Ministry of Higher Education
and Scientific Research
University of Baghdad
College of Dentistry

Posterior Inlay and Onlay

A Project
Submitted to the Council of the College of Dentistry at the University of Baghdad Department of Conservative Dentistry in Partial Fulfillment of the Requirements for the B.D.S. Degree

By
Ibrahim Nabil Aziz

Supervised by
Dr. Ala'a Jawad
B.D.S., M.Sc.

2018 A.D. 1439 A.H.

Dedication

This work is dedicated to my family, to my friend (Modar Abbas) for their great support and for always believing in me. Thank you from all my heart.

Ibrahim

Certification of the Supervisor

I certify that this thesis entitled "**Posterior Inlay and Onlay"** was prepared by **Ibrahim Nabil Aziz** under my supervision at the College of Dentistry/ University of Baghdad in partial fulfilment of the requirements for the for the B.D.S. Degree.

Signature
Dr. Ala'a Jawad
B.D.S., M.Sc.
(The supervisor)

Acknowledgement

Thanks and praise to **Allah the Almighty** for inspiring and giving me the strength, willingness and patience to complete this work.

My deepest gratitude and sincere appreciation to **Prof. Dr. Hussain F. Al-Huwaizi**, Dean of the College of Dentistry, University of Baghdad, for his kind care and continuous support for the postgraduate students.

I would like to thank **Prof. Dr. Nidhal H. Ghaib**, Assistant Dean for Scientific Affairs, for her advice and support.

My sincere appreciation and thankfulness to **Prof. Dr. Adel Frahan**, Chairman of the Conservative Dentistry Department, University of Baghdad, for his keen interest, help, scientific support and encouragement.

A million words would be too short to express my genuine appreciation to my supervisor **Dr. Ala'a Jawad** who supported me throughout this project and introduced me to the wonders of science. Thank you for your invaluable guidance and for your tremendous effort to help me finish this thesis. Thank you for your time, advice, care and motivation during the entire research period. I am very grateful for your supervision and I owe you the greatest degree of respect and appreciation. Being your student was a privilege- I have learnt so much from you. Thank you for being the perfect mentor. I can never really thank you enough.

List of contents

List of Figures

Introduction

Restorative procedures, like caries ex- cavitation, 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. An- other 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- 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 parafunction- al 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] .

1. Brief history of clinical development and evolution of esthetic inlay and onlay procedures

Amalgam fillings have been used for well over a century and offer the most user-friendly material for restoring posterior teeth. Their low technology advantages include technique forgiveness and tolerance for conditions encountered when not using a rubber dam, such as susceptibility to contamination from blood, sulcular fluid, or saliva. Amalgams are also condensable, so contact can be more readily achieved. From the dentist's standpoint, amalgam has been a good restorative material, being applied through a technique that is easy to learn and execute. Amalgam also has good longevity and the lowest cost of any of the restorative materials. Among amalgam's significant deficiencies are its susceptibility to constant corrosion, inability to strengthen the teeth, inability to seal teeth initially, and lack of esthetics. Many patients and dentists are also concerned about the mercury issue, because amalgam is 50% mercury. Recently, environmental concerns about contamination of the water supply have led to increased regulations and even calls for a ban on further use, which has been instituted in some countries. Cast gold has been used for over a century. Gold is an inert material, can be alloyed to almost an ideal hardness value, so as to be kind to opposing tooth structure, and when properly applied has been shown to have a longevity of decades. Often gold is considered the "gold standard" of restorative dentistry.

Its main deficiency is its color. However, when the restoration is placed in second molars or when the patient is not concerned about the color, selecting cast gold for moderate to large cavities is one of the wisest choices the dentist can make.

The esthetic inlay and onlay procedure successfully using ceramic and/or processed composites began to be used around the mid-to-late 1980s, shortly after the introduction of ceramic veneers for anterior teeth. Both treatments paralleled advances in adhesive dentistry in general. Stacked, feldspathic porcelain or indirect composite inlays and onlays were also introduced to address some of the deficiencies of direct composites, which at the time, were considerable when applied to posterior teeth

They included high wear, low strength, high shrinkage, and difficult placement, especially in light of dentists' training in placing metals in posterior teeth, a technique quite different from what is used for direct composites. In addition, laboratory fabricated ceramic and processed indirect composite yielded improved physical properties, improved contours, predictable idea proximal contacts, and the potential for better, more appropriately placed functional occlusal contacts [(13)] .

2. Indications

The indications for Class I and II indirect tooth-colored restorations are based on a combination of esthetic demands and restoration size and include the following:

2.1. Esthetics: Indirect tooth-colored restorations are indicated for Class I and II restorations (inlays and onlays) located in areas of esthetic importance for the patient.

2.2. Large defects or previous restorations: Indirect tooth-colored restorations should be considered for restoration of large Class I and II defects, especially those that are wide faciolingually or require cusp coverage. Large intracoronal preparations are best restored with adhesive restorations that strengthen the remaining tooth

3. Contraindications

Contraindications for indirect tooth-colored restorations include the following:

3.1. Heavy occlusal forces: Ceramic restorations can fracture when they lack sufficient thickness or are subject to excessive occlusal stress, as in patients who have bruxing or clenching habits

3.1. Inability to maintain a dry field: adhesive techniques require near-perfect moisture control to ensure successful long-term clinical results.7–9

3.2. Deep subgingival preparations: Although this is not an absolute contraindication, preparations with deep subgingival margins generally should be avoided. These margins are difficult to record with an elastomeric or even a digital impression and are difficult to evaluate and finish.

4. Advantages

Except for the higher cost and increased time, the advantages of indirect tooth-colored restorations are similar to the advantages of direct composite restorations.

4.1. Improved physical properties: A wide variety of high-strength tooth-colored restorative materials, including laboratory-processed and computer-milled ceramics, can be used with indirect techniques. These have better physical properties than direct composite materials because they are fabricated under relatively ideal laboratory conditions.

4.2. Variety of materials and techniques: Indirect tooth-colored restorations can be fabricated with ceramics using traditional laboratory processes or using chairside or laboratory CAD/CAM methods.

4.3. Wear resistance: Ceramic restorations are more wear resistant than direct composite restorations, an especially important factor when restoring large occlusal areas of posterior teeth.

4.4. Reduced polymerization shrinkage: Polymerization shrinkage and its resulting stresses are a major shortcoming of direct composite restorations. Although shrinkage of resin materials in thin bonded layers can produce relatively high stress, clinical studies indicate ceramic inlays and onlays have better marginal adaptation, anatomic form, color match, and overall survival rates than do direct composite restorations.

4.5. Support of remaining tooth structure: Teeth weakened by caries, trauma, or preparation can be strengthened by adhesively bonding indirect tooth-colored restorations.

4.6. More precise control of contours and contacts: Indirect techniques usually provide better contours (especially proximal contours) and occlusal contacts than do direct restorations because of the improved access and visibility outside the mouth.

4.7. Biocompatibility and good tissue response: Ceramics are considered chemically inert materials with excellent biocompatibility and soft tissue response. The pulpal biocompatibility of the indirect techniques is related more to the resin cements than to the ceramic materials used.

