



The use of bonded partial ceramic restorations to recover heavily compromised teeth

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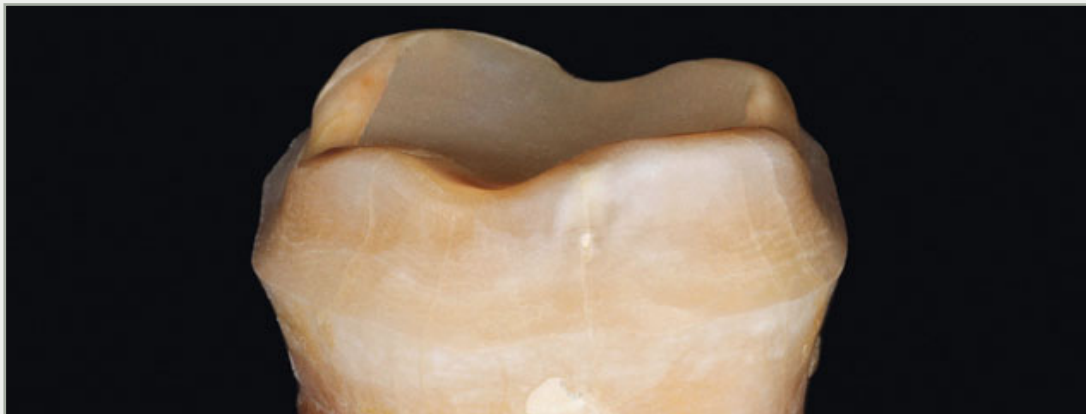
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Abstract

Restorative procedures are accompanied by a reduction of tooth stability, a decrease of fracture resistance, and an increase in deflection of weakened cusps. The choice between a direct or an indirect restorative technique, mainly in posterior areas, is a challenge, and involves biomechanical, anatomical, functional, esthetic, and financial considerations. In this article, the pros and cons of direct restorations are examined, as well as an analysis of indirect restorations and an overview of dental ceramics. In

particular, several clinical uses of lithium disilicate overlays with a circumferential adhesive ferrule effect are proposed: heavily compromised vital teeth with thin walls, cracked teeth, and endodontically treated molars. Clinical procedures are described step by step on the basis of data from scientific literature. In conclusion, the use of lithium disilicate in combination with adhesive technologies can lead to a more conservative, economic, and esthetic approach in the restoration of heavily compromised teeth.

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Introduction

Restorative procedures, like caries excavation, cavity preparation or endodontic treatment, are accompanied by the reduction of tooth stability, a decrease of fracture resistance, and an increase in deflection of weakened cusps.¹ The choice between a direct or an indirect restorative technique, mainly in posterior areas, is a challenge, and involves biomechanical, anatomical, esthetic, and financial considerations.²

In order to preserve residual tooth structure, it is often tempting to place a conservative intracoronal restoration.³ However, to avoid the risk of prosthetic failure, it is necessary to decide if a restoration with cuspal support is more suitable than an intracoronal restoration. Estimation of the required minimum amount of residual dentin thickness should be the deciding criterion, along with an evaluation of the survival rates of restorations with a cusp-supporting design (ie, occlusal veneers).⁴⁻⁶

Since endodontically treated teeth are highly susceptible to fracture, the decision regarding the most suitable restorative material and technique is even more difficult.⁷ The use of direct composite resin restorations in wide cavities or in endodontically treated teeth is time-consuming and cannot offer a long-term prognosis of the compromised tooth structure due to abrasion or fracture of the restorative material or incapability to protect residual dental substance. Another considerable limitation of composite resins as posterior restorative materials is the shrinkage stress that occurs during polymerization, which may cause marginal leakage and secondary car-

ies.⁸ Direct composite resin restorations also present a limited degree of polymerization, which may affect their mechanical properties strength and lead to an increased release of resin monomers.⁹ American Dental Association (ADA) statements regarding posterior, resin-based composites (1998) suggest the use of direct restorations in small lesions and low stress-bearing areas, and suggest they should be avoided in extended lesions, high-stress areas, or when rubber dam cannot be placed.¹⁰ Moreover, occlusal wear of direct composite resin restorations may be a concern for large cavities or for patients with parafunctional habits.¹¹ Covering cusps with direct composite restorations improves the fatigue resistance of Class II restorations with the replacement of the buccal cusp in premolars, but fracture of direct composite resin restorations with cuspal coverage leads to more dramatic failures.¹²

Indirect restorations can solve many of the deficiencies of direct restorations. It has been shown that light-cured indirect restorations with a cement thickness < 200 μm generated less contraction stress than light-cured direct composite restorations.¹³ Heating composite resins results in an increased degree of conversion of resin monomers, thus in improved physical and mechanical properties such as wear resistance.¹⁴⁻¹⁶ However, in clinical studies, this approach did not produce superior mechanical behavior;¹⁷ in addition, due to the chemical degradation process, a superficial degradation of composite resin occurs even if the material has been heat processed.¹⁸

Partial ceramic restorations allow the practitioner to achieve an excellent and



long-lasting shade match with the surrounding natural tooth structure. If the appropriate shade is selected and the restoration is fabricated with adequately matching translucency, it can be indistinguishable from the surrounding tooth structure. Bonded ceramic restorations (eg, ceramic inlays or onlays and partial ceramic crowns) are a clinically acceptable means of restoring extensively destroyed teeth.¹⁹ Ceramic onlay indications include most of the typical indications for cast-metal, with the added requirement for a tooth-colored restoration. These restorations offer the opportunity to preserve and strengthen compromised tooth structure, while taking advantage of the mechanical benefits of modern adhesive technology and ceramics.²⁰ In fact, the prepared tooth acts as a reinforcing core whereby the strengthening of the overlying ceramic is imparted by a synergistic bond between ceramic and dental tissues, mediated by the resin-based cement.²¹ In addition, the use of adhesive techniques permits more conservative preparation designs.^{20,22}

