must add considerations relative to the position and size of the prosthetic artifact. Therefore, let us summarize the prosthetic preparations for fixed dentures.

The first classification is determined by the size of the damaged portion and is represented by preparing a part of the coronal portion (inlay, onlay, or overlay) (📷 1.1) or by preparing the entire coronal portion (crown and bridge) (📷 1.2 and 1.3).



📷 **1.1** Examples of partial preparations.

1.2 Example of full coverage preparation with finishing line.



1.3 Example of full coverage preparation after completion.

Partial tooth preparations

Partial tooth preparations are those that allow complete restoration of the tooth, minimizing the area of surgical intervention, and only restoring the tooth partially.

Let us consider the partial preparations and include them in a table that provides a general overview. We shall now analyze the details of each preparation (1.2).

As shown in the table, the names themselves provide a precise indication of the amount of tooth structure to be sacrificed.

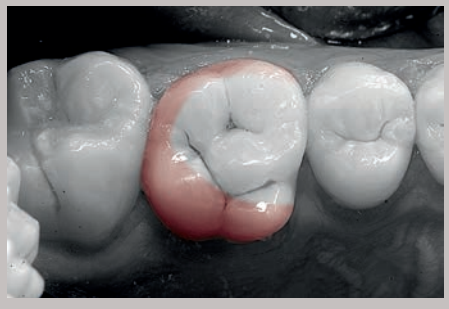
- **INLAY** between cusps: indicates that the cavity remains confined to a limited area and that the remaining tooth structure includes the natural cusps (1.4).
- **ONLAY** over the cusps: indicates that the cavity extends over one or more cusps. In this case, the reconstruction should include the missing the natural cusps (1.5–1.7).
- **OVERLAY** around the cusps: indicates that the preparation includes the entire occlusal area without covering the mesial, palatal/lingual, and buccal surfaces in their entirety (1.8–1.10).

Having said that, the question about how to perform a complete restoration arises. There are two possible scenarios: direct or indirect composite restorations (created in the lab).

1.2 Partial prosthetic preparations

Type	Definition	Tooth substrate	Substrate restoration	Isolation	Cementation
INLAY	Inlay is characterized by a preparation that remains confined between the intact cusps	Enamel and dentin	a) Composite b) Ceramic c) Gold (fused) d) Gold (cohesive)	Rubber dam	a) b) Adhesive cementation c) Calcium hydroxide d) Not required
ONLAY	Onlay is characterized by a preparation that reaches the cusps that are partially reduced	Enamel and dentin	a) Composite b) Ceramic c) Gold (fused)	Rubber dam	a) b) Adhesive cementation c) Calcium hydroxide
OVERLAY	Overlay is characterized by a preparation that involves cusps that are completely prepared	Enamel and dentin	a) Composite b) Ceramic	Rubber dam	a) b) Adhesive cementation
VENEER	The veneer is characterized by a thin restoration covering the buccal surface of teeth, particularly, in the anterior region	Enamel	a) Composite b) Ceramic	Rubber dam	a) b) Adhesive cementation
ENDOCROWN	Partial monolithic reconstructions, which replace the destroyed coronal tooth structure	Enamel, dentin and cementum	a) Composite b) Ceramic	Rubber dam	a) b) Adhesive cementation

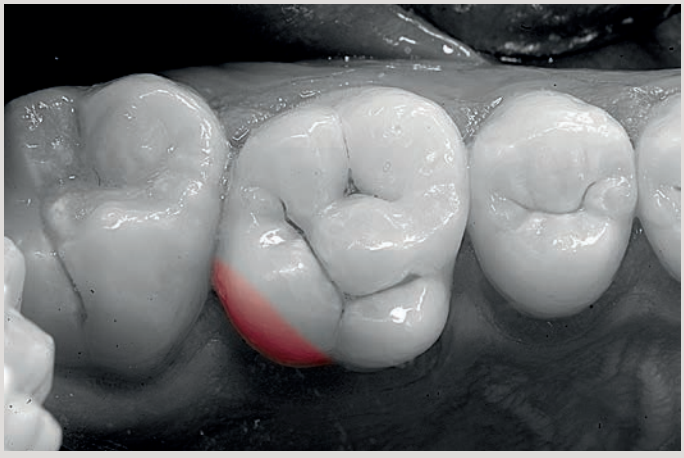
1.4 Extension of inlay.



1.5 Extension of onlay.

1.6 Onlay preparation.

1.7 Cemented onlay.



1.8 Extension of overlay.

1.9 Overlay preparation.

1.10 Cemented overlay.

DIRECT RESTORATION

Advantages

Thanks to the introduction of adhesive systems, direct restoration *only requires the removal of the decayed tissue without the need for creating a specific retention form of the cavity*. It is the most conservative type of intervention that mostly fits the concept of minimal invasiveness.

Direct restoration requires only a limited number of sessions (Clinical case 1).

- First session:
  - removal of the decayed tissue;
  - cavity preparation;
  - positioning of the rubber dam;
  - application of the bonding system, stratification, and polymerization of the composite material and finishing.
- Second session:
  - follow-up.

Direct composite restoration implies a relatively low cost for each patient and allows partial or total repairs and reconstructions.

Disadvantages

Direct restoration has a major limitation as follows: difficulty in controlling polymerization shrinkage. Polymerization shrinkage depends on the proportion between the filling material and organic matrix, as well as the level of polymerization obtained with exposure to a curing light. The greater the power of the curing light, the greater the activation depth for the reaction and the higher the level of polymerization obtained. However, one must remember that the wavelength of the emitted light must be in line with the one required by the main activator contained in the composite material. Therefore, power and wavelength are the fundamental parameters.

Clinical case 1

Direct restoration on posterior teeth

G. Derchi

The case involves the removal of amalgam filling (Q 1). After isolation of the area, the operator proceeds with the removal of the old amalgam filling (Q 2-3) and applies a matrix for distal surface restoration (Q 4-5). After the application of the Self-Etch adhesive system, the material is stratified by small increments (Q 6-7).

Q 1 Initial situation.

Q 2 Area isolation.

Q 3 Removal of old amalgam.

Q 4 Positioning and adaptation of a sectional matrix.

Q 5 Restoration of distal surface.

Q 6 Preparation with adhesive system.

The occlusal surface is modeled (Q 8–9), and once the last layer has been polymerized, it is completed (Q 10).

Final result and polishing after 24 hours (Q 11 and 12).

Q **7** Stratification.

Q **8** Modeling of occlusal anatomy.

Q **9** Occlusal anatomy.

Q **10** Complete occlusal anatomy.

Q **11** Restoration and aesthetic result at the end of the intervention.

Q **12** Control and polishing after 24 hours.

Furthermore, complete conversion of the composite material takes place within 24–48 hours after the appointment. *We shall examine in depth the concepts of polymerization in the chapter dedicated to the materials used for prosthetic restorations.*

Various studies have led to the production of high-performance adhesive systems and composite materials. However, there are still many problems as follows: possible gap formation, marginal discolorations, secondary fractures and caries, and limited duration of reconstructions, especially if these are made in areas subjected to chewing forces.[6]

Direct restorations are operator-dependent.

INDIRECT RESTORATION

Indirect restoration requires the operator to remove the damaged or decayed tissue concerned as well as the entire unsupported dental tissue, thus preparing a cavity in which the high-precision artifact can be inserted. Using an impression (analogical or digital), the shape and size of the tooth preparation are sent to the laboratory that will make the restoration. After carefully examining and adjusting the restoration, it will be cemented in the prepared cavity (Clinical case 2).

Clinical case 2

Preparation, impression, and cementation of overlay

E. Manca

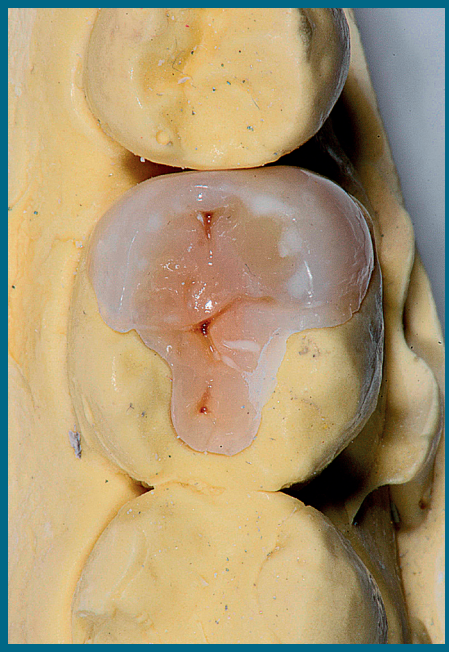
After preparation of the cavity, a precise impression is taken. In this case, the analogical technology known as double step revers (DSR)[7] developed and described by the authors, is used. After producing the artifact, the operator proceeds with cementation, making sure to extrude all the excess material. This should be removed when it reaches the plastic phase before polymerization.

