2019

# Aesthetic Considerations for Posterior Proximal Lesions

Dr. Shruti Mishra
Dr. Pradnya Nikhade
Dr. Gopal Tawani
Dr. Rutuja Gawarle

**Publication Partner: IJSRP INC.**

5/20/2019

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

# Aesthetic Considerations for Posterior Proximal Lesions

Dr.Shruti Mishra
Dr.Pradnya Nikhade
Dr.Gopal Tawani
Dr.Rutuja Gawarle

Publishing Partner:
**IJSRP Inc.**
**www.ijsrp.org**
ISSN 2250-3153
9 772250 315302

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

# Preface

With the persistent rise in evidence based dental practice, dental research has gained momentum in the field of restorative dentistry. Restorative dentists practice aesthetics in their day to day life by experimenting newer precise and less time-consuming techniques. Gone are the days of accepting the experiments done by doyens of restorative dentistry, just by virtue of their authority.

To enter the aesthetic era pertaining to the posterior teeth, many researches are being done, in the field of materials and methods. This writing provides budding restorative dental practitioners with a hope to enter into the world of posterior aesthetics. It throws light on every possible technique for restoration of posteriors in an aesthetic way.

Sincerely,

**Dr. Pradnya Nikhade**,
Dean Academics, H.O.D. and Professor,
Department of Conservative and Endodontics,
Sharad Pawar Dental College,
Sawangi, Wardha,
Maharashtra,
India

Publication Partner:

International Journal of Scientific and Research Publications (ISSN: 2250-3153)

# Copyright and Trademarks

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

# Authors

**Dr. Shruti Mishra**

Third Year Postgraduate, Department of Conservative Dentistry and Endodontics, Sharad Pawar Dental College, DMIMS, Sawangi (Meghe) Wardha, Maharashtra, India.

Email-shruti.mishra1792@gmail.com

**Dr. Pradnya Nikhade**

Professor (Dean Academics), Department of Conservative Dentistry and Endodontics, Sharad Pawar Dental College, DMIMS, Sawangi (Meghe) Wardha, Maharashtra, India.

Email-deanacademicsspdc@gmail.com

**Dr. Gopal Tawani**

Reader, Department of Conservative Dentistry and Endodontics, Sharad Pawar Dental College, DMIMS, Sawangi (Meghe) Wardha, Maharashtra, India.

Email-gopident@gmail.com

**Dr. Rutuja Gawarle**

Second Year Postgraduate, Department of Conservative Dentistry and Endodontics, Sharad Pawar Dental College, DMIMS, Sawangi (Meghe) Wardha, Maharashtra, India.

Email-rutusg@gmail.com

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

# Table of Content

# Chapter 1: Introduction

Dental caries is the most common disease of the oral cavity. Caries can be defined as the irreversible pathological process affecting the hard tissues and soft tissue of the tooth by microorganisms (Latin: caries = rottenness). Previously, caries have been reported in the fossil teeth of prehistoric dinosaurs, reptiles and early mammals. It has been found that, the incidence of caries is more evident in Homo sapiens since Palaeolithic times, and it is significantly increased in the Neolithic period. In early man, the caries prevalence was more commonly seen at Cemento-enamel junction or in the cementum whereas in the modern man, it is most commonly found in the occlusal grooves and fissures. This is due to the change in the dietary habits leading to increase in the incidence of dental caries. [1]

Currently, concepts of caries etiology has changed stating dental caries as a multifactorial disease due to three principal factors: the host (saliva and tooth substrate), micro flora, diet and also the fourth factor which is time should be considered in discussing any caries etiology. [2]

In simple words, for caries to occur, requires a susceptible host, cariogenic microflora, substrate that is suitable to those microorganisms and presence of all of these conditions over a long period of time. [3]

There are various classifications given for dental caries such as:

Dr.G.V. Black (1836-1915) had developed to classify caries based on the location:

Class I: Lesion present in pits or fissures on the occlusal surfaces of molars and premolars; facial and lingual surfaces of molars; lingual surfaces of maxillary incisors.