It is universally accepted that tooth structure has a significant influence on the survival of restored teeth and improves fracture resistance.²³ Furthermore, the adhesive technique is capable of reinforcing the remaining dental hard tissue.²⁴ In order to protect the weakened tooth, coverage of cusps with partial or full crowns is recommended.²⁵ It has been reported that thin, nonfunctional cusp walls should be protected to reduce the risk of enamel crack formation or marginal deficiency at the ceramic-tooth interface.²⁶⁻²⁸

Restoration wear is not a clinical concern with ceramic restorations. The main

operative problem is the development of a precise occlusal contact. In fact, the restoration is routinely bonded prior to final verification of the occlusion, which in most cases can result in an irregular surface finish at chairside than that achieved when polishing is performed in the dental laboratory. Even if intuitively an increased surface roughness may appear to be related to increased wear, *in vitro* enamel wear does not seem to be affected by porcelain-surface roughness due to a self-capability to smooth irregular ceramic surface during function.²⁹

An overview of dental ceramics

Ceramic materials were first used in dentistry to fabricate porcelain denture teeth in the late 1700s.³⁰ Later, Charles H. Land, a dentist from Detroit (MI, USA), fabricated the first ceramic crown. His process relied on providing support for a ceramic paste during firing with a thin platinum foil adapted to the dye, in order to reduce the slumping of the porcelain mass.³¹ However, because of their low strength, early feldspathic dental porcelains had limited applications in posterior areas. In the 1980s, the concept of acid-etching porcelain to use resin-based materials for luting porcelain restorations was developed.³² Successively, glass-infiltrated alumina (In Ceram) and pressed glass-ceramic restorations (Empress) were introduced.³³ Nowadays, high-strength ceramic materials (lithium disilicate or glass-reinforced ceramics) or alternatively, high-strength ceramic core materials veneered with



a more translucent esthetic feldspathic ceramic are commonly chosen for posterior and anterior ceramic restorations.

Dental ceramics can be classified into two groups, depending on their response to conditioning methods: etchable (leucite-reinforced feldspathic and lithium disilicate ceramics) and non-etchable (glass-infiltrated alumina/zirconia ceramic, densely sintered alumina ceramic, and yttrium oxide partially-stabilized zirconia [Y-TZP]). In etchable ceramics, surface topography is increased through selective dissolution of the crystalline phase through exposure to hydrofluoric acid (HF), while the surface characteristics of non-etchable ceramics do not change after exposure to HF.³⁴

With etchable ceramics, after HF conditioning, the application of a silane coupling agent promotes a chemical adhesion between the ceramic and the resin-based cement due to its bifunctional monomers.³⁴ Moreover, acid etching and silanization increase the wettability of the hydrophobic resin on the surface, improving the contact area for the resin cement.³⁵ After silanization, a low-viscosity adhesive resin is applied to penetrate into the micro-porosities created by acid-etching and to chemically bond to the resin cement used for final luting.³⁷

Dental ceramics that best mimic the optical properties of enamel and dentin are feldspathic glasses, which usually contain a crystalline phase between 15 and 25 vol percentage in the form of leucite. These types of dental ceramics have been classically designed to be veneered onto metal substructures. The addition of leucite to feldspar glass leads to the production of veneering

ceramics with a coefficient of thermal expansion compatible with that of the metal substructure.³⁸

Since the early nineties, the popularity of heat-pressed ceramics has increased significantly as a result of the ability to use the lost-wax technique to produce dental ceramic restorations. Dental technicians are usually familiar with this technique, commonly used to cast dental alloys. In addition, the equipment needed to heat press ceramics is relatively inexpensive. The first generation of heat-pressed dental ceramics contained leucite as the reinforcing crystalline phase; the second generation contained about 65 vol percentage lithium disilicate as the main crystalline phase, which is embedded in glass, with about 1% porosity,³⁸ resulting in a relatively high flexural strength (350 to 400 MPa).⁴⁰

The first lithium disilicate ceramic (IPS Empress 2, Ivoclar Vivadent) was used as veneering ceramic, but was not designed to be used in its monolithic form. The results of different studies showed low clinical failure rates in posterior and anterior crowns.⁴¹

The second generation of lithium disilicate ceramics (IPS e.max Press, Ivoclar Vivadent) presented smaller and more homogeneous crystals, and improved esthetic and physical properties (flexural strength and fracture toughness was about 10% higher) than its precursor.⁴² IPS e.max Press has been used successfully for monolithic fixed partial dentures (FPDs) even in the posterior area for as long as 8 years.⁴³ However, it is still questionable whether all-ceramic FPDs can compete with metal-ceramic FPDs, for which systematic reviews have shown 10-year sur-



vival rates of 87.0% to 89.2%.⁴⁴ In a recent clinical study, Kern reported success rates similar to those of conventional metal-ceramic FPDs.⁴⁵ Lithium disilicate-reinforced ceramics need a shorter etching time (20 s) than all other silica-based ceramics. The elongated crystals measure 0.4 to 5 μm in length, with an etching depth ranging from 5 to 20 μm .⁴⁶ After etching, lithium disilicate constitutes the main crystal phase as an interlocking microstructure. The lithium disilicate glass-ceramic system, whether computer-aided design/computer-aided manufacturing (CAD/CAM) processed or heat pressed, is indicated either as a full-contour (monolithic) restoration or as a core for subsequent porcelain veneering.⁴⁷ Fracture resistance of monolithic lithium disilicate while submerged in a wet environment appeared promising, stimulating second-phase testing to evaluate the behavior of various ceramic thicknesses for posterior single-tooth applications.⁴⁸