1 Cavity preparation for overlay.

2 Taking impression with DSR.

3 Impression taken with DSR.

4 Working model.



5 Artifact on model.

6 Last cementation phase.

7 Check of contact points.

8 Overlay positioned in situ.

Advantages

Indirect restoration is a minimally invasive procedure.[8]

Indirect restorations require the missing portion of the tooth to be replaced by a restoration that is made outside the oral cavity to simplify the preparation. This guarantees that each part of the restoration is precise.[9]

Indirect restoration allows one of the following two materials to be chosen: lithium disilicate or composite material. The first has improved performance in terms of wear resistance; however, it is more fragile even when an adequate thickness is ensured, which is in any case greater than that required with composite. Ceramic restorations show a marginal discrepancy that is significantly greater than that for composite materials.[10] The composite material, used in the laboratory, offers similar but not superimposable characteristics. *Two factors ensure that high level physical characteristics are achieved and hence permit application in the present situation.*

- Possibility of performing light curing in every part of the restorations, to guarantee a level of conversion much higher than the one obtained chairside, increasing the physical characteristics, and allowing polymerization shrinkage to develop outside the oral cavity without generating marginal tensions and gaps.
- Possibility of using high-power curing lights which, in addition to the light energy emitted within the correct wavelength, produce heat to promote polymerization.

Compared to ceramics, composite materials require lower thicknesses to promote the concept of "minimal invasion", show an elastic modulus similar to that of the dentin, are less fragile, limit the need for endodontic treatments, and allow repairs or reconstructions overtime. Indirect restoration allows correction before cementation and repairs overtime when it is made with composite materials.

Regarding the survival of indirect restorations, there are testimonies of many authors including the recent 12-year longitudinal study on 113 indirect composite restorations conducted by G. Derchi, V. Marchio, V. Lanteri, M. Özcan, and A. Barone;[11] they reported that 88% of the restorations were in good condition.

Modern dentistry offers the possibility of obtaining prostheses using the CAD/CAM technique, both with ceramic and composite materials, to guarantee maximum precision.

Disadvantages

Indirect restoration requires longer operation time:

- preparation of cavity and impression;
- creation of the artifact;
- reconstruction/prosthesis-testing appointment;
- cementation appointment;
- follow-up appointment.

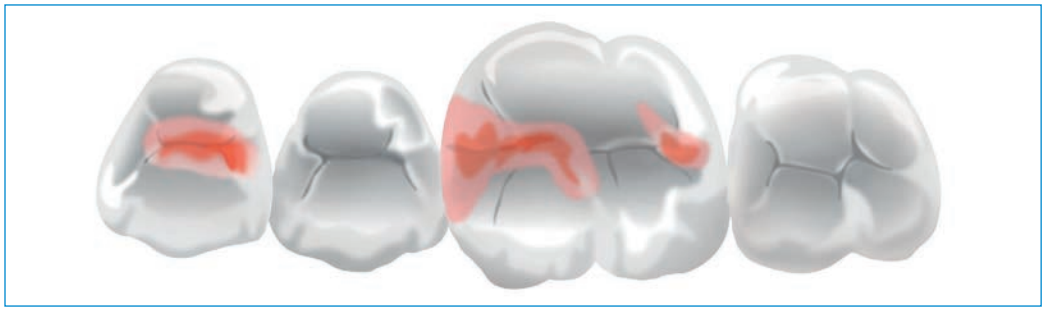
Indirect restoration also involves higher costs.

Conclusions

Partial tooth preparations for indirect restorations are an important alternative to direct composite restorations, and they represent *an effective reconstructive modality for large cavities*. The dentist should evaluate the extension and depth of the cavity prepared in the posterior teeth.

In this regard, the literature provides important indications as follows: presently, it is accepted that direct composite restorations on the posterior elements should be limited to small and medium cavities in the intracoronal areas (📷 1.11).[12]

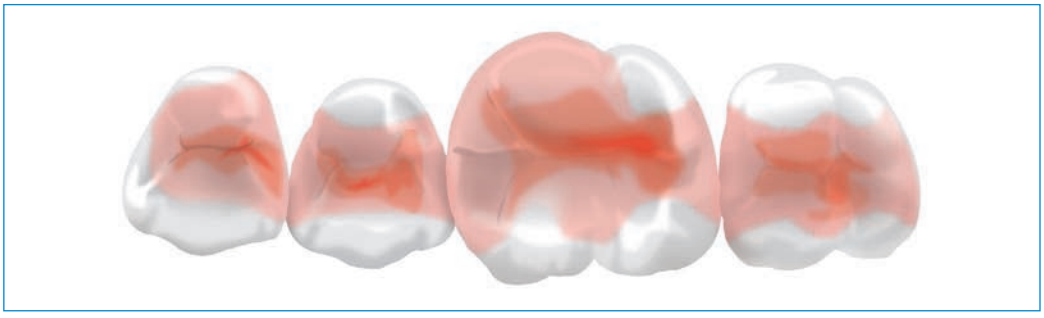
A randomized clinical trial on composite cuspid restoration analyzed the efficacy and time and concluded that in the short run, both direct and indirect composite restorations are adequate in restoring the original shape and function of premolars with class II cavities and loss of a cusp (📷 1.3).[12]



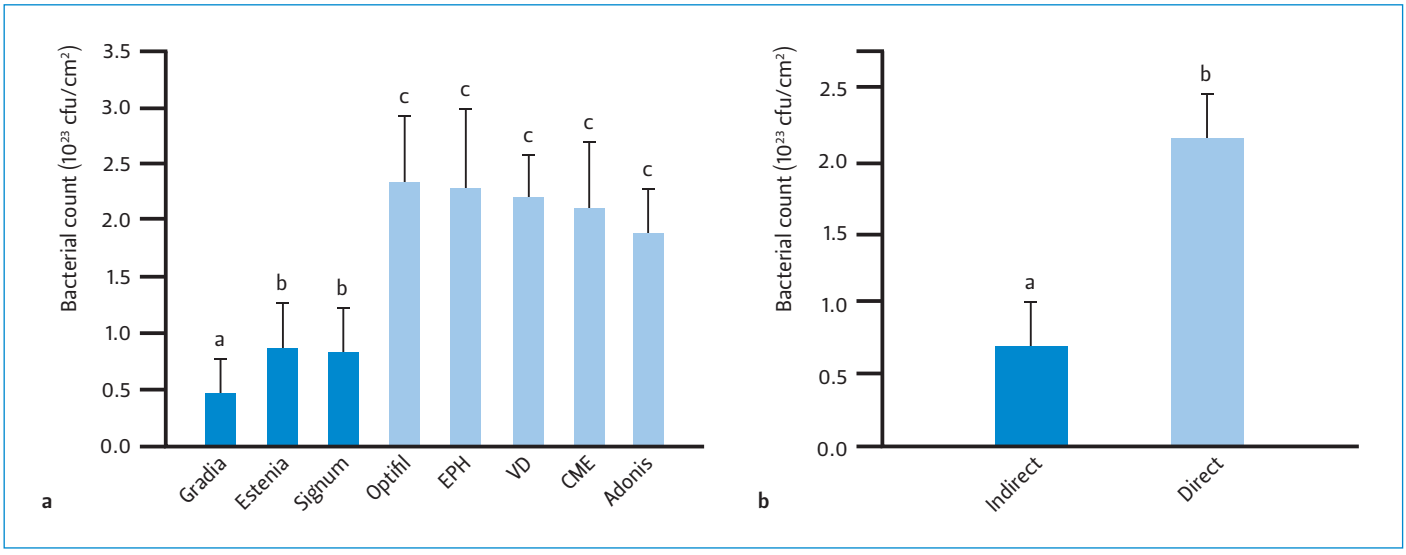
📷 **1.11** Suggested extension for direct composite restorations.

📁 **1.3** Assessment of treatment time in min (±) for the single steps of direct restoration procedures[12]

	Restoration technique	
Procedure	**Direct (min)**	**Indirect (min)**
Preparation	10 (±8)	10 (±4)
Matrix	4 (±3)	
Execution	14 (±4)	
Artifact test		8 (±5)
Cementation		12 (±6)
Finishing and polishing	18 (±6)	14 (±6)
Impression		13 (±5)
Temporary		12 (±5)
Total	45 (±13)	68 (±17)



1.12 Suggested limits for indirect restorations.



1.13 **(a)** Bacterial count for single materials. Different lowercase letters indicate groups with statistically significant differences (P<0.05). **(b)** Bacterial count for composites subdivided as "direct" (blue) and "indirect" (light blue). Different uppercase letters indicate groups with statistically significant differences (P<0.01).