4.8. Increased auxiliary support: Most indirect techniques allow the fabrication of the restoration to be delegated totally or partially to the dental laboratory. Such delegation allows for more efficient use of the dentist's time.

5. Disadvantages

The following are disadvantages of indirect tooth-colored restorations:

5.1. Increased cost and time: Most indirect techniques, except for chairside CAD/CAM methods, require two patient appointments plus fabrication of a provisional restoration. These factors, along with laboratory fees, contribute to the higher cost of indirect restorations in comparison with direct restorations.

5.2. Technique sensitivity: Restorations made using indirect techniques require a high level of operator skill. A devotion to excellence is necessary during preparation, impression, try-in, bonding, and finishing the restoration.

5.3. Difficult try-in and delivery: Indirect composite restorations can be polished intraorally using the same instruments and materials used to polish direct composites, although access to some marginal areas can be difficult. Ceramics are more difficult to polish because of potential resin-filled marginal gaps and the hardness of the ceramic surfaces.

5.4. Brittleness of ceramics: A ceramic restoration can fracture if the preparation does not provide adequate thickness to resist occlusal forces or if the restoration is not appropriately supported by the resin cement and the preparation.

5.5. Wear of opposing dentition and restorations: Some ceramic materials can cause excessive wear of opposing enamel or restorations.17 Improvements in materials have reduced this problem, but ceramics, particularly if rough and unpolished, can wear opposing teeth and restorations.

5.6. Low potential for repair: When a partial fracture occurs in a ceramic inlay or onlay, repair is usually not a definitive treatment. The actual procedure (mechanical roughening, etching with hydrofluoric [HF] acid, and application of a silane coupling agent before restoring with adhesive and composite) is relatively simple (14).

6. **Armamentarium**

As for metal inlays, carbide burs are used in the preparation, but diamonds may be substituted:

- Tapered carbide burs
- Round carbide burs
- Cylindrical carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels
- Gingival margin trimmers

• Excavators

• High- and low-speed handpieces.

• Articulating film

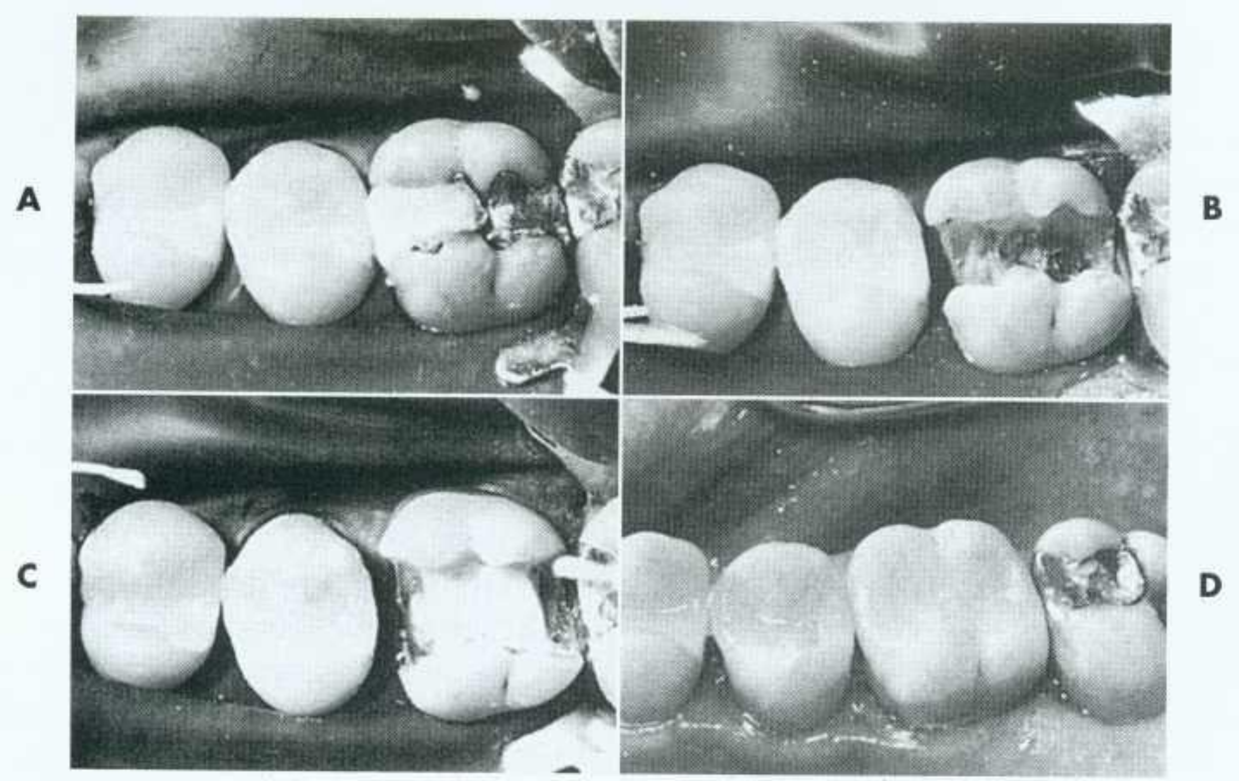

Fig. (a) Maxillary first molar preparation for an MOD ceramic inlay.

A. Defective restoration. B. The restoration and caries removed.

C. Unsupported enamel removed and glass ionomer base placed. D. The completed ceramic restoration. *(Courtesy Dr. R. Seghi.)*

7. Principle of inlay and onlay

Rubber dam isolation is recommended for visibility and moisture control. Before applying the dam, mark and assess the occlusal contact relationship with articulating film. To avoid chipping or wear of the luting resin, the margins of the restoration should not be at a centric contact.

7.1. Outline Form

7.1.1. Prepare the outline form. This will generally be governed by the existing restorations and caries and is broadly similar to that for conventional metal inlays and onlays . Because of the resin bonding, axial wall undercuts can sometimes be blocked out with resin-modified glass ionomer cement, preserving additional enamel for adhesion. However, undermined or weakened enamel should always be removed. The central groove reduction (typically about 1.8 mm) follows the anatomy of the unprepared tooth rather than a monoplane. This will provide additional bulk for the ceramic. The outline should avoid occlusal contacts. Areas to be onlayed need 1.5 mm of clearance in all excursions to prevent ceramic fracture.

7.1.2. Extend the box to allow a minimum of 0.6 mm of proximal clearance for impression making. The margin should be kept supra gingival, which will make isolation during the critical luting procedure easier and will improve access for finishing. If necessary, electrosurgery or crown lengthening (p. 150) can be done. The width of the gingival floor of the box should be approximately 1.0 mm.