Clinical suggestions and considerations

Traditionally, four clinical indications need to be followed for maximizing durability: 1) to provide an ideal occlusal ceramic thickness (strength increases with the square of the thickness); 2) to use the highest elastic modulus (stiffness) substrate possible (ie, metal or ceramic vs resin-based composite); 3) to bond the restoration by creating a strong ceramic–cement–tooth interface; and 4) to develop pinpoint occlusal contacts.⁴⁹ Clinical studies have demonstrated that all-ceramic restorations cemented with

methacrylate resin-based cements exhibit lower failure rates in comparison with those cemented with zinc phosphate and conventional glass-ionomer cements.⁵⁰ The strengthening effect of resin-based cements has also been demonstrated by many researchers during *in vitro* mechanical load failure testing of clinically representative restorations.^{51,52} This strengthening mechanism relies on the assumption that the critical surface flaws are infiltrated, promoting a durable interfacial bonding between coating and glass,⁵³ and that load transfer to the underlying tooth substrate is improved.⁵⁴

The preparation of ceramic partial restorations requires the omission of previous design dogmas for dental preparations in favor of those designed for ceramics and adhesive procedures.⁵⁵ Ceramic partial restorations can be manufactured indirectly in the dental laboratory or in the dental office by using chairside CAD/CAM systems. Several materials can be used for this purpose, each with their advantages and disadvantages. Current choices include feldspathic porcelains, leucite-reinforced lithium disilicates, glass-infiltrated ceramics, and, more recently, translucent zirconia.⁵⁶ A limiting aspect of feldspathic ceramics is their weaker mechanical properties in comparison with other materials. In the authors' clinical experience, the material with appropriate strength and pleasant esthetics is stained monolithic pressed lithium disilicate. It can be used for the fabrication of inlays, onlays, crowns, and short-span anterior FPDs. Such restorations tend to exhibit excellent marginal adaptation and good fracture resistance.



Cavity design

Finite-element modeling suggests that composite restored teeth exhibit increased coronal flexure whereas ceramic inlays result in increased coronal rigidity.⁵⁷ Indirect composite restorations with a low modulus of elasticity exhibit increased tension at the dentin–adhesive interface, suggesting that porcelain restorations have a lower risk of debonding.⁵⁸ This could explain the higher risk of both bulk fracture on ceramic partial restorations and tooth fracture on elements restored with composite restorations.⁵⁹

The cavity design for all-ceramic partial restorations requires the simplest possible basic geometry. In fact, due to adhesive bonding technology, a retentive shape of the preparation is not necessary. The traditional preparation guidelines for monolithic ceramic restorations are 1.5 mm of pulpal depth starting from the base of the development sulcus, rounded internal line angles, 10 to 12 degrees of axial wall convergence, 10 degrees or more of divergence on buccal and lingual walls, 1 to 1.5 mm of axial wall reduction, 90 degree cavo-surface margins, 2 mm isthmus width, 2 mm occlusal reduction for cuspal coverage, smooth flowing margins, and no undercuts.⁶⁰ As reported by Krifka, the remaining wall thickness of non-functional cusps of adhesively bonded ceramic restorations, especially ceramic inlays, should have a thickness of at least 2 mm to prevent crack formation, avoid tooth fracture, and reduce marginal deficiency at the dentin–luting agent interface.²⁶

Supragingival preparation margins are preferred for adhesive bonding and

are recommended for caries prevention and for periodontal reasons. Furthermore, with this type of preparation it is easier to prepare the cavity, to take the impression, to place rubber dam, to enable visual control of the marginal seal, and to remove excess cement. In addition, the quality of the marginal seal is better when evaluated during follow-up.⁶¹ Due to the excellent mechanical properties of lithium disilicate ceramics, chamfer margins are preferred, with a ferrule effect well recognized as capable of strengthening the tooth–restoration complex. The ferrule strengthening effect is improved if the ferrule is kept at a more coronal level.⁶² The simultaneous presence of the ferrule effect and adhesive cementation may confer to the restored tooth a remarkable resistance to masticatory loads, in a sort of “active adhesive ferrule effect.”

When preparing posterior partial or full-coverage restorations, an occlusal and axial clearance of 1.5 mm was traditionally recommended, even if a reduced thickness of 1 mm was recently reported to be acceptable if bonding is performed on enamel.⁶³ In one study, Holberg reported that ceramic restoration thickness did not seem to be an important factor influencing the fracture risk of ceramic inlays if related to high-strength ceramics.⁶⁴ Preparation design for inlays and onlays can vary greatly, depending on the existing conditions of the tooth being restored. The strength of undermined cusps should be considered carefully to evaluate whether cusp coverage with porcelain is necessary.⁶⁵ Acute preparation angles should be avoided, as this will make it difficult for the dental technician to finish the prosthetic margin accurately.



Pressed ceramics are the preferred restorative material. This is related to the fact that even if the overall porcelain thickness requirements are essentially the same for laboratory made pressed restorations and CAD/CAM restorations, users of the latter option need to be aware of the limitations imposed by bur dimension and geometry during milling.⁶⁶

Under ideal clinical circumstances, preparation margins should be conveniently positioned. However, decay, existing restorations, and the presence of fractures will determine the final shape of a preparation. Existing undercuts due to caries removal of existing restorations will sometimes force the clinician to remove an otherwise sound cusp. Undercuts arising after removal of caries can be blocked out with plastic filling materials.⁶⁷

To reduce excessive removal of sound dental substance, a composite build-up can be placed in the cavity. It can also provide adequate resistance and support for the ceramic restoration. Reducing the depth of the pulpal floor also reduces the need to open the cavity, thus reducing its width. Composite resin build-ups can also withstand axial and lateral loads and contribute to the support of final restorations.⁶⁸ The occlusal margins of the inlay restorations should not be located in the region of occlusal contact points.⁶⁹

Compressive stresses are beneficial and must be preferred in the design; if possible, it is advisable to transform tensile into compressive stresses by design measures. It is also important to avoid stress peaks and material accumulations; soft transitions at shoulders and edges, as well as large radii, can reduce

stress peaks, and build-up can lead to uniform ceramic reconstructions with uniform thicknesses.⁷⁰