A study showed that indirect cusp restorations of mesial-occlusal-distal (MOD) cavities are more resistant to fractures over time than direct restorations (1.12).[14]

Indirect restorations have shown a higher success rate (97.4%) after 3 years. Furthermore, the type of the restoration and the type of tooth did not significantly affect the success rates.[15]

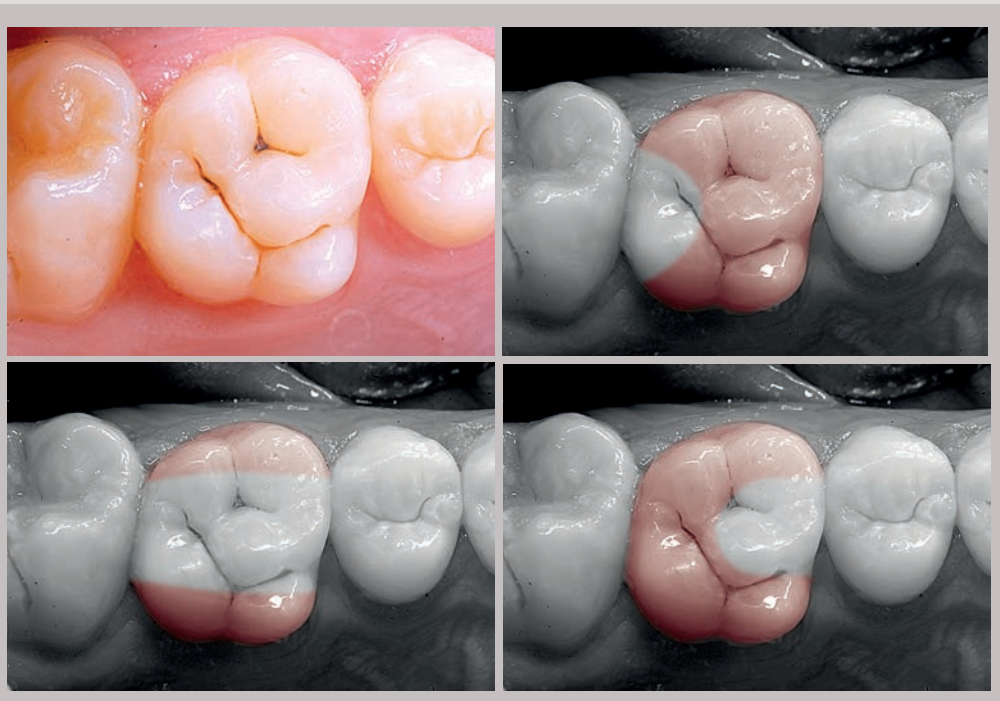
Indirect composite restorations show a lower level of plaque accumulation than direct restorations (1.13).[16]

Cavity preparation for indirect restorations

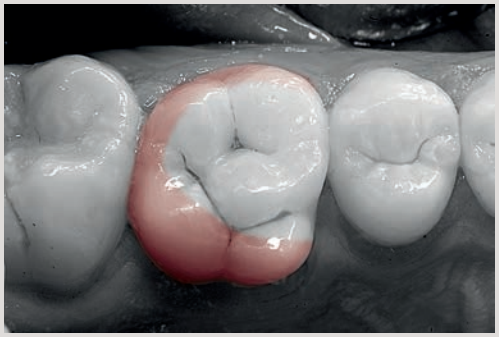
As already mentioned, the analysis of the condition of the tooth to restore determines the choice for the possible options: inlay, onlay, and overlay.

Bottacchiari[9] suggests that the type of reconstruction can be decided only after complete removal of the damaged tissue prior to the careful evaluation of the quality and quantity of the residual tooth structure.

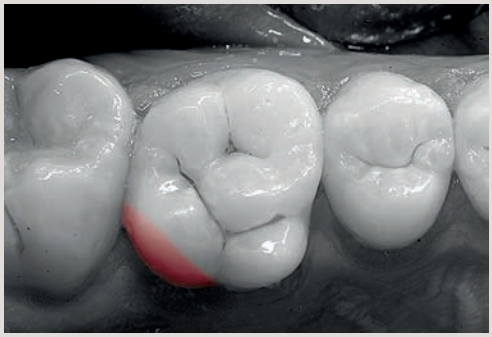
- **INLAY** – in the absence of one or two marginal ridges and in the presence of a thickness of dentin and enamel adequate to support the residual cusps, a class II MO/OD/MOD cavity without cuspal coverage should be prepared (1.14).
- **ONLAY** – in the absence of one or more marginal ridges and in the presence of a thickness of enamel and dentin of <1.5/2 mm (vital tooth) and 3 mm (endodontically treated tooth), a total covering of the cusp concerned is prepared (1.15).
- **OVERLAY** – in the absence of one or more marginal ridges as well as two or more cusps not supported by enamel and in the presence of an endodontically treated tooth, a total covering of all the cusps is prepared (1.16) (Clinical case 3).



1.14 Inlay positions.



1.15 Example of position of an onlay.



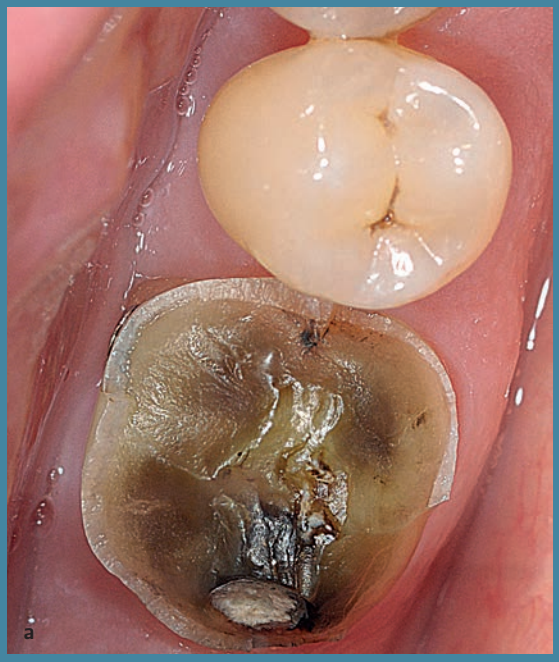
1.16 Overlay covering three cusps.

Clinical case 3

Overlay with total cuspal cover on sclerotic dentin

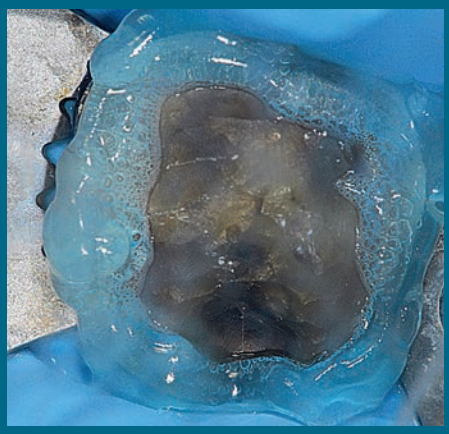
G. Derchi

The peculiarity of this case lies in the features of the dental substrate. This shows a large portion of sclerotic dentin, whose treatment will be described in detail in Chapter 4. After enamel and dentin treatment, the situation requires a build-up to provide adequate support and maximum stability to the onlay.



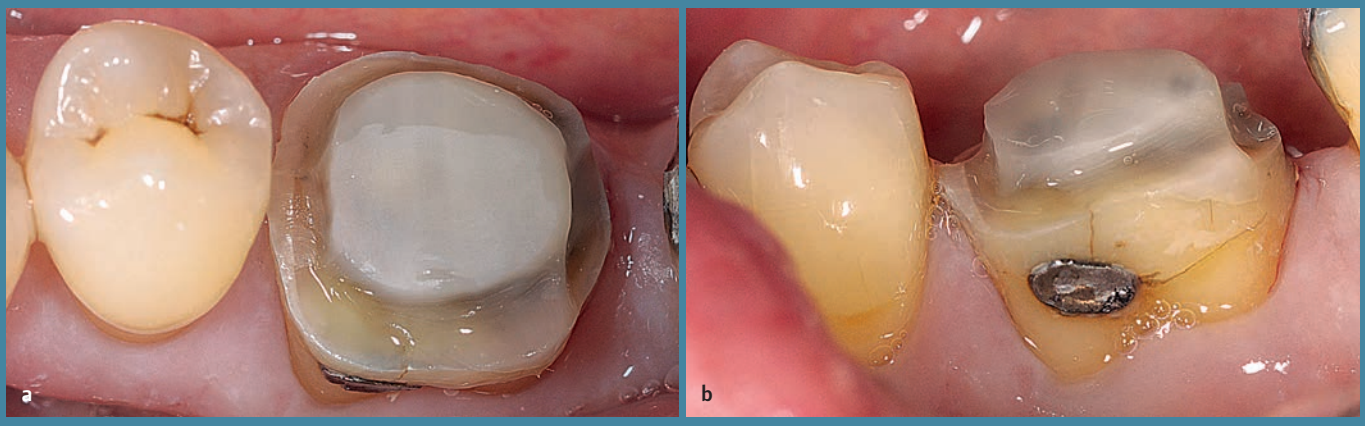
1 a–b Initial case.