Class II: Lesions present on proximal surfaces of premolars and molars.

Class III: Lesions present on proximal surfaces of incisors and canines that do not involve the incisal angle.

Class IV: Lesion on proximal surfaces of incisors or canines that involve the incisal angle.

Class V: Lesion on the cervical third of the facial or lingual surfaces of any tooth.

Class VI: Lesion on incisal edges of anterior teeth and cusp tips of posterior teeth. [4]

Also, caries have been classified depending upon its severity, such as

1) Incipient: lesions present less than half way through the enamel.

2) Moderate: lesions extending halfway through the enamel but does not involve the DEJ.

3) Advanced: lesion extending through the DEJ but does not extend more than half distance to the pulp.

4) Severe: lesions extending more than enamel, dentin and more than half the distance to the pulp.

The second most susceptible area to caries is the smooth surface area or the proximal area that are present gingival to the contact area. They are physically and relatively free from functions of mastication, tongue movement and salivary flow.

The important ecological determinants of the smooth surface caries are:

a) Location of caries on the tooth surface.
b) Shape and form of the gingival papilla.
c) Maintenance of oral hygiene by the patients.

Lesions present on smooth enamel surfaces have broad area of origin and conical, or pointed, extension towards the DEJ. [5]

The ideal restorative material should:

- allow for conservative cavity preparation.
- provide mechanical resistance and restore normal form and function.
- provide proper seal between the restoration and the tooth.
- be biologically compatible
- provide satisfactory longevity.

Amalgam has been used as a traditional material for cavity preparation since past 150-165 years due to its longevity and cost effectiveness. It is still used in most of the developing countries. But as this is known that there are various shortcomings of its use and also the release of mercury from the amalgam restorations has led to the concerns over its use. Traditional metallic restorations made from gold and other amalgam restorations make the preparations too invasive. Also secondary caries below such restorations are quite common due to the invasiveness of the cavity preparation. [6]

The prevention and improved oral hygiene methods have led to the dramatic decrease in the incidence of caries and prosthetic treatment needs. This has put the restorative dentistry on center stage and has called for a newer approach to caries management by applying conservative adhesive methods. Composite resins have replaced amalgam restorations and there are a lot of improvements in the physical and mechanical properties since its development to restore posterior teeth. [7]

There have been a lot of difficulty amongst clinicians to select the restorative material for posterior lesions. In countries where amalgam free practices are followed, direct composite is the first option. The usage of amalgam has drastically reduced since then. Also the demand for aesthetic restorations have also increased amongst the patients. [8]

There are various methods that can be used to restore teeth by composite- direct method, semi direct method and indirect method.

1. The direct method is used for preventive as well as relatively conservative preparations. The composite is placed in small increments and are light cured using LED curing light. [9]
2. A Semi-Direct Technique — it is required when more volume of tooth structure has to be replaced. A same type of layering technique is used but the prepared restoration is fabricated outside the mouth and then luted in the cavity. This compensates the polymerization shrinkage and increases resistance to fracture and finally it is bonded on to the tooth. [10]
3. Indirect methods are indicated when a large amount of tooth structure needs to be replaced. There might a lot of tooth structure that is not sufficient enough to take the direct placement of resin and requires more than one sitting for the placement.

Composite fillings have following advantages such as it can repaired in a single appointment, and also there is no need for expensive additional equipment and the time required for the restoration is comparatively less. But the disadvantage is the polymerization shrinkage, high thermal coefficient of expansion with hard tissue of the teeth and difficult application techniques. [11]

The advantages of ceramic inlays compared to gold inlays are:

1) Aesthetic advantage as the colour is similar to that of the natural tooth.
2) Offers a more conservative approach than gold inlays.
3) In cases where cusp tips are damaged or eroded, adhesive techniques can help restore the bulk of the restoration as opposed to metallic restorations where a large amount of tooth substance has to be removed in order to prepare retention form for the material.
4) The similarity of physical properties to enamel.
5) Ceramic can be etched and silanized creating a strong bond with the fixed composite resulting in tightly sealed edges and the stability of thin cavity walls.
6) It provides better marginal integrity and good border seal. [12]

Despite of various available aesthetic materials and techniques, the most ideal system for restoring will ultimately depend upon the clinical situation as ceramic cannot be fabricated for single or small cavities as well as full arch rehabilitations cannot be done with direct composite restorations. Hence the knowledge of most appropriate dental restorative material is important to be applied in each clinical situation.