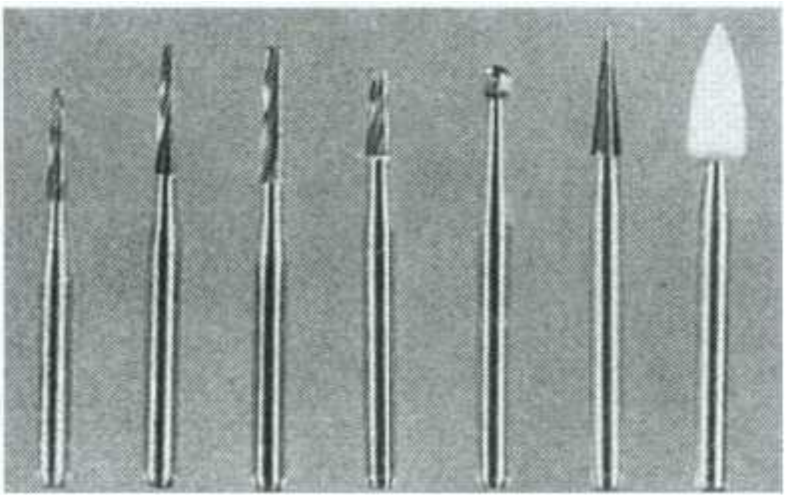

Fig. b Armamentarium for the porcelain laminate veneer preparation.

7.1.3. Round all internal line angles. Sharp angles lead to stress concentrations and increase the likelihood of voids during the luting procedure.

7.1.4. Caries Excavation

Remove any caries not included in the outline form preparation with an excavator or a round bur in the low-speed handpiece.

7.1.5. Place resin-modified glass ionomer cement base to restore the excavated tissue in the gingival wall.

7.2. Margin Design

7.2.1. Use a 90-degree butt joint for ceramic inlay margins. Bevels are contraindicated because bulk is needed to prevent fracture. A distinct heavy chamfer is recommended for ceramic onlay margins.

7.3. Finishing

7.3.1. Refine the margins with finishing burs and hand instruments, trimming back any glass ionomer base. Smooth, distinct margins are essential to an accurately fitting ceramic restoration.

7.4. Occlusal Clearance (for Onlays)

7.4.1. Check this after the rubber dam is removed. A 1.5-mm clearance is needed to prevent fracture in all excursions. This can be easily evaluated by measuring the thickness of the resin provisional restoration with a dial caliper [15].

8. Relating function and esthetics

Achieving a predictable-quality proximal contact can be challenging in class II direct resin restorations, particularly in a moderately broken down tooth. It can also be difficult to routinely achieve adequate contacts in teeth with a compromised arch position or a mal-alignment. Certainly, the amount of tooth structure being replaced can be a factor in treatment planning specific to the ease of placement and quality of the definitive result.

The functional loading on the restorative material, especially when one or more cusps are missing, is certainly greater than in smaller cavities. Also, it is known that occluding forces increase from anterior to posterior. Therefore, posterior esthetic restorations not only have to satisfy patient desires for natural appearance, but they need the necessary strength factors to be durable over time.

Finally, the reduction of microleakage, particularly when gingival margins are in dentin, may also be a factor when choosing an inlay or onlay over a direct composite restoration, especially in larger cavities. Although there are studies showing these type of indirect restorations show reduced microleakage in such instances, not all investigations are in agreement, and complete elimination of microleakage at dentin margins has not been achieved by any of the current adhesive systems (16).

9. Treatment planning for esthetic inlays or onlays

9.1. Options

Figure 1 shows a very large amalgam in the first molar replacing a cusp. In the second molar there is an occlusal amalgam. In treatment planning for the second molar, which has some recurrent caries, the amalgam restoration can easily be replaced with a direct composite because of the relatively small size. The first molar has a very large amount of amalgam in need of replacement, so the decision is between going to a full-coverage crown, which would necessitate virtually removing the three remaining cusps, or removing all the old alloy plus any associated disease, leaving the three remaining cusps, and placing a bonded esthetic onlay. The latter is far more conservative because of the tooth reinforcement achieved by bonding to a significant amount of enamel and because the three cusps are preserved. Potentially this tooth may never need to be crowned. The case in Figure 2 shows the advantages, both conservative and esthetic, of adhesive onlay restorations. Figure 3 shows four amalgams, two in molars and two in premolars. Those in the premolars would be defined as relatively small restorations. When one also considers the amount of occlusal force premolars are subjected to, these amalgams could be replaced with direct composite resin restorations. The distal lingual cusp of the first molar is cracked. Because the restoration will be an onlay, and given the heavy functional demand on first molars, this author believes that an onlay is the best restoration, whether it be cast gold, ceramic, or indirect composite. This patient preferred an esthetic restoration, so an indirect composite was used. The width of the cavity in the second molar qualifies it as a small cavity, which might be well served by a direct composite restoration. However, the functional aspects of this particular tooth must also be considered. There is a greater than normal inter-tooth distance between the first and second molars as evidenced by the placement of the amalgam on the distal of the first molar well into the proximal space and the placement of the amalgam in the second molar well into the proximal space so that these two fillings contact.

This creates a very large gingival embrasure and a lack of support. Although this is not a particular problem with amalgam, which has great strength to withstand function without tooth support, direct resin has neither the flexural strength nor the fracture toughness to withstand the functional forces in the second molar area when the restoration is virtually cantilevered into the proximal area. Therefore an indirect restoration, such as indirect composite or ceramic inlay, would be preferred over direct composite material, which otherwise might have been considered because of the small size of the cavity. The ideal option for the second molar is an inlay, but that inlay could have been of cast gold as well as an esthetic material. The patient desired a non-metallic restoration [(17)] . (Figure 4).

FIGURE 1 Case demonstrating the advantages (conservative and esthetic) of adhesive onlay restorations.

FIGURE 2 A, A very large amalgam in the first molar (replacing a cusp) and occlusal amalgam in second molar. B, Amalgam replaced with direct composite (second molar) and bonded esthetic onlay (first molar).

FIGURE -3 Four amalgams, two in molars and two in premolars.

FIGURE 4 Non-metallic restoration of the case in Figure 3.

10. Cavity design for ceramic

Finite-element modeling suggests that composite restored teeth exhibit increased coronal flexure whereas ceramic inlays result in increased coronal rigidity (18) · 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 [19] . This could explain the higher risk of both bulk fracture on ceramic partial restorations and tooth fracture on elements restored with composite restorations [20] .

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 [21] . 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 [22]. 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 [23] . 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 [24].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 sup- port for the ceramic restoration [25]. The occlusal margins of the inlay restorations should not be located in the region of occlusal contact points [26]. 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 [27, 28]. 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 [29]. Dual-cure resin luting agents re- quire 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 [30]. 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 [31, 32]. Dual cure etch-and-rinse adhesives seem to achieve adequate bond strengths and should be preferred [33]. 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 thick- ness, and translucency of the restorative material. D’Arcangelo and co-workers 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 [34]. 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 [35]. 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.

11. CLINICAL PROCEDURES

11.1. Preparation

The principles of cavity preparation for esthetic inlays or onlays differ from those for gold restorations. For esthetic inlay or onlay restorations, bevels and retention forms are not needed. Resistance form is generally not necessary but may be required in very large onlay restorations. Cavity walls are flared 5 degrees to 15 degrees in total (10 degrees to 12 degrees ideal), and the gingival floor can be prepared with a butt joint. The internal line angles are rounded, the minimum isthmus width is 2 mm, and the minimum depth thickness is 1.5 mm (Figure 5).