2 Cleaning and roughening of the sclerotic dentin surface.



3 Acid etching of residual enamel portion.

4 Application of adhesive system.



5 a–b Creation of build-up.

6 Positioning of rubber dam before cementation.

7 Cemented artifact.

8 Final result, occlusal view.

9 Final result, buccal view.

10 Follow-up after 3 years.

Partial indirect restoration:

1. allows a conservative approach;
2. does not require a retention form;
3. requires only the removal of damaged tissue;
4. guarantees the preservation of peripheral enamel.

Let us take a brief look at what the related literature[17] indicates regarding the biomechanical and structural analysis of the residual healthy dental tissue, to reach an optimal result with a partial restoration:

- depth and width of the isthmus (interaxial dentin);
- absence or presence of pulp chamber (roof of pulp chamber);
- integrity or lack of integrity of marginal ridges;
- thickness of amelodentinal cusps.

The same authors subdivided the previously mentioned criteria based on their importance, defining the interaxial dentin and the roof of the pulp chamber as critical, and the marginal ridges and the cuspal residue as less critical.

INTERAXIAL DENTIN

The interaxial dentin is the cervico-occlusal continuation of the roof of the pulp chamber, and it joins the buccal wall to the lingual one. It is the most important structural element because its presence reduces the risk of fractures for the other residual structures.[18,19] While assessing the residual interaxial dentin, it is important to remember that a greater depth leads to a greater structural weakening than a greater width.[20]

- What is important is not width, but the control of depth.
- By increasing the depth of the isthmus by two times, the cuspal deflection increases by eight times.
- The interaxial dentin is completely lost in the endodontically treated tooth.

ROOF OF PULP CHAMBER

The roof of the pulp chamber is always present in vital teeth, but not in the endodontically treated elements. In 1989, Reeh et al.[21] discovered that a non-vital tooth that only has access to the pulp chamber but has preserved marginal ridges (loss of resistance of 5%) is more resistant than a vital tooth that has lost one or both marginal ridges (loss of resistance of 35% and 55%, respectively).

- The absence of the roof of the pulp chamber, if not associated with the loss of one or both marginal ridges, does not interfere with the biomechanical and structural quality.
- The maintenance of a marginal ridge for preserving a minimum portion of the interaxial dentin increases the restoration strength.
- The extent of cuspal deformation depends on the depth and thickness of the base of the residual cusp.

MARGINAL RIDGES

We have already described what can determine the presence or absence of the marginal ridges. Mandelli and Larson[20,22] proved that if the occlusal isthmus is entirely present, the absence of the marginal ridge does not lead to the weakening of the residual structure. In contrast, as previously mentioned, the absence of only the interaxial dentin drastically reduces the strength of the structure. Thus, structural weakening is particularly high in the absence of the marginal ridge and interaxial dentin.

The loss of the marginal ridge results in the presence of a box with three dimensional values to check: occlusal-cervical depth, mesio-distal width, and buccal-lingual width. As far as we know, the first two parameters affect the quantity of residual interaxial dentin; therefore, higher values are connected to more pronounced structural weakening.[23,24]

CUSPAL THICKNESS

The size of the residual cuspal thickness is dependent on the adjacent marginal ridges and absolutely independent of the adjacent cusp.[24–26] This evaluation is fundamental to establish whether to preserve or eliminate the cusp during the cavity preparation phase. Hood[27] has provided a numerical assessment that is certainly a valuable aid. Considering that the greater the depth of the base of the residual cuspal structure, the more its thickness should increase to keep the deflection constant, a thickness of 2 and 3 mm for vital and non-vital teeth respectively, should be taken as reference.

BUILD-UP

If the tooth appears particularly damaged or the preparation does not allow the complete fulfillment of the previously described criteria, it is necessary to reconstruct the missing tooth portions before taking the impression to create the restoration.

Furthermore, to facilitate artifact creation and its positioning inside the cavity, the latter should have smooth and continuous surfaces. These interventions are known as build-up and are generally made with flowable composite materials with medium-sized cavities to make the elasticity gradient more effective by reducing the polymerization shrinkage stress by 20%-50%.[28] For large cavities, a base of flowable composite is used and a restoration with microhybrid composite is performed to make the cavity more uniform and to make sure that the artifact has a thickness of <3 mm, so that polymerization can occur during the cementation phase.[29]

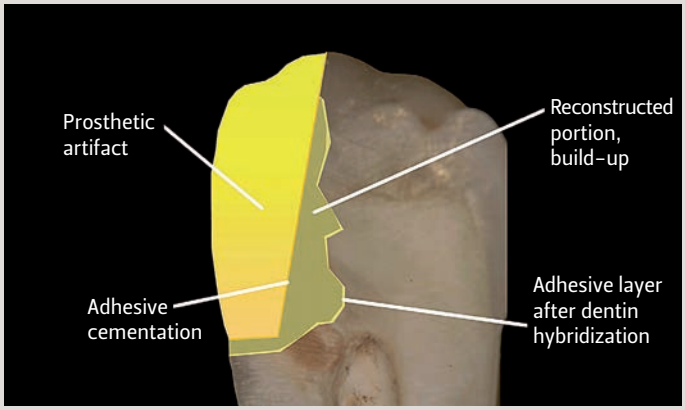
The choice of the build-up technique to be used is determined by evaluating the pulpal, occlusal, and periodontal states considering that:

- creating a build-up means to reconstruct and preserve the residual tooth portion;
- a build-up protects the dentin. In fact, during the first session, it is possible to seal the dentin as soon as this is prepared as indicated by Magne.[2] Dentin hybridization prevents bacterial infiltrations and reduces dentinal sensitivity in favor of greater patient comfort. In this regard, the positioning of the composite material used for the build-up has the function of creating a further protective barrier for the dentin;
- the creation of a build-up therefore protects the pulp;
- the creation of a build-up allows to evaluate the thickness available for the reconstruction. Complying with the minimum thicknesses necessary for the restoration material, the material must be as uniform as possible (📷 1.17 and 1.18).

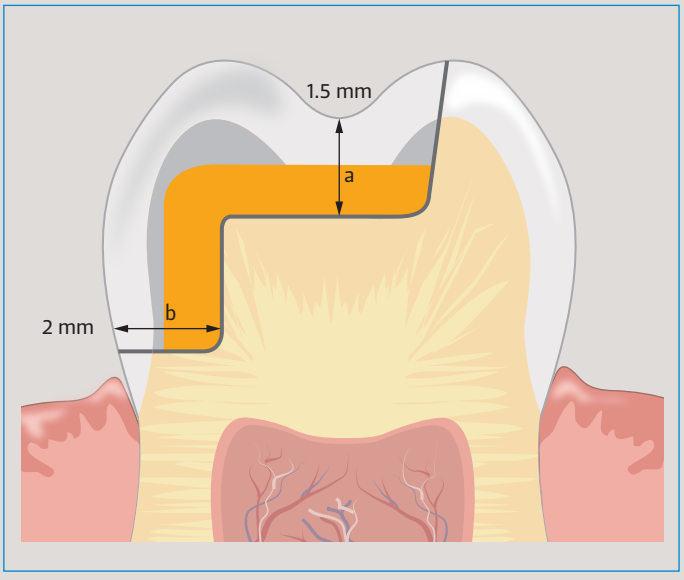
After looking at the main concepts, it is time to turn them into numbers. Bottacchiari[9] who improved, broadened and exposed Schillinburg's suggestions[30] published in 1976 and subsequently updated with three additional editions up to 2012.

The preparation depth should be at least 1.5 mm to guarantee sufficient thickness of the artifact to resist chewing loads. This measure is approximative and needs to be revised according to the material used to create the artifact, in compliance with the thickness of the axial dentin available. It is important to remember that the increase in depth leads to a proportional increase in the cuspal deflection; doubling the value is equivalent to multiplying the deflection by eight. Similarly, the isthmus should be at least 2 mm wide (1.19 and 1.20).

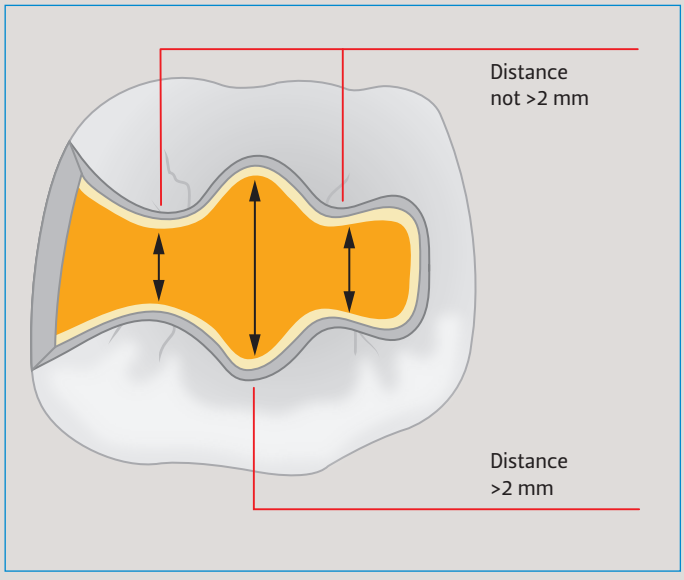
1.17 Build-up.