For cementation, a low-viscosity adhesive resin can be used to achieve a strong micromechanical bond to the HF-etched ceramic restoration.⁷¹ The use of silane coupling agents further enhances the bond; it improves the wettability of the ceramic through the adhesive resin and the formation of chemical bonds.^{35,72} The use of dual-curing cements has been advocated for luting ceramic inlays/onlays; the light can pass through the varied ceramic thickness and activate the polymerization reaction.⁷³ Dual-cure resin luting agents require visible light exposure to improve the degree of conversion, thus reducing discoloration; exposure time should be as long as possible, taking light attenuation into consideration as a function of restoration thickness.⁷⁴

When using dual-cured resin cements, the final hardness is related to light exposure, and marked differences have been reported between various materials in terms of the ratio of chemical and light-activated catalysts.^{75,76} Dual cure etch-and-rinse adhesives seem to achieve adequate bond strengths and should be preferred.⁷⁷ However, many clinicians (and authors) prefer to cement indirect ceramic restorations using light-curing restorative composites due to their "on demand polymerization," better mechanical properties, and improved handling. With this procedure, the degree of conversion of resin composites used as luting agents is affected by the curing time, indirect restoration thickness, and translucency of the restorative material. D'Arcangelo and co-work-



ers suggested that a 3.5-mm thickness limit should not be exceeded, and that a dual-curing luting agent should be preferred to lute thicker and more opaque indirect restorations.⁷⁸ The potential of curing cements through ceramic inlays is superior in comparison to composite resin inlays due to better light transmission, which helps to achieve a higher degree of conversion.⁷⁹

Adhesive cementation is the final step. It is one of the most important clinical steps for ceramic restorations because it increases the restoration's strength and affects its clinical performance.⁸⁰ Several studies have indicated that the longevity of ceramic restorations is associated with the adhesion of resin cements to both the tooth substance and the ceramic material.⁸¹ Hence, incorrect selection of the adhesive resin and/or the resin cement, incorrect procedures, or the possible incompatibility between both aspects may lead to failure at the ceramic–cement or tooth–cement interface.⁸²

Indication for treatment

On the basis of these considerations, we propose several clinical uses of lithium disilicate overlays with circumferential adhesive ferrule effect: heavily compromised vital teeth with thin walls, cracked teeth, and endodontically treated molars and premolars.

Clinical procedures

The selected tooth is prepared according to the abovementioned guidelines for all-ceramic overlay restorations. Among

the parameters to be analyzed prior to treatment is the presence of parafunctions (ie, bruxism), cracks, and occlusal wear. After placement of rubber dam, existing restorations are removed (Fig 1a).

This procedure can be performed with a 2P SS White carbide bur if an amalgam restoration is present, or with a 201 Intensiv diamond bur (Intensiv SA) in the presence of an old composite restoration. The infected tissues are removed, and the remaining sound structure is carefully evaluated. The affected dentin is cleaned with a Komet H1SEM carbide bur (Komet Dental) in a handpiece at low speed (6000 to 8000 RPM) in order to reach soft tissues under cusps and marginal ridges. After the use of rotating instruments, a vanadium excavator (Hawe-Neos, Kerr no. 2) may help to evaluate the hardness of remaining tissues and remove any remaining soft infected dentin, if present, to prevent secondary decay and to improve the hybridization quality and stability – and hence the clinical performance – of the final restoration. If needed, a micro and selective build-up with a low-stress resin composite (GC EverX) is layered, to reconstruct the damaged tooth (Fig 1b). The remaining sound dental structure is carefully analyzed with the intention of preparing a mechanically correct restoration. During the treatment of heavily compromised teeth, the occlusal surface must be completely protected. At least 1.0 mm of occlusal reduction is advisable when a lithium disilicate ceramic is used.⁶³ If a working cusp needs to be covered, an occlusal reduction of 1.5 mm is preferred. This is best done with a cylindrical bur, such as a 880 Intensiv diamond bur. Remnant surfaces



Fig 1 Old restoration on endodontically treated first mandibular molar; build-up is applied on the cavity after the complete removal of the affected dentin.

are then prepared. A buccal and lingual sulcus is designed with a 801 023 Intensiv round bur to define the margins of preparation in these areas (Fig 2a).

Whenever the margins of an overlay invade the buccal area, the homogeneous passage between the indirect restoration and the tooth may represent an esthetic challenge. In this case, three alternatives are possible:

- The margins can be placed in the cervical region, close to the gingiva.
- A more conservative approach would suggest placing the margins in the middle third of the tooth, if possible. This choice is more esthetically demanding, but allows for the achievement of the ferrule effect required with minimal substance removal. This is the strategy preferred by the authors.
- The third option consists of the minimal removal of buccal substance just covering the cusp lightly. This approach seems to be adequate for the buccal cusp, but is not capable of achieving a ferrule effect.

With a rounded cylindrical bur or a rounded bur, the interproximal boxes and ves-

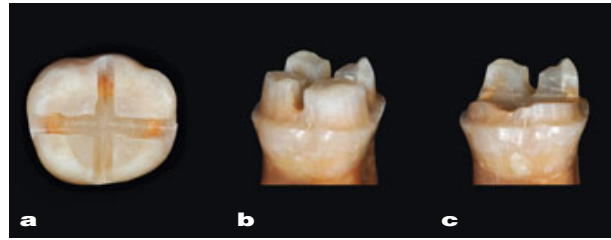


Fig 2 (a) Occlusal reduction of at least 1.5 mm; **(b)** buccal and lingual sulcuses are designed with a round bur to define the margins of preparation in these areas; then, the complete reduction of the vertical surfaces is performed with a cylindrical bur; **(c)** with the same cylindrical bur, the occlusal surface is connected to the vertical surfaces.

tibular/lingual surfaces are connected (Fig 2b). With the same cylindrical bur, the occlusal surface is connected with the vertical surfaces. Then, a peripheral chamfer is obtained all around the tooth (Fig 2c).