For onlay restorations, nonworking and working cusps are covered with at least 1.5 mm and 2 mm of material, respectively. If the cusp to be onlayed shows in the patient's smile, a more esthetic blended margin is achieved by a further 1- to 2-mm reduction with a 1-mm chamfer (Figure 6). The proper cavity form can be prepared using bur kits (e.g., Esthetic Inlay/Onlay, Brasseler USA, Savannah, Georgia).When the occlusal aspect of the cavity is prepared, undercuts should not be eliminated by removing healthy tooth structure, which compromises the conservatism of this approach. The objective is to establish divergence in the enamel, then block out all undercuts. This is possible using bonded resin or a resin-modified glass ionomer. For cemented castings it is generally best to overlay a working cusp when the cavosurface margin is more than 50% up the incline of the cusp. The cavosurface margin can extend up to 75% up the cuspal incline of a nonworking cusp before overlaying of the cusp is considered. Studies have investigated the use of bonded inlay or onlay restorations for this area, but no clinical consensus on when to remove a cusp has been reached. Because these restorations reinforce the remaining tooth structure, the traditional guidelines for overlaying a cusp as in cast gold onlays have been modified. When there is no dentin support directly underneath the cusp tip, the author routinely onlays the cusp. The palatal or working cusp is onlayed, even with dentin support if the margin is within 1 mm of the cusp tip (Figure -7). When the margin is beyond 1 mm from the cusp tip, the cusp gains dentin supprt and bond strength increases. The horizontal lines depict the direction of the enamel rods. At the cusp tip the enamel rods are almost vertical and etching would be on their sides. As the margin moves away from the cusp tip the ends become etched, which has been shown to increase bond strength (Figure 8). The non-working or buccal cusp is not onlayed in this diagram even when the margin is at the cusp tip. If the posterior teeth are discluded in lateral jaw movements, there are no forces applied to this cusp.

In the author's experience it is not uncommon to find cracks on the pulpal floor under cusps when removing amalgams that have been in place for some time, particularly moderate-sized ones.

Whether the teeth exhibit pain on chewing (e.g., cracked tooth syndrome) or are asymptomatic, these cusps should be overlayed.

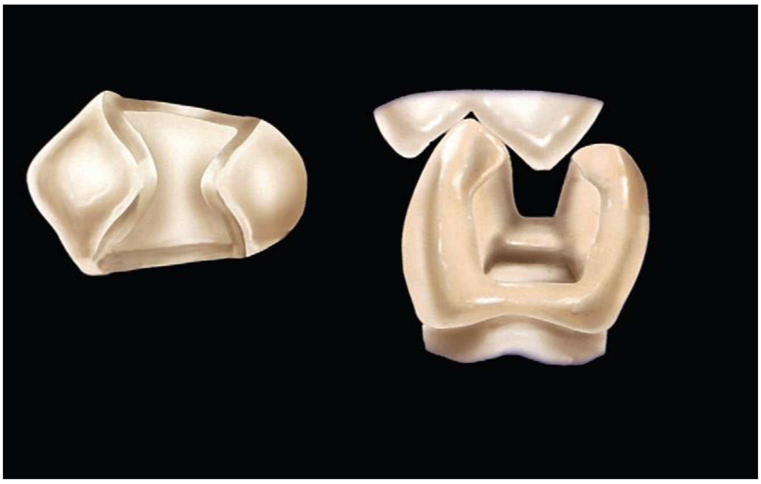

FIGURE 5 Preparation for aesthetic inlay. (Courtesy Montage Media Corporation, Mahwah, New Jersey.)

FIGURE 6 Preparation for aesthetic onlay. (Courtesy Montag , Media Corporation, Mahwah, New Jersey.)

Logic also dictates that for patients with parafunctional habits (e.g., bruxism or clenching) the cusps should be overlayed more aggressively.

A popular technique to which this author subscribes is called *immediate dentin sealing* (IDS). First described by Paul and Scharer in 1997, this technique has been clinically popularized by Dr Pascal Magne. The technique is based on the logic that them strongest dentin bond is achieved when dentin is bonded immediately after being cut and before becoming contaminated, such as occurs during the provisional phase. Besides the pulpal protection afforded by this procedure, the patient has more comfort while the provisional is in place. Finally, early data show that the ultimate bond of the restoration and the marginal integrity over time are improved. There are different approaches using different adhesives to achieve IDS, but this author prefers placing a selfetching adhesive followed immediately after curing by a very thin layer of very-low-viscosity flowable composite resin. Any undercuts are blocked out simultaneously with the flowable resin. After curing, it is necessary to remove the air-inhibited layer. This can be done by wiping the surface with a cotton pledget soaked in alcohol. An alternative technique is to cover the surface with a glycerin product such as DeOx (Ultradent, Products, Inc., South Jordan, Utah) and light curing again. After washing and drying, the vertical enamel walls are prepared again with a finishing bur to remove any adhesive that may have flowed onto these surfaces.

After preparation, an impression is obtained using an accurate re-pourable material. This is sent to the laboratory with any additional models, records, or information needed to fabricate the restoration. The level of esthetics achieved with this restoration is directly proportional to the level of communication between the clinician and laboratory technician. Consequently, the color prescription must contain the occlusal base shade of the restoration, the gradient of shade from central fossa to cavosurface margin, the degree and color of the desired pit and fissure stains, and any maverick highlights present. For onlay restorations in the esthetic zone, the base shade at the facial margin must be communicated to the laboratory technician via a detailed color prescription or a color photograph that includes a shade tab in the picture. The shade is taken before preparation to avoid the misleading effects produced in a desiccated tooth.

Once this diagnostic information has been obtained, a direct provisional restoration (e.g., E-Z Temp Inlay or Onlay [Cosmedent Inc., Chicago, Illinois], Systemp Inlay or Onlay [Ivoclar Vivadent, Amherst, New York]) is placed while the definitive restorations are fabricated in the laboratory [36].

11.2. Impressions

A polyvinyl siloxane impression material was used to take a teeth to be prepared impression. A light body material was injected around the margins as the impression tray was loaded with a heavy body material The tray was seated and the material was allowed to set completely before it was removed from the patient’s mouth. The final impression is shown in An opposing full arch impression was also taken in a polyvinyl material A hard-setting occlusal registration was taken , shows the bite registration after removal from the patient’s mouth [37].