1.18 Section of an indirect restoration.



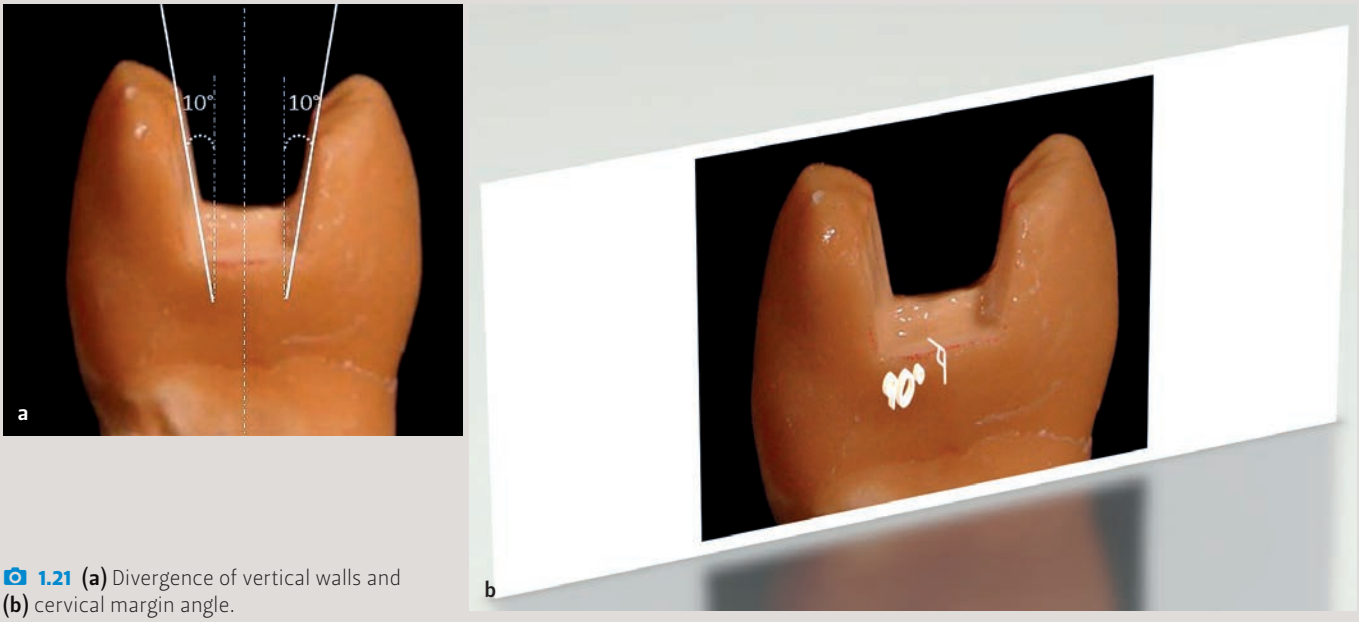
1.19 Minimal preparation depth for indirect restorations.



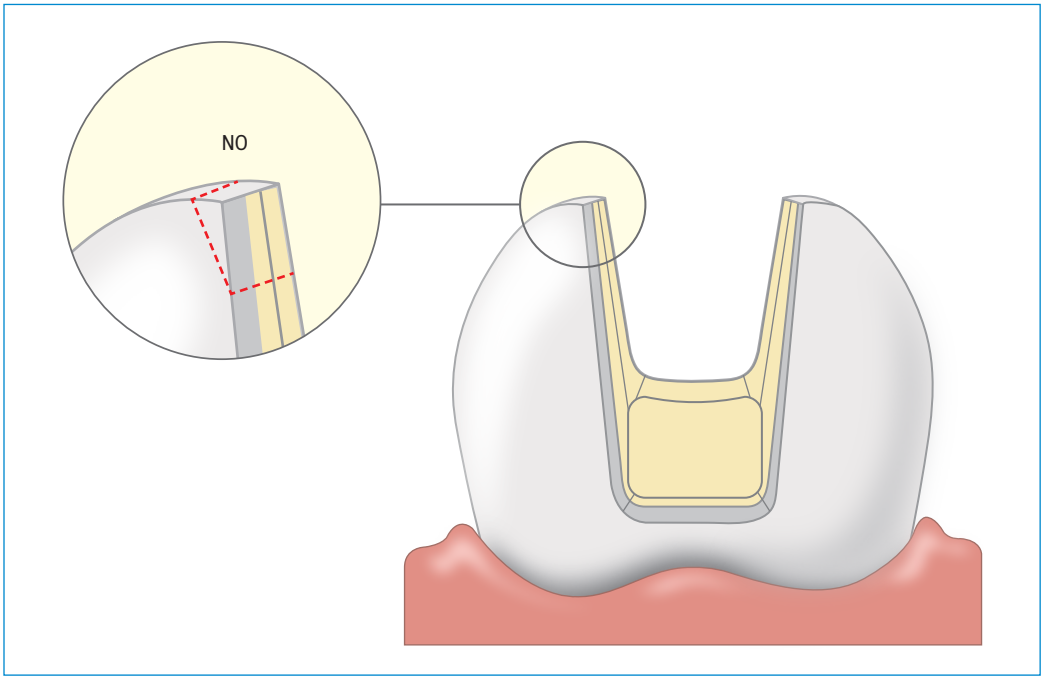
1.20 Maximum and minimum preparation depth for indirect restoration.

The preparation for an indirect restoration requires that the cavity walls and floor are smooth enough to allow an adequate impression and a correct insertion of the restoration. For the same reasons, the vertical walls should be divergent in the apico-coronal direction, with an inclination between 10° and 15°, whereas the angle of the cervical ridge should be of 90° (1.21a-b).

At the end of the preparation, the ridge should be clear, and it is important to remove unsupported enamel prisms in each part of the preparation (1.22).



1.21 **(a)** Divergence of vertical walls and **(b)** cervical margin angle.