A 6 to 8 degree of divergence of vertical walls is required to avoid undercuts and permit the overlay's allocation. The final result is a marginal design at different levels and a circumferential chamfer design with a ferrule effect (Fig 3a). Then, the preparation is refined with a rounded cylindrical fine diamond bur, all the surfaces are connected (Fig 3b), and the final preparation is polished with a rubber mini point (Brownie, Shofu) (Fig 4).

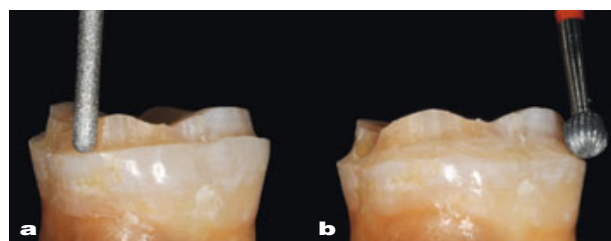


Fig 3a and b A round, low-granulometry diamond or multi-blade bur is used to refine the preparation and to connect and smooth all the surfaces.



Fig 4 Preparation completed, ready for adhesive IDS procedures.



Fig 5 Lithium disilicate painted overlay after the adhesive cementation.

After an air polishing decontamination with glycine powder (Clinpro Prophy Powder, 3M ESPE), the tooth may be hybridized. A three-step dental adhesive (Optibond FL, Kerr) may be applied prior to the final impression, following the immediate dentin sealing (IDS) protocols.⁸³ The application of a small amount of flowable composite may help to eliminate small undercuts (micro-selective build-up), to protect and increase the polymerization conversion degree of the neo-formed hybrid layer and its mechanical properties, and to smooth the inner dental surfaces, achieving a more regular morphology of the prepared tooth. After this step, a little re-preparation may be required on the enamel margins. To avoid bonding between the hybridized layer and the impression materials, a layer of glycerine is applied, and light curing is performed for 20 s.⁸⁴ After rubber dam removal, a retraction cord (if needed) is placed in the sulcus, but generally this procedure is seldom required due to the coronal placement of the margins.

The impression material, usually a polyether or a polyvinylsiloxane, is placed in a dual-arch impression tray, which will record the preparation, the antagonist arch, and the occlusion, with generally less discomfort for the patient.⁸⁵ A

temporary, light-cured soft filling is then placed to protect the dental tissues (Telio, Ivoclar Vivadent).

In the dental laboratory, the overlay is waxed and pressed using lithium disilicate e.max ingots (Ivoclar Vivadent). To improve the esthetic appearance, stains and ceramic glaze are applied.

During the second appointment, the temporary material is removed.

The temporary filling cannot usually seal the tooth–restoration interface completely;⁸⁶ then, after rubber dam placement, a decontamination with air polishing and glycine powder is performed on the adhesion's surface.

The luting procedure is then started: First, aluminum oxide sandblasting (50 μ m particles) is performed to clean the tooth surface and to increase adhesion by promoting micro retention. The internal surface of the restoration is etched for 20 s with 5% hydrofluoric acid (Power C etching, 5% hydrofluoric acid, BM4), rinsed with water or ultrasonically treated in distilled water, and air dried with an oil-free air stream.^{87,88}

Etching with 35% phosphoric acid is then performed to remove remineralized salts stemming from previous acid etching. The ceramic restoration is silanized and air dried with a gentle and warm

air stream before insertion, to achieve higher bond strength.⁷² Enamel and IDS are etched with 35% phosphoric acid for 20 s and rinsed, followed by vigorous air drying. A bonding agent is applied following the manufacturer's instructions, and is brushed without light activation. The adhesive-filled resin is also applied to the inner surface of the restoration. The restoration is filled with heated composite or dual cement and then seated. The excess of luting material is removed with a probe. During luting procedures, matrix strips are placed between adjacent teeth and secured with wooden wedges (Hawe-Neos) to prevent excess interdental cement. Alternatively, Teflon tape can be used.

A high-power LED light device is used for 60 s on each side. After this first polymerization, glycerol gel is applied to completely polymerize the outer composite resin with the separation from the oxygen. Then, a second polymerization is performed for 20 s on each side (VALO LED curing light, Ultradent). Contours are polished with Sof-Lex (3M ESPE) flexible disks, and margins with an Identoflex yellow C13 silicon point. High-speed diamond burs are avoided for the removal of superficial stains so as to prevent scratches and thus compromise the esthetic appearance.

The proximal surfaces are contoured with the corresponding diamond files (Proxoshape Set, Intensiv, EVA system), and any residual remnant is removed with a scalpel or curette. Finally, a Sof-Lex medium/fine strip is used to perform the last finishing of the interproximal space, and final local remineralization of the treated teeth is performed with GC Tooth Mousse (GC). At this time, af-

ter rubber dam removal, the occlusion is evaluated and adjusted, if necessary. Any adjusted surfaces can be polished with a suitable polishing system, such as diamond polishing paste or rubber points for ceramic glossing (Fig 5).

Case 1

Failing amalgam restorations were evident on the first and second mandibular left molars, and recurrent decay with multiple stained fracture lines was noted (Fig 6). Wear facets and enamel cracks were present in all the occlusal surfaces (Figs 7 and 8). Radiographic evaluation revealed deep existing restorations with no periapical translucency or other pathologic findings. The patient was asymptomatic in both teeth, and an e.max pressed restoration was planned on the first molar. The amount of recurrent decay (Fig 9) and the location of fractures (Figs 10 and 11) made necessary the prophylactic removal of all weakened or undermined cusps (Fig 12).