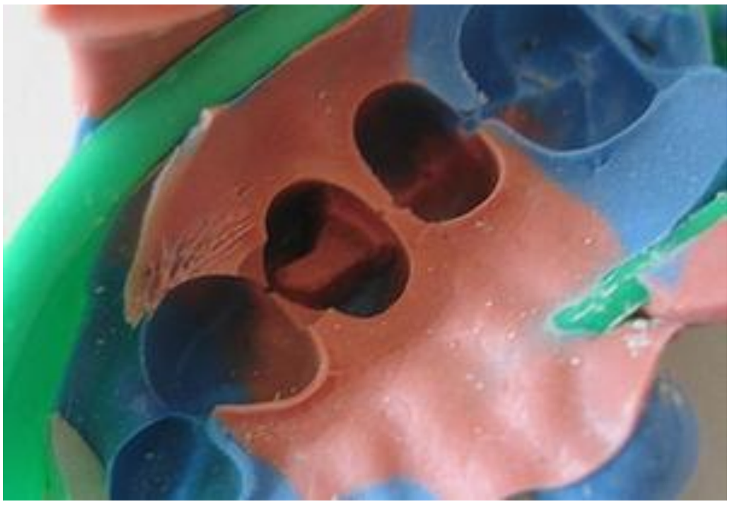

Figure 7: inlay and onlay impression

11.3 Maintenance

There are two aspects to maintenance: normal patient maintenance (brushing, flossing, and routine home care) and reparability of the restoration. Compared with ceramic, indirect composite is more predictable in terms of intra-oral repair. Having a reparable restoration extends its longevity without replacement issues, which almost always involve the removal of extra tooth structure and added tooth trauma. In repair of an indirect composite resin, first the fractured area—including the enamel and the existing resin composite restoration—is roughened using a diamond bur. Often the restoration is also micro-etched before etching of the cavity and placement of the bonding agent. The missing structure is then built up in direct composite. The restoration is then finished and polished [38].

12. Indirect restorative materials

All indirect restorations require a cement for the prepared teeth to retain them. The cement can have a large influence on the performance and biocompatibility of the overall restoration. Two broad categories of available cements are water-based cements and resin-based cements. From these two categories, a dentist has a wide variety of materials with different working characteristics and properties from which to choose. The choice often depends on the type of material selected for the indirect restoration and the clinical requirements, such as setting characteristics, film thickness, setting rates and adhesion to the underlying tooth.

12.1 Porcelain

For machined restorations, porcelain blocks (eg, IPS Empress CAD, Ivoclar Vivadent, Vitabloc Mark II,) with corresponding pressable materials (eg, Empress, Ivoclar Vivadent; Vita PM9, Vita North America,) are available. These block materials possess high translucency and similar mechanical properties. In comparison to pressed restorations, block materials tend to have minimal porosity and better longevity. If the clinician can achieve the manufacturers' recommended 2-mm occlusal minimum thickness, then success rates for bonding to the tooth are equivalent to dental zirconia materials. Most of these studies were performed using Vita Mark II and have posterior success rates of 95% to 98% up to 7 years [39].

12.2 Glass-Ceramics

Another broad category with corresponding pressable materials is glass-ceramics, which start as glass. The application of a second heat cycle changes the ionic state, causing crystallization in the glass. This heat cycle is critical to producing the correct amount and size of crystals as well as the proper shade. Dental professionals should closely follow the manufacturers' recommended cycles and make sure furnaces are properly calibrated. If crystallization is not performed correctly, then weak, soluble glass and improper shade can be produced. The most widely known glass-ceramic is the IPS e.max® CAD block (Ivoclar Vivadent,) with the corresponding pressable e.max press (Ivoclar Vivadent). However, a number of other glass-ceramic blocks such as Celtra Duo (Dentsply Sirona,), Vita Suprinity® (Vita Zahnfabrik), and Obsidian® (Glidewell Laboratories, glidewelldental.com) are available. Celtra Duo block also has a corresponding pressable. However, pressables tend to have porosity due to the pressing method. Blocks are fabricated under strict conditions at the factory and tend to have minimal defects. Due to the relatively high crystal content of up to 70%, these materials tend to have lower translucency than porcelain. The improved mechanical properties and fracture resistance allow for the use of these materials at about 1.5-mm occlusal reduction. Although manufacturers state that these materials may be "cemented" with glass monomer, it is my opinion, based on clinical studies and laboratory research, that maximum resistance to failure is achieved by bonding with composite resin cement.

12.3 Polymer-Based Materials

A number of polymer-based materials have been developed for use as permanent machined restorations. These include traditional composite resin such as LavaTM Ultimate (3M ESPE,) and GC CerasmartTM (GC America). Both materials have a silica glass (Cerasmart) and/or zirconia silicate glass filler (Lava Ultimate). Lava Ultimate has about 65% volume filler and Cerasmart has approximately 55%. These materials have good translucency and excellent fracture resistance. However, they do have much higher flexibility than other block materials and still may exhibit wear and discoloration over time. Usage indications for Lava Ultimate include inlays and onlays; however, the crown indication has been removed due, in part, to issues related to debonding. Cerasmart still retains all its indications. The issue of bonding is critical, and again careful attention must be paid to the manufacturer's recommendations for restoration and tooth preparation when bonding these restorations. The high degree of cure of the polymer resin and the individual filler particles make it more difficult to achieve a good bond. Minimum occlusal thickness is also recommended as 1.5 mm. A number of dental practices have eliminated the use of direct-fill composite resins and switched to machined composite resins. The relatively fast machining, high density (bubbles in hand layered), and full control of the contours generally provide superior restorations and may take less time than hand layering composite.

12.4 Polyaryletherketones

A completely different polymer type is called polyaryletherketones (PAEKs), which are thermoplastic materials with different properties relating to their exact chemical composition. Three basic types are becoming increasingly used for frameworks on which composite resins or ceramics may be bonded. These include poly-ether-ether-ketone (PEEK) (PEEK-Optima, Invibio Biomaterial Solutions,) and poly-ether-ketone-ketone (PEKK) (Cendres+Métaux, cmsa.ch).

PEEK is an amorphous material that may be compounded with fibers to create a fiber-reinforced polymer, and PEKK is a crystalline material with higher mechanical properties. An increasingly popular use of these materials is for implant-supported frameworks. Although PAEKs may have high strength values, they are highly flexible similar to indirect composite resins and have much higher flexibility as compared to the composite resin blocks [(40)]. Only fiber-reinforced materials have flexibility similar to composite resins.

12.5 Interpenetrating Phase Ceramics

A unique category of materials, interpenetrating phase ceramics are essentially comprised of two completely interconnected networks—a ceramic and polymer. One might think of a ceramic sponge being filled with a polymer such that the ceramic and polymers are completely connected to themselves and to each other. The bulk of the material is the ceramic network, 75% by volume. Because the ceramic is dominant, issues such as color stability are eliminated, as color is dependent on the ceramic and not the polymer. The flexibility issues seen with conventional composites are also nonexistent due to the interconnected ceramic "backbone." Interpenetrating phase ceramics such as Vita Enamic® (Vita Zahnfabrik) may represent a new area of development for advancing machined materials that are resistant to damage and easy machinability. It is a first-generation material with a unique microstructure, easy to machine (4 minutes for a crown), is bur kind, and requires polishing only. Enamic tends to be more resistant to chipping than feldspathic material or glass-ceramics. Due to the unique structure, load-bearing capacity is higher and requires only 1.0 mm of occlusal thickness.