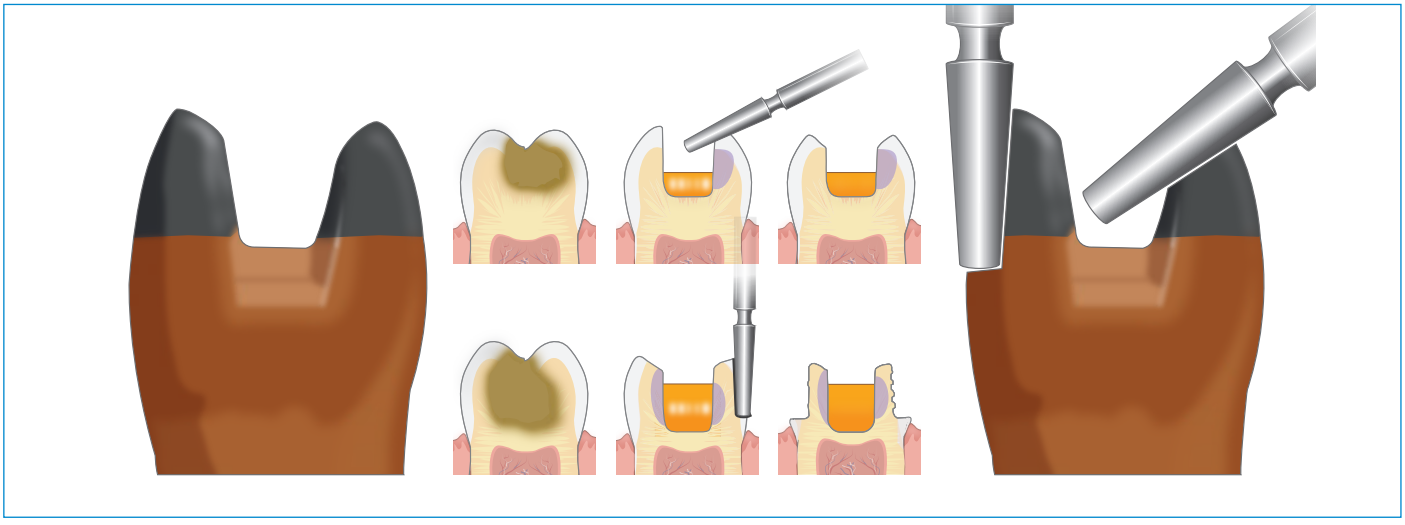


1.22 Finishing of margins.

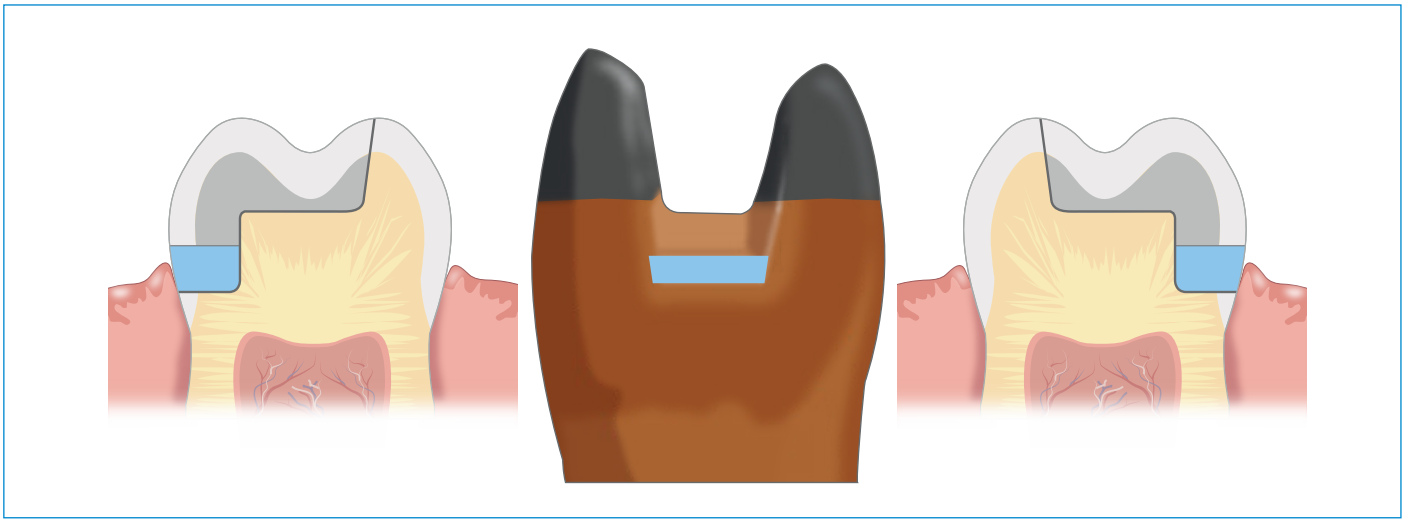
When a cuspal covering is necessary, the preparation requires a clear shape without retention form that follows the cuspal inclination, removing at least 2 and 1.5 mm for the shearing and stamp cusps, respectively (1.23).

We have so far considered the preparations of those teeth in which the damage invades the coronal portion. If the damage reaches the middle and cervical third, it is necessary to cover and surround the cusps by 360 degrees. It is also necessary to reduce the marginal ridge which further implies a reduction in the occlusal-axial dimension. After reducing the cusps, removing the entire compromised tissue, and making sure there are no unsupported enamel prisms, it is important to create a build-up or block-out for obtaining a structure that is suitable for indirect partial restoration. As previously mentioned, in cases where the preparation margin is subgingival, one of the options would be to relocate the margin to the supragingival position. This can be done by applying appropriate increments of the composite over the existing margin (1.24) (Clinical case 4).[12]

A second option based on the existing diagnostic factors is the apicalization of hard and soft tissues (crown lengthening) simultaneously exposing the prosthetic margin.



1.23 Preparation of cusps for cuspal covering.



1.24 Margin relocation.

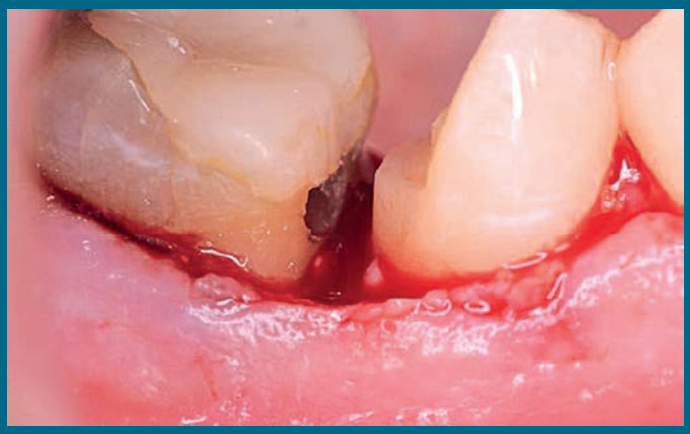
Clinical case 4

Margin relocation

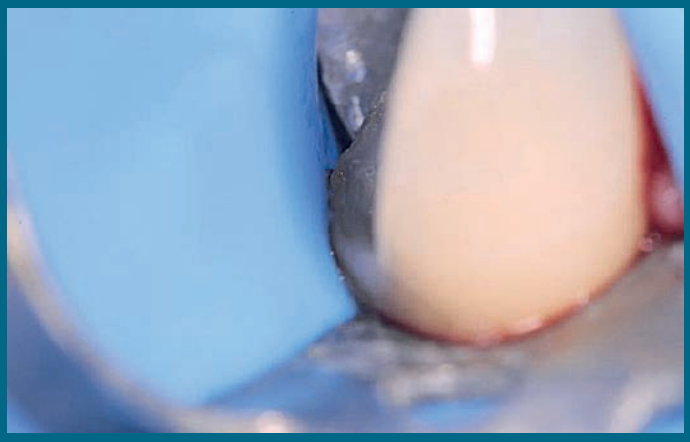
E. Manca

A clinical case showing margin relocation.

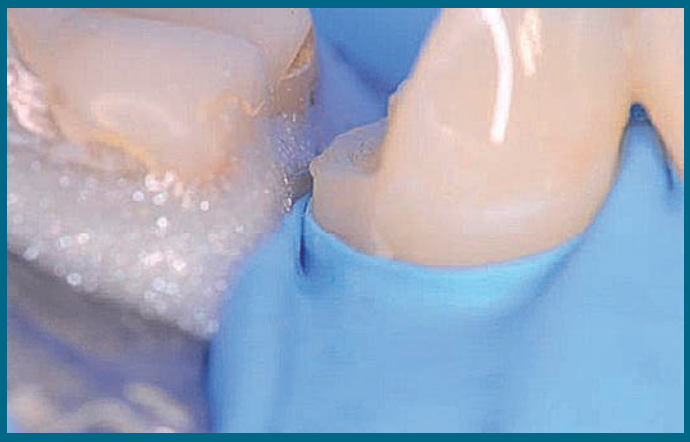
1 Margin exposure.



2 Dam repositioning and margin relocation using flow-type composite material.



3 Margin relocated with healing after 10 days.



4 Dam positioning.

5 Inlay cementation.

6 Case finished, cemented, and polished.

Partial restorations on anterior teeth

We have described how it is possible to comply with the principle of minimally invasive intervention in posterior teeth. At this point, it is important to evaluate the possibility of acting in the same way with the anterior teeth that need restoration to correct their shape and position, close diastemas, replace old composite restorations, repair and correct teeth, incisal abrasions, and erosions, and hide discolorations.[31]

The ceramic materials available on the market in recent years have drastically shifted the options for professionals in the restoration of anterior teeth. As indicated by Gurel[32], the "old" full coverage crowns are the first form of aesthetic restoration for anterior teeth, however they implied the need of sacrificing the enamel and a high risk of damaging the periodontal tissues and pulp.

It has been proven that the aesthetic goals can be achieved with stratified ceramic veneers without sacrificing the enamel and the entire tooth structure; therefore, these veneers have become the best choice possible in this regard. This procedure comprises creating a veneer prepared as a thin shell covering the buccal surface. Several authors[33–36] have suggested that the minimum thickness of the preparation for ceramic veneers should not exceed 0.5 mm. However, the thickness of the current ceramic veneers is between 0.4 and 0.7 mm; these values are close to the thickness of the natural dental enamel. Due to the evolution of ceramic materials, today clinicians can show their skills by creating restorations that allow preserving enamel and promoting a better and longer adhesive cementation.

Regarding the preparation required to accommodate the veneer, there are different indications in the literature from the classical preparations of only the buccal surface, to those that require the prosthesis to cover the incisal ridge and the so-called "no-prep veneer".

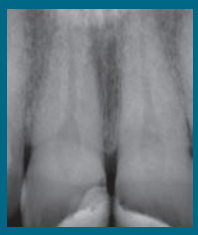
What should always be the mantra for these preparations was defined by Friedman[37] in 2001, who supported and recommended the importance of preserving the enamel as much as possible because a better retention of ceramic veneers, in the long run, can be obtained by preserving at least 50% of the enamel surface by positioning all the finishing margins in the enamel. The reason for this choice, shared by most professionals, lies in the possibility of guaranteeing the resistance and duration offered by the adhesion on the enamel, as shown in previous studies on this topic.