## Chapter 2: History of Restorative Materials

In 1830, Amalgam was introduced in England and France which contained silver, tin, copper, and mercury. The introduction of amalgam had revolutionized the dental era. Many concerns regarding leaching of mercury in the oral cavity due to amalgam fillings were raised, in 1840, members of the American Society of Dental Surgeons pledged against use of mercury fillings.

In 1859, a new organization was formed over the use of mercury in Dentistry- the American Dental Association.

After a lot of hustle over leaching of mercury from amalgam restorations, it was finally established in 1997 about safety of amalgam restoration.

Meanwhile in 1960 and 1970, the development of adhesives was in place. The first generation bonding agents were introduced but had weaker bond strength. In 1980's, 3$^{rd}$ generation bonding agents were introduced but had a separate primer. In the early 1990's fourth generation bonding gents were introduced based on the concept given by Nakabayashi on "hybrid layer" and the "wet bonding concept" given by Kanca.

In the mid 1990's fifth generation bonding agents combined etchant and primer in one bottle and maintained high bond strengths. The late 1990's and early 2000's witnessed the self-etching bonding agents. The bond strengths of these agents were lower than fifth generation bonding agents. In 2002, seventh generation bonding agents were introduced. In 2012, eighth generation bonding agent were introduced which has combined etchant, primer and adhesive in a single bottle and also it contains nanoparticles in it. It has a fluoride release and hence it is anticariogenic and smart than the older adhesive systems.

The development of adhesives improved the bonding efficacy of resins to the tooth surface. The discovery of resins dates back to 1932, when Dr.Leo Bakeland gave Phenol formaldhehyde. In 1937, Dr.Walter Wright discovered plastic methyl methacrylate. These materials were previously used for inlays, crowns and fixed partial dentures.

Since 1940, the properties of resins subsequently improved and has been widely used for fabrication of dentures and required heat curing. In 1941, self-curing resins were made by German scientists which had tertiary amine with benzoyl peroxide to initiate polymerization.

In 1955, Acid Etch Technique was given by M.Buonocore.

1956: Dr.Bowen made BisGMA.

1962: Silane Coupling agents were introduced.

1970: Light cured composites were introduced.

1972: Visible light cured composites

1976: Microfilled composites

Early 1980’s: posterior composites

Mid 1980’s: hybrid composites

Early 1990’s: Indirect composites were introduced.

1991: Beta Quartz inserts were developed. Composite inlays were developed.

1996: Flowable composites were developed.

1997: Packable composites were developed.

1998: Ormocers were developed and ion releasing composites were developed. Fiber reinforced composites came into picture.

1999: Single crystal modified composites

2000: Mini hybrid composites.

2005: Low Shrinkage Composites

2010: Nanofilled and Nanohybrid composites were developed.

**History of Ceramic Inlays:**

Charles H Land was the first dentist from USA to fabricate the first ceramic crown. He used ceramic paste during firing with a thin platinum foil adapted to the die to minimize slumping of porcelain mass.

He was also granted a patent for his extra -coronal restoration technique in 1887. He used feldspathic porcelain which were later applied to the fabrication of intra-coronal restorations.

In 1856, prefabricated ceramic inlays were used as an aesthetic filling.

In 1882, fired ceramic inlays were developed by Herbst in Germany7 and was first reported in Dental literature by Bruce in 1891.

The advent of ceramics were older than that of amalgam but since it was difficult to lute these materials on to the tooth surface, these materials were not frequently used. Also, previously the ceramics were air fired which resulted in a lot of porosities and surface roughness until vacuum firing came into existence.