12.6 Zirconia

Polycrystalline materials include alumina and zirconia. Alumina was first fabricated for all-ceramic restorations by Nobel Biocare () and marketed as NobelProcera. Since then, zirconia has become the most dominant machinable material, technically called yttria-partially stabilized zirconia (Y-TZP). In the past year, some important developments have occurred in the material type and processing of the zirconia family. Zirconia (ZrO_2) is the oxidized form of zirconium (Zr) just as alumina (Al_2O_3) is an oxide of aluminum (Al).

Zirconia exists in three major phases: monoclinic, tetragonal, and cubic. Monoclinic is the largest form, tetragonal is the intermediate, and cubic is the smallest. Biomedical and structural/functional applications of zirconia typically do not use pure zirconia. The addition of other ceramic components may stabilize the monoclinic phase at room temperature. If the right amount of component is added, then a fully stabilized material can be created. The addition of smaller amounts (5 percentage by weight [wt%]) produces a partially stabilized zirconia. Although stabilized at room temperature, the tetragonal phase may change under stress to monoclinic with a subsequent 3% volumetric increase. This property is called transformation toughening.

Dentistry typically has used Y-TZP with about 5 wt% yttria. Another key component is a small amount of alumina to help prevent uncontrolled transformation that would result in cracking and failure. The “standard” zirconia has about 0.25 wt%. Yttria is responsible for the zirconia’s ability to resist damage and stop cracks, while alumina prevents wholesale transformation leading to failure of the material under aging. Due to transformation toughening, this type of zirconia has excellent fracture resistance. This property, in part, allows clinicians to use this material at only an occlusal thickness of about 0.8 mm. However, it remains a traditionally brittle ceramic. Therefore, extreme caution should be used when going below the 1.0-mm thickness.

12.7 “Ultra/Super/Mega” Translucent Zirconia

With only about 0.05 wt% alumina and 9.0 wt% yttrium, “Ultra/Super/Mega” translucent zirconia has arrived in the marketplace in the past year. Research conducted at Boston University has revealed that the crack-stopping/damage-resistant property in a standard zirconia is not present in the high translucent material. In fact, typical procedures that may be performed in the laboratory or by the dentist when adjusting this material can reduce the strength from an untouched value of about 700 MPa to 400 MPa after using a 125-micron wheel and only 300 MPa once sandblasted with 50-micron alumina [(41)]. Thus, caution must be used when considering this material for various clinical applications and particularly if adjustments need to be made chairside. Usage may be best for low-stress areas such as centrals and laterals. Studies into the fatigue resistance are needed to fully determine proper clinical use.

12.8 Single-Unit Standard Zirconia

Advances in production of single-unit standard zirconia have taken two approaches. Both might allow for single-visit chairside fabrication of zirconia restorations. One is by Glidewell Dental with the release of BruxZir® Now, which is a traditional Y-TZP zirconia that is already fully dense as opposed to the porous blocks that require sintering. The block and bur are supplied together for single use. Machining time is approximately 45 minutes, and the standard 6-hour sintering cycle is eliminated. Only polishing or polishing and glazing is required before placement of the restoration.

Dentsply Sirona has taken a different approach for single-visit zirconia crowns. A porous zirconia block is machined to produce a crown. The crown is then placed in a special furnace, CEREC Speed-Fire (Dentsply Sirona), which allows for sintering and glazing of the crown in approximately 15 minutes. Findings from a recently completed, yet-unpublished, double-blind study performed at Boston University revealed the strength of the speed-fired zirconia and conventionally fired zirconia (6-hour cycle) was statistically the same. In other research using fast firing with a different furnace and different zirconia, the zirconia was found to be significantly weaker [(42)].

13. CAD\CAM inlay and onlay

Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) was first introduced to dentistry in the mid-1980s. Both chairside and chairside—laboratory integrated procedures are available for CAD/CAM restoration fabrication. In selecting which procedure to follow, consideration should be given to esthetic demands, chairside time, laboratory costs, number of visits and convenience and return on investment associated with CAD/CAM equipment. Depending on the method selected, CAD/CAM ceramic blocks available for restoration fabrication include leucite-reinforced ceramics, lithium disilicate, zirconia, and composite resin. In order to determine which type of ceramic to use, the practitioner must take into account esthetics, strength, and ease of customizing milled restorations. CAD/CAM gives both the dentist and the laboratory technician an opportunity to automate fixed restoration fabrication and to offer patients highly esthetic restorations in just one or two visits.

13.1. CAD/CAM Restorative Technique

Using a CAD/CAM restorative technique, a number of steps can be simplified or eliminated. Traditional impressions can be replaced by use of a handheld scanning device that digitally records the form and margins of the preparation. Care must be taken to ensure that the whole preparation is scanned, to avoid introducing errors. As with a traditional impression, soft tissue retraction and hemostasis are prerequisites for an accurate result. In fact, these steps are more critical for CAD/CAM preparation scanning than with traditional impressions. While impression material has some tolerance for small amounts of sulcular fluid, and light-body material can flow into deeper subgingival margins, scanners require a dry field and soft tissue that must be thoroughly separate at the level of the margin from the hard tissue. For this reason, it has been suggested that a soft tissue diode laser (Odyssey Navigator, Ivoclar Vivadent; GENTLEray 980, Kavo; DioDent Micro 980, HOYA ConBio) be used to expose subgingival margins. The soft tissue diode laser has been found to offer precision, to result in a narrow band of lased tissue, and to produce good hemostasis [43]. Good healing has also been the case following use of diode lasers on gingival tissues [44]. Selecting a laser with sterilizable sleeves assists with infection control, and portability and precut laser tips aid convenience (Odyssey Navigator). Alternative soft tissue management techniques include electrosurgery and one of the standard manual retraction techniques. In addition, a modified preparation design may be necessary.

13.2. Chairside CAD/CAM Technique

The chairside technique involves scanning the preparation and then fabricating the restoration in the milling device (CEREC 3, Sirona; E4D, D4D TECH). Prior to scanning, a very thin layer of powder is distributed over the preparation using the CEREC system. During scanning, the clinician must ensure that all margins of the cavity are captured by the scan and visualized [45]. The CEREC 3 uses still images, while the E4D uses a laser in the handheld scanning device. A third system, CICERO, was developed in The Netherlands and used a pressing, sintering, and milling technique prior to laboratory finishing of the restoration [46].

Table 1 advantages and disadvantages of CAD/CAM

Advantages
One-visit fixed restorative procedure
No impression making
No temporary restoration required
Reduced potential for tooth sensitization
No laboratory costs
No model or die pouring
Accuracy
Less opportunity for error compared to traditional technique
Aids prep visualization
Projects a state-of-the-art image
Disadvantages
Soft tissue management more critical than with traditional technique
Depending on the material and patient, customization may be required
High learning curve
Higher production required to cover capital investment

13.3. Replacement of Failing Amalgams

CAD/CAM conservative preparation design preserves more of the natural tooth structure compared with a crown and offers the clinical longevity of gold without the esthetic drawbacks. When using the current generation bonding adhesives according to the manufacturer’s instructions, the CEREC ceramic will re-create a tooth like strength.

13.4. Replacement of Posterior Restorations

CAD/CAM produces high strength ceramics for functionally demanding areas such as molars. The software is designed to precisely stitch together multiple digital images and propose an effective virtual die for multiple restoration design (CEREC). With proper design, digital image, and bite registration, the operator has control in occlusal design resulting in minimal adjustments.