As a first step, after rubber dam placement and anesthesia delivery, the previous amalgam restoration was removed using a carbide bur (eg, H21E, Brasseler USA; 557, Dentsply Midwest).



Fig 6 Failing amalgam restorations on teeth 36 and 37.

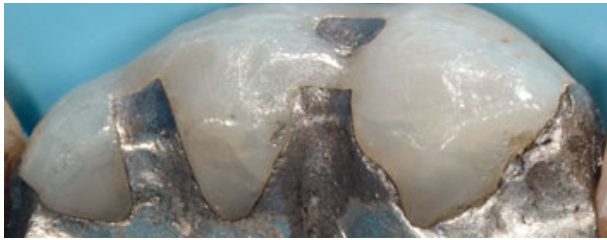


Fig 7 Preoperative functional and biomechanical analysis of working cusps.

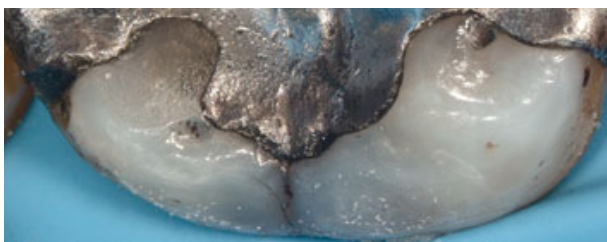


Fig 8 Preoperative functional and biomechanical analysis of non-working cusps.

The operative field was isolated from the seventh to the central incisor to facilitate the space available to the operator and increase visibility and ergonomics. We preferred to use a high-speed, small-diameter multiblade tungsten carbide bur, which allows the separation of the metallic restoration into several sections, and then the detachment of the sections using an excavator or with the aid of an ultrasonic scaler, always having the foresight to preserve the enamel margins.

Following alloy removal, the tooth was evaluated for recurrent decay, fractures, and undermined cusps. Low-speed carbon steel round burs were used to further remove decay and soft tissues (Fig 9). After using rotating instruments, it is advisable to evaluate the remaining

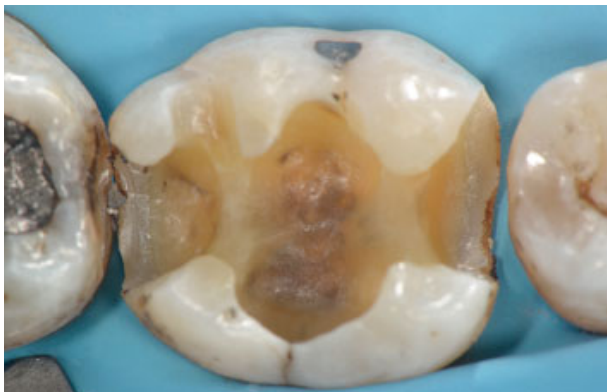
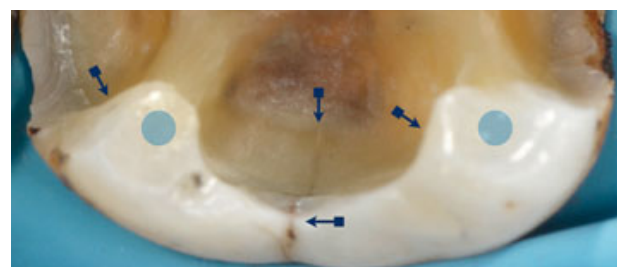
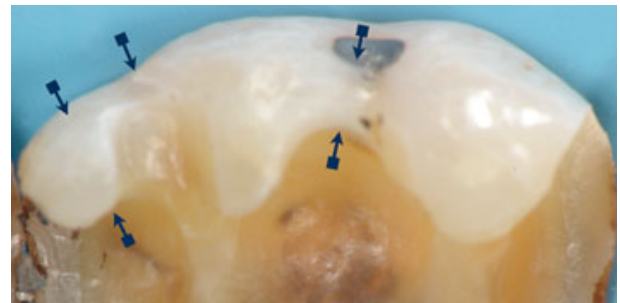


Fig 9 First operative step: remaining tooth structure after removal of old filling and dentinal decayed tissues.



Figs 10 and 11 Second operative step: post-operative analysis phase of the residual dental structure after removal of the old filling and infected tissue. Functional, parafunctional, and mechanical problems are marked.

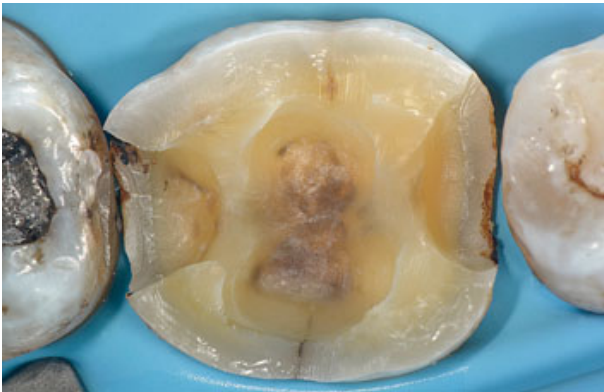


Fig 12 *Third operative step:* start of the preparation phase: circumferential cusps reduction.



Fig 13 *Fourth operative step:* connection and smoothing of the existing interproximal boxes. This is the end of the preparation, ready for hybridization procedures (IDS).

tissue with a valuable sharp excavator. In fact, in some conditions the mechanical instrumentation performed by rotating instruments tends to compact dentin, making it unsuitable for hybridization. The selection of an adequate dentin is important in the long-term prognosis of the hybrid layer. Once all the decay and fractures are removed, the remaining cusps and tooth structure are examined for potential areas of weakness.

The remaining tooth structure (Figs 9 and 10) and its mechanical value were then reevaluated.

As lingual cusps presented wear facets and enamel cracks, and the lingual wall was neither thick enough nor adequately supported by dentin (Fig 11), the coverage of both cusps was considered.