The advent of silicate cements in 1871 by Fletcher had encouraged the use of ceramic restorations but the most significant breakthrough in this field was due to the advent of Dental adhesives and the ability of the adhesives to form hybrid layer.

Gradually the use of aesthetic material in the posterior teeth came in because of the improvements in the physicochemical properties and the development of new and various techniques. Also, the strength and the aesthetic properties of ceramics have been improved a lot.

In the early 1970's, Duret designed the use of CAD/CAM in Dentistry. In 1980's Mormann et al developed the CEREC system. Later, the concept of acid etching porcelain for luting porcelain restorations with the help of bonding agents were developed.  In Ceram (glass infiltration of alumina), these were shrink free ceramics given by Sadoun.

Dong et al gave pressed glass ceramic restorations (Empress) a few years later. Nowadays, opaque zirconium restorations have become more prevalent due to their superior strength.

Given the best choices of various restorative materials and techniques available today, the most suitable restorative material will depend upon the patient's clinical situation and operator's choice.

# Chapter 3:- Various restorative materials used for restoration of class II cavity

A) Adhesives:-

Over the past 50 years, dentin bonding agents have evolved with so many new improvements. The rationale of using dentin bonding agents rely on the formation of resin tags which is usually preceded by etching of tooth substrate and the formation of hybrid layer or the interdiffusion zone that is made up of resin impregnated with tissues. [13]

The various bonding agents are as follows:

*First and second Generation*

The first and second generation bonding agents were introduced during 1960's and 1970's. It totally depended upon adhesion to the attached smear layer. They had a weaker bond strength (2MPa-6MPa) and did not have good clinical results and marginal integrity.

*Third Generation*

The third generation system came in 1980's which had introduced the step of acid etching and a separate primer designed to penetrate the dentinal tubules which was intended to increase the bond strength. These agents had a bond strength of 12-15 MPa.

*Fourth Generation*

The fourth generation agents enlightened the concept of formation of hybrid layer. As stated by Nakabayashi and Fusayama that penetration of resin infiltration into the decalcified dentinal tubules and dentin substrate. The wet bonding concept given by Kanca were reported with this system. Examples of fourth generation agents are All-Bond® 2 (Bisco), OptiBond® FL (Kerr), and Adper™ Scotchbond™ Multipurpose (3M ESPE). They perform clinically well as reported by various studies. The bond strength of these adhesives were around 20 MPa and they had significantly reduced marginal leakage. But the disadvantage lied in the fact that it was technique sensitive and also a lot of steps has to be followed for the restoration. Because of the inconvenient multiple steps and bottles, more simplified bonding agents were in demand.

*Fifth generation*

These were introduced in mid-1990's, which combined primer and adhesive in a single bottle and the three steps were reduced to two steps. These bonding agents had high bond strengths. Examples are Excite (Ivoclar Vivadent), OptiBond® Solo Plus™ (Kerr), Prime and Bond® NT (Dentsply), and Adper™ Singlebond™ (3M ESPE).

*Sixth generation*

These agents were introduced in the latter part of 1990's and the early 2000's- also known as the self-etching primers- were a breakthrough in the technology of dentin bonding agents. The separate step of acid etching was removed and the acidic primer was incorporated which is to be directly applied on the enamel and dentin after preparation of the tooth surface. So the acidic primer and adhesive has to be mixed and applied over the tooth surface. Examples are, Clearfil® SF Bond (Kurarray), Simplicity™ (Apex), Adper™ Prompt™, and L-Pop™ (3M ESPE). But these systems were reported to have lesser bond strength than fifth generation agents.

*Seventh generation*

This is the latest category of bonding agents, "all in one" adhesives that combine etchant, primer and bonding agent in a single bottle. This was introduced in late 2002. Examples are iBond™ (Heraeus), Xeno® IV (Dentsply), G-Bond™ (GC), Complete (Cosmedent), and OptiBond® All-In-One (Kerr).