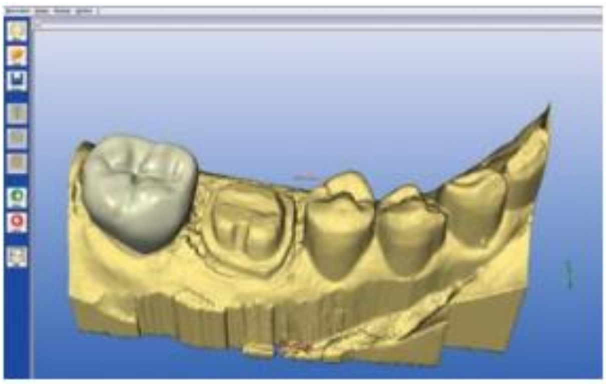

Figure 8 digital impression and digital preparation

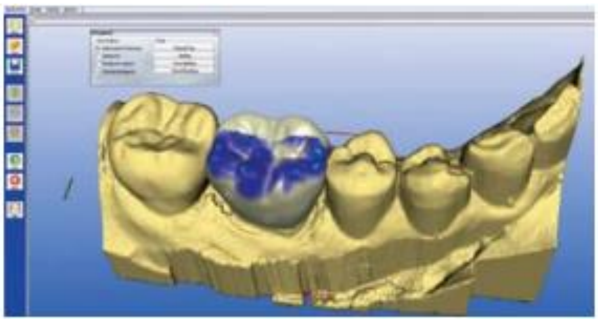

Figure9 professional 3D prosthesis treatment

Figure10 CAD/CAM Restoration

Flow chart: CAD/CAM methods and options

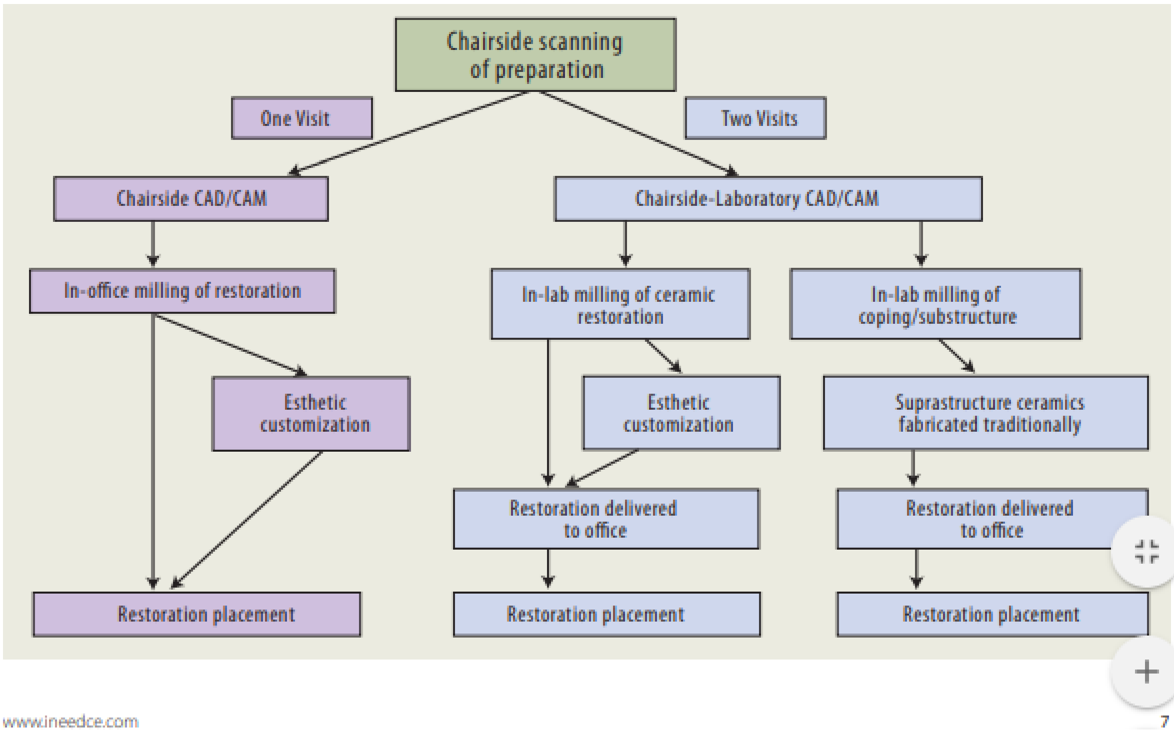

Figure 11 comparison between CAD/CAM and laboratory technique

Conclusion

Advances in tooth-colored materials and adhesive technology have expanded the scope of restorative dentistry. Fortunately, this progress has come at exactly the right time. Patients today want their dentistry to be more esthetic and less invasive. Also, today's patients are living longer, keeping their teeth, and placing higher value on oral health. Although dentists learn to apply inlays and onlays in dental school, it has been stated that many, if not most, do not do these restorations after entering practice.

Consequently, either large non–tooth-supporting amalgams that are difficult to properly contour or crowns, which are significantly more invasive, are placed. Because they seal teeth and reinforce remaining tooth structure, esthetic inlays and onlays are considered by many teaching clinicians as ideal for the moderately broken-down tooth. These restorations may even delay or prevent the progression of medium to large cavities, previously restored with amalgam, that have already been restored with amalgam from progressing to the point at which they would require a full-coverage crown. At the very least, their conservative nature, when compared with the preparation for full-coverage crowns, "banks" the tooth structure for future use.

These benefits, combined with the durability and esthetics of the indirect composite or ceramic inlay or onlay restoration, are very important to patients and should continue to direct the nature of restorative dentistry.

References

1. St-Georges AJ, Sturdevant JR, Swift EJ Jr, Thompson JY. Fracture resistance of prepared teeth restored with bonded inlay restorations. J Prosthet Dent 2003; 89:551–557.
2. Sorensen JA, Martinoff JT. Endodontically treated teeth as abutments. J Prosthet Dent 1985;53:631–636.
3. Otto T, De Nisco S. Computer-aided direct ceramic restorations: a 10-year prospective clinical study of Cerec CAD/CAM inlays and onlays. Int J Prosthodont 2002; 15:122–128.
4. Ahlers MO, Mörig G, Blunck, U, Hajtó J, Pröbstere L, Frankenberger R. Guidelines for the preparation of CAD/ CAM ceramic inlays and partial crowns. Int J Comput Dent 2009; 12:309–325.
5. Arnetzl GV, Arnetzl G. Reliability of nonreten- tive all-ceramic CAD/CAM overlays. Int J Comput Dent 2012;15:185–197.
6. Jain N, Railkar B, Mootha A. A comparison of fracture resistance of endodontically treated teeth restored with bonded partial restorations and full-coverage porcelain- fused-to-metal crowns. Int J Periodontics Restorative Dent 2014; 34:405-411.
7. Soares PV, Santos-Filho PC, Gomide HA, Araujo CA, Mar- tins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part II: Strain measurement and stress distribution. J Prosthet Dent 2008; 99:114–122.
8. Lutz F, Krejci I, Barbakow F. Quality and durability of mar- ginal adaptation in bonded composite restorations. Dent Mater 1991;7:107–113.
9. Cramer NB, Stansbury JW, Bowman CN. Recent advances and developments in composite dental restorative materials. J Dent Res 2011;90:402–416