Clinical case 5

Protocol for producing aesthetic veneers

E. Manca

The restoration of the front group with veneers has the purpose of establishing a fresh smile for patients. The images below show the operating sequence.



1 Radiographic check.

2 Initial situation.

3 Detail of old restorations (buccal view).

4 Detail of old fillings (palatal view).

5 Diagnostic wax-up.

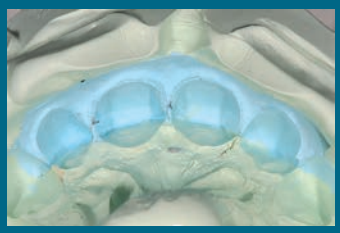
6 Preparation of buccal surface.

7 Finishing of margins.

8 Elimination of unsustained enamel prisms.

9 Assessment of occlusal margin reduction by means of mask.

10 Check of residual enamel thickness after preparation.



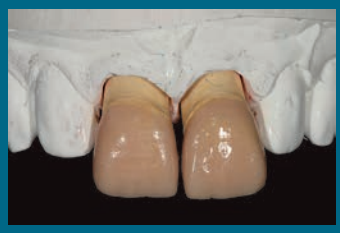
11 Impression detection using DSR.

12 Preparation of elements that receive temporary materials.

13 Cementation of temporary materials.

14 Plaster base for removable stumps.

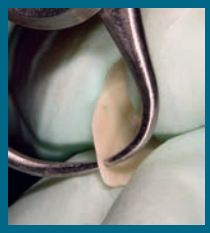
15 Summary of laboratory phases.



16 Wax model on plaster cast.

17 Plaster stumps.

18 Artifact test on plaster cast.



19 Check of thickness.

20 Four-tenth thickness.

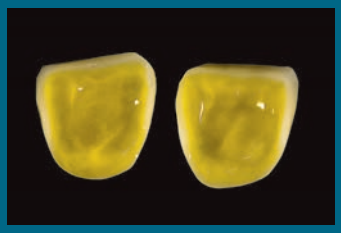
21 Artifact test.

22 Start of cementation phase.

23 Surface cleaning.

24 Acid etching.

25 Adhesive distribution.



26 Acid etching of the artifact.

27 Etched veneers.

28 Photopolymerization of cement.

29 Finishing of margins before dam removal.

30 Finishing of cervical margin after rubber dam removal.

31 Final result.

32 Smile with the integration of reconstructed elements.

The veneers can be made from different materials as follows, which affect cementation thickness and protocol:[38]

- resin composites;
- fused glass-ceramics;
- traditional feldspar-based ceramics;
- heat-pressed ceramics (leucite-reinforced ceramics; one of the most commonly used);
- CAD/CAM digital production.

RESIN COMPOSITES

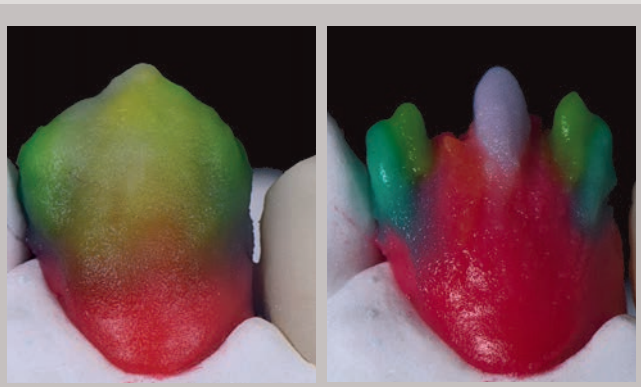
They are the cheapest option and can be stratified by the technician with a traditional sequence or be milled via the CAD/CAM systems. We will be able to evaluate the differences in Chapter 3. These veneers do not guarantee a stable aesthetic result because they tend to opacify, change color, and frequently fracture along the margins. Furthermore, the intrinsic porosity of the composite material represents a good substrate for plaque accumulation (1.25 and 1.26).

FUSED GLASS-CERAMICS

They are the first ceramic materials for dental use. Derived from Chinese porcelain, they are made of a glass phase and crystalline fillers. Baking of the modeled powders leads to the fusion of the glass portion that wraps and blocks the crystalline matrix. This ceramic, correctly termed porcelain, is chemically stable, provides excellent aesthetic results, and is long-lasting. Moreover, it shows a high resistance to compression (350-550 MPa), but an inadequate resistance to traction (20-60 MPa). As it is made mostly of glass, it has an insufficient hardness. This results in surface microcracks, which have severely limited its use.

TRADITIONAL FELDSPAR-BASED CERAMICS

It was present in the market in the mid-60s of the 20th century, thanks to the studies of McLean and Hughes who defined it as "reinforced ceramic core system" as reinforced with feldspar glass and alumina (PJC, alumina - reinforced Porcelain Jacket Crown).



1.25 Characterization after stratification on model (courtesy of Andrea Piacentini, dental technician).

1.26 Block-milled composite element.

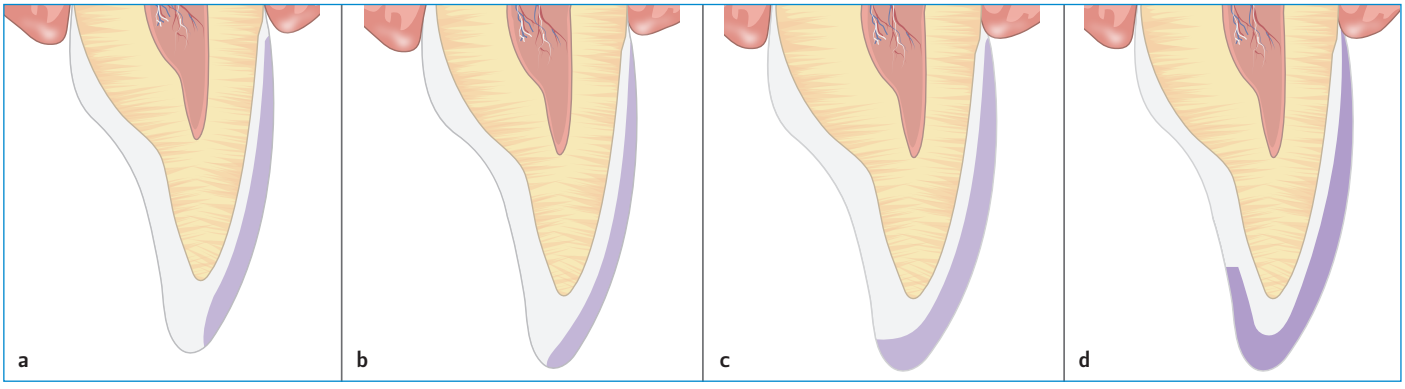
The presence of 40%–50% alumina provides to the structure resistance to flexion equal to 120–150 MPa and a lower level of diffusion of surface microcracks. Suitable for anterior structures, though it is not used on the posterior teeth due to its low resistance. The aesthetic results are insufficient due to the difficulty in obtaining the natural tooth color and the lack of translucency. The industry subsequently tried to overcome these limitations by introducing new formulations and production systems for powders. In the 80s, the glass-infiltrated high strength ceramic cores (In-Ceram) were proposed followed 10 years later by the All-alumina core (Techceram®, Techceram; Baildon and Provera® AllCeram, Nobel Biocare Italiana Srl, Milan). Although these products provide clear improvements in terms of resistance and aesthetics, the major limitation regarding adhesion to the tooth substrate still remains. The research of new ceramic structures (glass-ceramics), that allow acid etching to modify the structure of the tooth adhesion surfaces, gave rise to leucite-reinforced feldpar glass-ceramics. These require the production of artifacts by pressing (heat-pressed ceramics). However, leucite-reinforced ceramics too are not currently indicated for the production of prostheses for posterior teeth and bridges. The subsequent evolution gave rise to lithium disilicate, with high levels of resistance to flexion (450 MPa) and excellent aesthetic results. For further details, refer to Chapter 3.

Digital fabrication has become increasingly more reliable, and today, it is very easy to obtain 5-µm thick veneers with good aesthetic results. There are many materials used for this process, from alumina to zirconia to leucite, and considering their ongoing evaluation, more materials are expected to follow.

Preparations (1.27)

Veneers can be made from composite or ceramic material, with the latter being the most common. The duration of composite materials is shorter because these are subject to discoloration, wear, marginal fractures, opacification, and plaque accumulation.[31]

It is possible to divide veneers into two types depending on their thickness and preparation: classic ceramic veneers that, as previously described, require a specific preparation for the dental element and additions, better known as non-prep veneers.