These adhesives are quite simple and operator friendly as the multiple steps are reduced. Also OptiBond® All-In-One (Kerr) and Xeno® IV (Dentsply) are fluoride releasing and have an anticariogenic potential. [14]

*Eighth generation*

This is a dual cured bonding agent and works with all light, self and dual cured resins. It does not require photo curing. It has highly functionalized silicon dioxide nano particles (<20 nm) in Futurabond DC which facilitates a cross link of the resin components and enhances its film building properties. Thus the adhesive optimally wets the exposed collagen fibres and the etched surface allows micro retention. It offers an “immediate stick effect” that guarantees the bond between the cavity and the restoration. The hybrid layer of 9 microns is created which provides a superior marginal integrity and protection against sensitivities.

VOCO’s new patented Single Dose System prevents the evaporation of solvent; which is a common problem encountered with other bonding systems. This reduces the bond strength in each use. On the fresh cut enamel, this agent acts by infiltrating the enamel surface leading to etching of the enamel. On the dentin, this agent dissolves the smear layer and demineralizes and infiltrates the collagen net and dentinal tubules.

The bond strength of FuturaBond DC is found to be around 35.6 MPa which is equal or higher than the total etch systems. Also the other advantages of this system include anticariogenic properties and the least amount of steps make it simpler to use.

In toto, there is a lot of options available with the dentin bonding agents. As clinicians, we are always looking for the materials that are easier and simpler to use. However, in a clinical situation, the cost effectiveness and patients most suitable clinical situation will help us to decide to go for the available options. The most commonly used agents in routine practice are 5th, 6th, 7th and 8th generation bonding agents.

B) Base liners:-

As the dental adhesives have taken over the liners and bases, these are less routinely used nowadays. Previously, liners were used for partial lining which provided biologic protection in deep penetration areas and for total lining to protect the pulp from thermal and chemical insults.

Nowadays, the indication for placing a liner under an adhesive restoration is mainly the protection of the pulp in the form of a "partial lining" using Ca (OH) 2 cements (Virgilitto and Holz, 1989; Elbaum et al, 1992). [15,16] Modern adhesives seem to replace the "total lining" function of former varnishes and cements and may even provide superior restoration adaptation and seal (Dietschi et al, 1995). [17]

C) Bulk filling Materials

1) **Conventional GIC's:**

These contain the polycarboxylate cement liquid and silicate cement powder (aluminosilicate glass). This cement was first developed by Wilson and Kent in 1972, and offers some cariostatic and bacteriostatic activities and has chemical bond with the tooth substance. It is the most biocompatible cement. The disadvantage lies in the fact that it is highly technique sensitive because of the longer setting time, as cement hydration takes place. Also, the compressive strengths are weaker than silver amalgam and composite restoration. [18]

2) **Light curing ionomer based cements and Compomers:**

To overcome the disadvantages of glass ionomer cement, properties of glass ionomer cement and composite restorations were combined to yield resin modified Glass Ionomer cement. The matrix is similar to that of the original Glass Ionomer cement, which is reinforced by light cured monomers, with mostly resinous in nature with ionic substructure. [19]

Resin modified glass ionomer cement upon polymerization, the modified polyacid copolymerizes with the HEMA. The setting reaction takes due to the photoinitiation while the acid base reaction strengthens the cement. The polymerization reaction provides an umbrella effect over the acid base reaction. But the only disadvantage of resin modified GIC is that it is less anticariogenic than the conventional Glass Ionomer Cement.

Compomers combine the properties of **Compo**site and glass iono**mer** cement. They are also known as polyacid modified cements. It is basically a water free cement consisting of polyacid modified di-methacrylate monomers with strontium or barium aluminosilicate glass particles. It has less cariogenic activity than conventional GIC and RMGIC but the mechanical properties such as tensile strength and flexural strength are superior to that of conventional GIC. It has good aesthetic properties of composite as well. Examples are Dyract, Dentsply and Compoglass, Ivoclar Vivadent.

These cements are generally indicated in class V cavities and pediatric class I and class II cavities as an alternative to conventional GIC. They are also used as a provisional restoration in restoring cavities prior to final restorative procedure. [20]

3) **Ceramics**

There are many variants of ceramics used in restorative dentistry. These differ greatly in their physical and mechanical properties and manufacturing process and indications.