10. ADA Council on Scientific Affairs; ADA Council on Dental benefit programs statement on posterior resin-based composites. J Am Dent Assoc 1998;129:1627–1628.
11. Ferracane JL. Is the wear of dental composites still a clinical concern? Is there still a need for in vitro wear simulating devices? Dent Mater 2006;22:689–692
12. Fennis WM, Kuijs RH, Kreulen CM, Verdonschot N, Creugers NH. Fatigue resist- ance of teeth restored with cuspal-coverage composite restorations. Int J Prostho- dont 2004;17:313–317
13. Freedman G. A. Contemporary Esthetic Dentistry 2012 chapter 17 469-470
14. Edward J. Swift, Jr., John R. Sturdevant and Lee W. Boushell , Sturdevant's art and science of operative dentistry 2013 (280,281)
15. ROSENSTIEL S. F. , LAND M.F. ,Contemporary Fixed Prosthodontics , 2001,Third edition, (266,267)
16. Freedman G. A. ,Contemporary Esthetic Dentistry ,2012, chapter 17 ,470
17. Freedman G. A. ,Contemporary Esthetic Dentistry ,2012, chapter 17,471
18. Mehl A, Kunzelmann KH, Folwaczny M, Hickel R. Stabilization effects of CAD/ CAM ceramic restorations in extended MOD cavities. J Adhes Dent 2004;6:239– 245.
19. Thordrup M, Isidor F, Hörsted-Bindslev P. A prospective clinical study of indirect and direct composite and ceramic inlays: ten-year results. Quintessence Int 2006;37:139–144.
20. Costa A, Xavier T, Noritomi P, Saavedra G, Borges A. The influence of elastic modulus of inlay materials on stress distribution and fracture of premolars. Oper Dent 2014;39:E160–170.
21. Holberg C, Rudzki-Janson I, Wichelhaus A, Winterhalder P. Ceramic inlays: is the inlay thickness an important factor influencing the fracture risk? J Dent 2013;41:628–635

22. Shillingburg HT, Hobo S, Whitsett LD. Preparations for intra-coronal restorations. In: Hobo S, Whitsett L, Jacobi R, et al. Fundamentals of Fixed Prosthodontics, ed 2. Hano- ver Park, IL: Quintessence Publishing, 1981.
23. Sato K, Matsumura H, Atsuta M. Relation between cavity design and marginal adap- tation in machine-milled ceramic restorative system. J Oral Rehabil 2002;29:24–27.
24. Jackson RD. Indirect resin inlay and onlay restorations: a comprehensive clinical overview. Pract Periodontics Aesthet Dent 1999;11:891– 900.
25. Burke FJ, Shaglouf AG, Combe EC, Wilson NH. Fracture resistance of five pin-retained core build- up materials on teeth with and without extracoronal preparation. Oper Dent 2000;25:388–394.
26. Dietschi D, Spreafico R. Adhäsive metallfreie Res- taurationen – Aktuelle Konzepte für die ästhetische Versorgung im Seitenzahn- bereich. Berlin: Quintessenz, 1997:27–99
27. . Brentel AS, Özcan M, Valandro LF, Alarça LG, Amaral R, Bottino MA. Microtensile bond strength of a resin cement to felds- pathic ceramic after differ- ent etching and silanization regimens in dry and aged conditions. Dent Mater 2007;23:1323–1331.
28. Fabianelli, A, Pollington, S, Papacchini F, et al. The effect of different surface treatments on bond strength between leucite reinforced feldspathic ceramic and composite resin. J Dent 2010;38:39–43
29. Nathanson D. Etched porce- lain restorations for improved esthetics, part II: Onlays. Compendium 1987;8:105– 110
30. Aguiar TR, Di Francescanto- nio. M. , Arrais CA, Ambros- ano GM, Davanzo C, Gian- nini M. Influence of curing mode and time on degree of conversion of one conven- tional and two self-adhesive resin cements. Oper Dent 2010;35:295–299.

31. Ilie N, Simon A. Effect of curing mode on the micro- mechanical properties of dual-cured self-adhesive resin cements. Clin Oral Investig 2012;16:505–512.
32. Hasegawa E A , Boyer D B, Chan D C. Hardening of dual- cured cements under com- posite resin inlays. J Prosthet Dent 1991;66:187–192
33. Manso AG, González-Lopez S, Bolaños-Carmona V, Mau- rício PJ, Félix SA, Carvalho PA. Regional bond strength to lateral walls in class I and II ceramic inlays luted with four resin cements and glass- ionomer luting agent. J Adhes Dent 2011;13:455–465.
34. D'Arcangelo C, De Angelis F, Vadini M, Carluccio F, Vital- one LM, D'Amario M. Influ- ence of curing time, overlay material and thickness on three light-curing composites used for luting indirect com- posite restorations. J Adhes Dent 2012;14:377–384
35. el-Badrawy WA, el-Mowafy OM. Chemical versus dual curing of resin inlay cements. J Prosthet Dent 1995;73:515–524
36. Freedman G. A. , Contemporary Esthetic Dentistry ,2012, chapter 17:472-474
37. Freedman G. A. , Contemporary Esthetic Dentistry ,2012, chapter 17: 474
38. Freedman G. A. , Contemporary Esthetic Dentistry ,2012, chapter 17P:743
39. Giordano R. Materials for chairside CAD/CAM–produced restorations. J Am Dent Assoc. 2006;137(Suppl 1):14S-21S.
40. Cendres-Mateaux, Scientific Documentation, PAEK Ivory, 2016.
41. Tosiriwatanapong T, Giordano R II, Pober R. Surface treatments effects on strength and monoclinic contents of Y-TZPs. J Dent Res. 2016;95(Spec Iss A):Abstract 3391.
42. Kim J, Fan Y, Giordano R II. Flexural strength of YTZP zirconia with various sintering schedules. J Dent Res. 2016;94(Spec Iss A):abstract 2320

43. Stübinger S, Saldamli B, Jürgens P, et al. Soft tissue surgery with the diode laser − Theoretical and clinical aspects Schweiz Monatsschr Zahnmed. 2006;116(8):812-20.
44. Romanos G, Nentwig GH. Diode laser (980 nm) in oral and maxillofacial surgical procedures: clinical observations based on clinical applications. J Clin Laser Med Surg. 1999;17(5):193-7.
45. Öztürk AN, Inan O, Inan E, Öztürk B. Microtensile bond strength of CAD-CAM and pressed-ceramic inlays to dentin. Eur J Dent. 2007;1:91-6.
46. van der Zel J, Vlaar S, de Ruiter W, Davidson C. The CICERO system for CAD/CAM fabrication of full-ceramic crowns. J Pros Dent. 2001;85(3):261- 7.