Using a 801-023 Intensiv round bur working at 50% of its diameter, a groove was produced with a width of about 1.2 mm in the buccal and lingual walls. This groove allowed for the achievement of the proper thickness for the best mechanical performance required by the

material used for the final restoration (ie, lithium disilicate). To determine the height of the preparation and ensure sufficient material thickness, a reduction of about 1.2 mm was performed both buccally and lingually (Fig 12).

The interproximal boxes already present in the old cavity were connected with the buccal and lingual surfaces using the same bur. This resulted in a smooth and continuous light chamfer surrounding the entire tooth at different levels, determined by the extension of the lesion, the depth of the preexisting boxes, and the occlusal clearance. The final aspect of the preparation is a smooth, short crown with extra-sulcular preparation and a complete adhesive ferrule substrate (Fig 13). An important consequence of such a preparation is that it makes it easy for the technician to develop an overlay with perfect margins and a pleasing esthetic.

Before taking the impression, the tooth was hybridized with a fourth generation dental adhesive (Optibond FL), and a

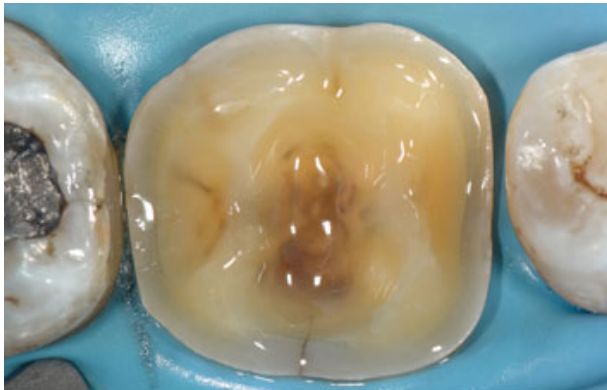


Fig 14 The tooth is hybridized using a three-step adhesive system with filled bonding. Immediately after this, a micro, punctual and selective build-up was performed. A thin layer of flowable composite was applied to protect the neo-formed hybrid layer.



Fig 15 Inactivation and elimination of the last non-polymerized layer of composite under glycerine hydro-soluble gel. Preparation is ready for impression procedures.

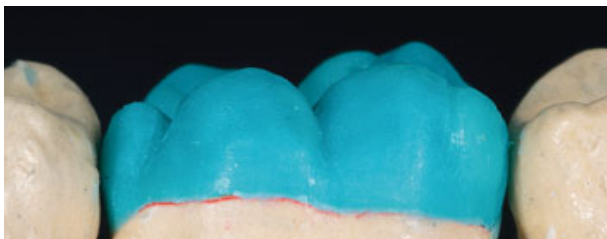


Fig 16 Laboratory: painted monolithic lithium disilicate: wax-up.

small amount of flowable composite used as a liner was added and polymerized to protect the neo-formed hybrid layer and smooth and flatten the floor of the preparation, eliminating eventual little undercuts (Fig 14). Immediately afterwards, the last layer of composite was

polymerized under glycerine hydro-soluble gel to create the best physical and chemical conditions to ensure a good impression (Fig 15).

Then, a dual-arch sectional impression was detected with a polyether impression material (Permadyne L, 3M ESPE, in a syringe; and Impregum Penta, 3M ESPE, in the tray). A temporary restoration was placed and put in occlusion to protect the remaining tooth and to avoid undesirable extrusions/movements of the tooth (Telio temporary, LC, Ivoclar Vivadent), and was light cured.

After 1 week, the overlay was ready for luting procedures. First, the temporary restoration was removed and the overlay



Fig 17 Laboratory: contouring and painting procedures of the lithium disilicate overlay.

was gently inserted to check the interproximal contacts with dental floss. After anesthesia and rubber dam placement, the entire preparation was decontaminated with glycine (Clinpro, 3M ESPE), and gently sandblasted with aluminum dioxide 50 mn to avoid the eventual exposition of dentin islands. The prepared tooth was etched with 37% orthophosphoric acid for 20 s, then rinsed and dried. The bonding agent was applied on the entire dental surface and left uncured. In the overlay side, 5% hydrofluoric acid was applied (Power C etching) for 20 s on the intaglio surface. Care was taken not to etch the external surface.

After rinsing the etching agent and drying the overlay, one layer of a silane coupling agent was applied, and the solvent evaporated with air spray. A layer of uncured bonding agent was applied on the treated surface. A restorative composite resin (G ænial A2, GC) was applied on the cavity, after which the overlay was inserted on the preparation. After an accurate removal of resin excess, two high-power light-curing units (VALO LED) were applied both buccally and lingually for at least 20 s to achieve a high degree of conversion of the composite under the overlay and to reduce the amount of unreacted monomers, thus improving the mechanical properties. A layer of glycerine gel was applied to eliminate the unreacted, exposed superficial composite at the overlay–tooth margin. Dental floss was used to remove the interproximal composite debris, then polymerization procedures and finishing took place with diamond red ring metal strips. The restoration–tooth complex was then glossed with a Sof-Lex plastic strip, and polished with a rubber point



Fig 18 Volumetric integration of the prosthetic.

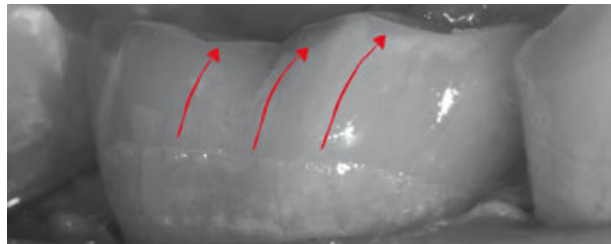


Fig 19 Relocation of occlusal stresses from the periphery to the center of the tooth, one of the most important aspects during the adhesive prosthetic's planning.



Fig 20 Buccal emergency profiles.



Fig 21 1-year control before hygienic and repolishing procedures.