They can be of two types:

*Heterogenous porcelain*

*Homogenous porcelain*

**Heterogenous Porcelain:**

The microstructure of fired dental ceramic consists of two phases mainly: glassy matrix and crystalline inclusions. These are mainly reinforced heterogenous ceramics fused with alumina and leucite (crystals with high elastic modulus).

In glass ceramics, the crystal phase consists of mica or apatite crystals created by the process of ceramization of glass through heat treatment. Examples are Dicor, Dentsply and Cerapeart, Kyocera).

Another procedure is slip casting. The materials used for inlays and onlays have sintered spinelle matrix (MglO2) which is infiltrated with glass particles. This has a very high crystalline content. But due to the high crystal content, these materials are less translucent and can only be used for posterior regions or as a core material.

CAD/CAM ceramics or machined ceramics are a new group of materials. They are prefabricated and homogenous materials and have reported better physical characteristics and polishability.[21]

**Homogenous Porcelain**

LFC Ducera is a low fusing ceramic which consists of hydrothermal glass, applied on a conventional ceramic core. It is a homogenous material and has excellent polish ability.

Till date, no available ceramics produce high mechanical resistance and simple elaboration procedures. Hence, satisfactory clinical success of the ceramic restoration ultimately depends upon the bond of the adhesives to the restoration and the tooth surface.

### 4) Composite resins

Composite (componere = to combine) is the universally used tooth-coloured direct restorative material. Composites were first developed in 1962. They are a combination of di-methacrylates with silanized quartz powder. It is made up of three components: resin matrix, fillers and coupling agents. The resin matrix mostly consists of BisGMA. But due to the high viscosity of BisGMA, various combination like BisGMA and TEGDMA, BisGMA and UDMA are used. Composites were developed in 1962 by combining dimethacrylates (epoxy resin and methacrylic acid) with silanized quartz powder (Bowen 1963). The fillers are usually made up of quartz, colloidal silica and ceramic. Earlier quartz was used as a filler but the composites were more brittle and did not have good polishability. Nowadays quartz has been replaced by colloidal silica. This offers the best polishability to composite and a life like appearance to the tooth. The ceramic filled composite are also called ormocers. These are organically modified ceramics. They consist of organic portion, inorganic portion and polysiloxanes. Examples of ormocer is Admira®, Voco, America. The coupling agent is the binder between the resin matrix and the fillers. Silanes are generally used as coupling agents.

Light curing is universally followed for polymerization instead of chemical curing. The advantage of light activation is that it provides homogeneity to the set material and also the material can be used in increments and applied layer wise and hence this reduces polymerization shrinkage and shrinkage stresses inside the restoration. But inspite of so many new developments, polymerization shrinkage remains a big problem. This demands the need for the improvement in dentin adhesion and placement techniques to produce a good restoration that maintains function as well as aesthetics. [22]

## 5) Luting Materials

Conventionally glass ionomer cement was used for cementation but because of its insufficient mechanical resistance and inability to adhere to the dental hard tissues and the restoration materials, it has resulted in many clinical failures. The compomer luting cements were developed with superior dentin adhesion and fluoride release, but bonding of intracoronal restorations still remains a controversy.

To lute resin and ceramic inlays, generally microfilled and fine hybrid brands are used but the wear resistance of microfilled composite seems better than that of hybrid materials. To provide adequate working time for the luting agents, self-cure and light curing components are to be incorporated. These products are highly viscous in nature, which facilitates hand mixing and full restoration seating. The lower filler content results into a low viscosity resin cement. Ultrasonic energy is helpful in assisting the seating of the restoration. To date, no ideal luting cement exists with ideal minimal thickness and thixotropic properties, so improvements in this aspect are anticipated. As there is no ideal restorative system that can be applied to every clinical situation, it is the clinician’s choice that matters to select the ideal material for the case.