1.27 Examples of different preparations for veneers. **(a)** Minimally invasive window preparation that involves only the buccal surface. **(b)** Buccal preparation with minimal preparation of incisal edge (feathered edge). **(c)** Palatally extended incisal preparation (butt joint or incisal bevel). **(d)** Palatal Chamfer preparation with extension to the incisal margin that will be replaced (palatal Chamfer or overlapped).
Modified from: Walls et al. Crowns and other extracoronal restorations: Porcelain laminate veneers. British Dental Journal. 2002;193(2):73–81.

Classic veneers

To prepare the tooth for accommodating the veneer, the operator should proceed by abrading the buccal surface, proximal surfaces, and incisal margin, and a knife-edge or Chamfer preparation of the cervical area.

There are four common preparation designs for ceramic veneers, subdivided in two main categories as follows:

- **Category 1:** preparation of dental surfaces with incisal coverage;
- **Category 2:** preparation of dental surfaces without incisal coverage.

The four most common preparation designs are as follows:

- minimal buccal intraenamel window preparation without reducing the incisal margin (the window);
- feather-edge buccal preparation from the cervical to the incisal margins (feathered edge);
- chamfer palatal preparation that also includes the incisal margin covered by the ceramic veneer (palatal Chamfer or overlapped);
- Palatally extended incisal preparation overlapped by ceramic veneers (butt joint or incisal bevel) (1.28).

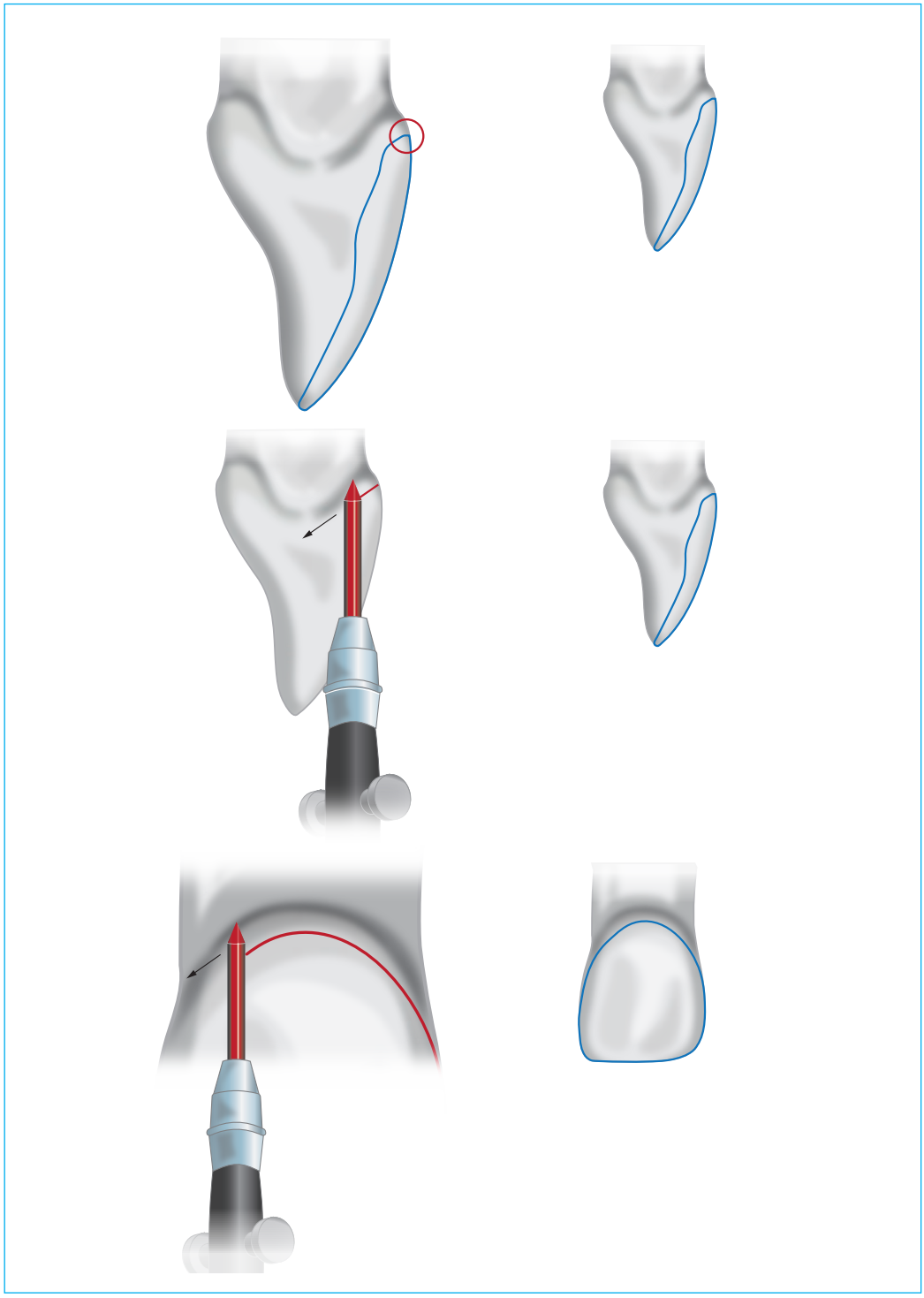
No-Prep: no preparation

Over the last 20 years, it has been possible to determine indications for restorations using veneers that require no preparation. There are several philosophies inspired by companies or reported by renowned researchers and clinicians. However, the majority of proposals for preparationless veneers come from clinical practice. The analysis of these proposals shows incomplete indications that generally tend to create confusion.[39–41]

D'Arcangelo et al.[42] proposed a protocol that starts from the selection of the patient in whom it is possible to apply the veneers without preparation, and indicates the clinical and laboratory processes step-by-step with the choice of materials and methods of fabrication, and suggests the cementation protocol. The starting point for D'Arcangelo is

1.28 Preparation of incisal edge (butt joint) for veneer restoration.

defining the margins: "The critical consideration for the technique is the identification of the optimal margin position; the margin is placed at the points of maximum convexity of the tooth, avoiding the overcontour of traditional preparationless veneers" (1.29).[42]



1.29 Diagram for veneer preparation in accordance with what is described by Professor C. D'Arcangelo.

Endocrown

The prosthetic restoration most often encountered by clinicians is doubtless the endodontically treated posterior tooth with reduced coronal portion.

After endodontic treatment, molars lose their mechanic properties. They become fragile due to the removal of the pulp and the adjacent tissues.

The most commonly described reconstruction in literature[43,44] suggests a crown with or without supporting posts. Choosing to restore a tooth with these characteristics, as shown by two researches on finite models,[45,46] requires a careful analysis. There are various factors that affect stress distribution in a post-endodontic restoration such as: length of the post, diameter, ferrule, elastic modulus of the material used for the tooth restoration, and adhesive materials. The endocrown is a possible solution to this dilemma, made possible due to the development of adhesive systems. It is a partial monolithic restoration that replaces the destroyed coronal component.

The preparation technique has been meticulously described in a case report by Dogui[47], whose procedure is followed herein. These procedures have also been described more concisely, but similarly, by other authors.[48,49]

The preparation for an endocrown restoration requires an overall reduction in the occlusal surface height of at least 2 mm in the axial direction, to obtain a cervical margin with a butt joint. The cervical margin must be supragingival and all the enamel walls of <2 mm thick must be removed.

The differences in heights of various parts of the margin must be linked to a slope not exceeding 60° to avoid the ladder effect. To reduce the occlusal surface, a cylindrical-conical diamond burr placed parallel to the occlusal plane is used. Subsequently, a diamond wheel burr is used to check the orientation reduction and to ensure a flat surface.

To create continuity between the coronal pulp chamber and the endodontic access cavity, a cylindrical-conical burr is used to create a 7° occlusal convergence. The burr is oriented with the long tooth axis, applying a low pressure without touching the pulp floor.

Excessive removal of tooth structure from the walls of the pulp chamber reduces the thickness and width of the available enamel. The cavity depth must be at least 3 mm.

The access to the pulp canal is opened and the gutta percha must be removed at a depth not exceeding 2 mm, to create a saddle-like anatomy of the pulp chamber. This action requires the use of non-abrasive tools to preserve the integrity of the canal access.

The preparation is completed by covering the access to the root canal with glass ionomer cement to protect the orifice of the canal.

A final impression is made to be sent to the lab for fabrication of the restauration (Clinical case 6).

The endocrown restoration is an optimal solution in the molar area, particularly in case of compromised crowns and calcified or narrow root canal. It is contraindicated if optimal adhesion is not possible, if the pulp chamber is <3 mm deep, or if the cervical margin is <2 mm thick for most of its circumference.

Clinical case 6

Post-endodontic treatment on particularly diseased elements with endocrown

M. Gagliani

1–3 Despite the scarcity of the residual dental tissue, it is possible to note the presence of enamel at 360°. Endocrown allows the preservation of this precious tissue, which would otherwise be sacrificed with other techniques.

4–5 It is important to check the adaptation of the endocrown, which in turn is subsequently cemented with adhesive technique.

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