(Brownie, FG; and Identoflex C13 yellow mini point).

After rubber dam removal, occlusal checks were performed with articulating papers. Undesired occlusal adjustments were accurately re-polished with a rubber point or disc for ceramic use. The final result after 1 year is shown in Figure 21.

Case 2

The patient presented with severe sensitivity under load of the first and second

maxillary left molars (Fig 22). With magnification it was possible to assess the presence of a mesiodistal occlusal fracture of the elements (Fig 23) even under the preexisting amalgam restorations. It was decided not to endodontically treat these teeth as, in our opinion, there was no further chance of endodontic and mechanical problems connected to the treatment. The ideal overlay was prepared with the grooving of the fracture, using an IDS approach to hybridize and flatten the preparation (Figs 24 and 25). The same procedure was followed as for Case 1. An accurate follow-up con-



Fig 22 Patient presents with sensitivity under two old amalgam restorations.

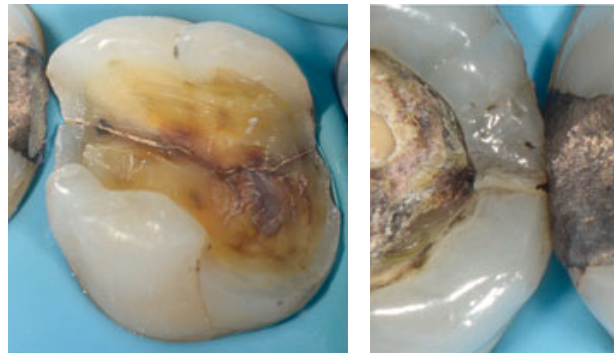


Fig 23 Deep longitudinal MOD crack under element 26.

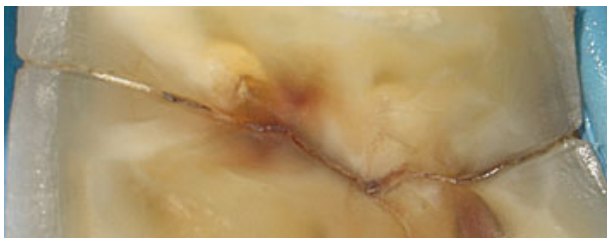


Fig 24 Detail of the crack after preparation with aluminium dioxide 50 mn and successive decontamination with air polishing and glycine powder of the fracture rime.



Fig 25 Final preparation, micro build-up, IDS procedures, and hybrid layer protection.

firmed the success of the therapy. In this clinical situation, the patient reported an absence of pain, comfortable function, and a good esthetic. At 1-year radiographic control, the restorations were in service and the teeth vital.

Although this case had a doubtful prognosis, the aim to be minimally invasive and maintain dental tooth structure was achieved.

Case 3

The first maxillary molar was symptomatic for pain during chewing and needed to be treated (Fig 27). Upon examination of the structural integrity of the remaining hard tissue volumes, it was deemed necessary to reduce the distovestibular cusp due to the propagation of a horizontal crack. Similar reduction was performed on the palatal aspect due to the propagation of a vertical crack due to high masticatory loads, as exemplified by the heavy wear facet (Fig 28). The tooth was prepared for a lithium disilicate overlay following the procedures mentioned above (Fig 29).



Fig 26 Control after 7 months without any repolishing procedures.

Controls at 6 and 12 months showed good clinical performance and good esthetics (Figs 31 and 32).



Fig 27 Initial case: sensitivity during bite on an old composite restoration.



Fig 28 Mechanical problems of the tooth on working and non-working cusps.

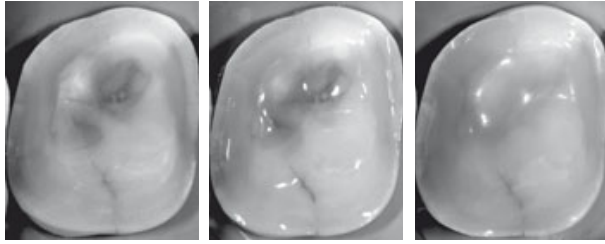


Fig 29 Preparation, hybridization, and micro-selective build-up sequence.



Fig 30 Adhesive cementation with microhybrid composite mass.



Fig 31 Detail of the marginal adaptation of lithium disilicate overlay immediately after cementation procedures.

Discussion

There are some advantages to using a lithium disilicate overlay in endodontically treated teeth or teeth with a severe loss of structure. Compared to a full-crown preparation, covering the cusps of weakened teeth with a lithium disilicate overlay can improve the resistance to fracture and save tooth structure. Also, the time required to complete the therapy is reduced: only one appointment is required from impression to cementation. In addition, the placement of ferrule in a wider and more coronal area, in association with an adhesive cementation, can improve the strengthening effect of the overlay. The placement of an overlay-tooth interface far from the gingival margins avoids the negative effects of submarginal margins, thus reducing the risk of iatrogenic periodontal problems. Margins allocated in an esthetic area represent a challenge for both the tech-



Fig 32 Final case: control after 6 months without any repolishing procedures.



nician and the clinician. If high esthetics is required, margins can be placed close to the gingival margin or coronally, just after the buccal crests of the cusps. However, success depends largely on the skill of the technician.

Finally, an interesting aspect is the lower cost of the overlay, compared to porcelain fused to metal or porcelain fused to zirconia crowns.

Due to these considerations, and with the support of a solid analysis of the literature, our suggestion is to use this more conservative approach when there is the

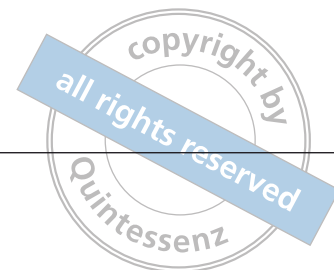
need to reconstruct a severely damaged tooth, and to use crowns only for the replacement of old crowns and bridges, or in selected complex esthetic cases. This topic warrants further clinical studies.

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