# Chapter 4:- Class II Cavity Designs and Features

## Cavity preparation for direct composite restoration

The general principles of cavity preparation apply such as:

a) Establishing access to the carious structure.
b) Removal of caries, defective or older restoration
c) Providing convenience form for the restoration

Cavity preparation for direct composite restoration depends upon the size of the lesion. They can be differentiated as:

a) Small class II direct composite restoration involving only proximal surface.
b) Moderate to large class II direct composite restoration (involving proximal and occlusal surfaces)
c) Extensive class II direct composite restorations

*Small class II direct composite restoration involving only proximal surface.*

The cavity designs are as follows:

- **Tunnel preparation:**

  This preparation is generally indicated when only the proximal surface is carious or defective with intact marginal ridge. The advantage of this preparation is that it is conservative as compared to conventional preparation or tunnel preparation. Also preserving the marginal ridge helps in maintaining the tooth integrity and strength.

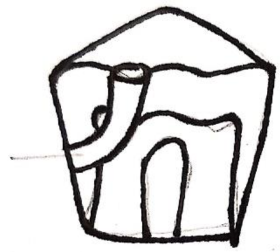

Fig 1. Tunnel Preparation

Clinical procedure:

**Closed tunnel preparation**

Tungsten carbide bur (Jet 330) is used to clean the carious defect. The entry point is usually made 2 mm away from the marginal ridge in an axial direction which makes an ovoid shape of cavity and about reaching dentin, the bur is directed towards the carious lesion and thereafter the cavity preparation is done with the help of low speed round bur till the dentin feels hard to probe.

**Open tunnel preparation**

The procedure is same as that of closed tunnel. The only difference is that, while preparing the cavity, if the remaining dentin is still soft, the proximal end of the tunnel is not preserved in order to remove all the carious tooth structure.

- **Box only design:**

  Indicated only in cases where the proximal surface is carious or defective and the marginal ridge is also involved or weak.

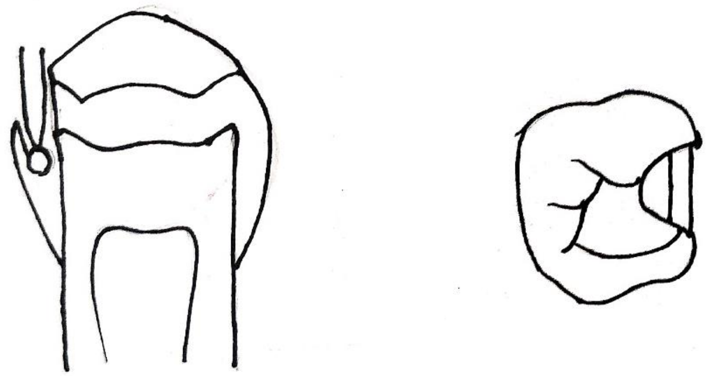

Fig 2, 3. Box Preparation

Clinical Procedure:

A proximal box is prepared with the help of a small elongated pear or round shaped bur which is directed parallel to the long axis of the tooth. The bur is directed parallel to the long axis of the tooth. The instrument is extended through the marginal ridge to reach the gingival floor and the axial depth is usually decided by the extent of the caries. If the pear shaped bur is used, the cavity appears as a box shape whereas when round bur is used, the cavity appears round in shape. All the other extensions towards the facial lingual and gingival are decided by the defect or caries.

Secondary retention or bevels are not needed in the design as it will be obtained from the adhesive.

- **Slot Design**

This design is indicated when the clinician can gain access to the proximal site from either a facial or a lingual direction rather than thtorugh the marginal ridge.

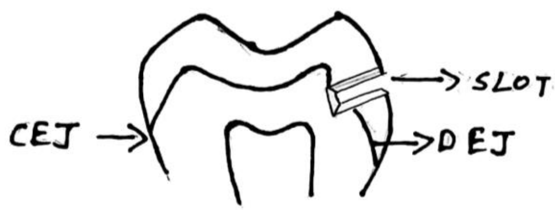


Fig.4. Slot preparation

Clinical procedure:

A small round bur is used for gaining access and the instruments are held at the right occlusogingival position. The preparation should be extending occlusally, gingivally and facially just enough to remove the carious defect. The axial depth is dictated by the extent of the caries.

*Moderate to large class II direct composite restoration*

The tooth preparation for moderate to large class II direct composite restorations is similar to that of conventional amalgam restoration with occlusal step and proximal box.

Occlusal step:

The occlusal step is prepared with the help of No.330 or No.245 diamond or bur which is used to enter the pit next to the carious proximal surface. The instrument is held parallel to the long axis of the tooth. The pulpal floor is prepared with the instrument to a depth 0.2mm inside the dentin. The pulpal floor is flat in buccolingual plane and may rise and fall to some extent in a mesiodistal plane. The occlusal extension towards the proximal area is prepared in a conservative fashion. The instrument extends through the marginal ridge to 0.5mm of the outer surface of the marginal ridge.

Proximal box:

The extent of the facial, lingual and gingival extensions of the proximal box are determined by the extent of the carious lesion and by the amount of any old restorative material, if present.

Clinical technique: the proximal surface is accessed with the instrument which is directed gingivally and is 0.2mm inside the DEJ. The cutting motion in the faciolingual side is usually slightly convex and outward. Important to note is that no bevels are placed in the entire cavity form.

*Extensive class II direct composite restorations*

This type of cavity is generally indicated:-

- When the patient cannot seek for expensive indirect restoration.
- When there is less crown height and the remaining tooth structure is inadequate to provide resistance and retention for the crown, these type of restoration are done to establish a foundation.
- As an interim restoration in cases of indirect and direct pulp therapy.

Some of the features that are required in such cavities include:

- Cusp capping
- The cavity extensions are dependent upon the extent and depth of caries in all the directions
- Placement of secondary resistance and retention features are necessary to prevent the dislodgement of restoration.
- The retention features for foundation restorations should be placed at least 1mm into DEJ for the extracoronal restoration to remain.[23]

## Cavity preparation for Indirect restorations (Composites/ Ceramics)

Before the cavity preparation, two important factors have to be kept in mind. These are:

i) Biologic factors

ii) Mechanical factors

Biological factors include:

a) Height of the clinical crown.
b) Anatomic contours
c) Tooth position in the arch
d) Occlusion and proximal relationship
e) Unusual aesthetics if present
f) The gingival and the periodontal health of the patient
g) The severity and location of caries present.

Whenever the tooth is planned for any kind of restoration, the above mentioned factors have to be kept in mind. These factors are called biological factors. The factors that are related for the resistance and retention forms of the restoration are called mechanical factors. Together these are called as biomechanical factors.

Mechanical factors:

The principles of cavity preparation for such type of restoration will include

a) Outline form

- All faulty pits and fissures along with questionable grooves and fissures should be included. The cavosurface margin is kept on the sound enamel wall.
- Cavity depth is kept at 1.75-2 mm from the central groove.
- If the crowns are tilted lingually as in case of mandibular molars and premolars, the bur should also be tilted at 5-10º lingually in order to conserve the strength of the lingual cusps.
- For the proximal outline, the preparation is extended towards the contact area from the marginal ridge.
- The width of the bur is around 0.8mm, therefore, 0.3mm of enamel and 0.5mm into dentin is being cut.
- The gingival seat is kept below the contact area by giving a proximal ditch gingivally. The depth of the proximal box can be checked with the length of bur.
- The buccal and lingual walls of the proximal box should be perpendicular to the proximal surface, providing clearance to the adjacent teeth.
- The clearance should be around 0.5mm with the adjacent tooth.
- The axial wall should follow the contour of the tooth buccolingually. The depth of the gingival floor should be 0.2-0.5mm into the dentin. A reverse bevel is to be given on the cervical wall.

- The cavity width is one third of the intercuspal distance on both sides of the central grove.

b) Resistance and Retention Form

- The cavity preparation should be such that it should resist the dislodging forces principally delivered along the long axis of the tooth and it should retain the restoration
- The preparation walls are kept parallel to one another as it aids in the frictional retention.
- The pulpal floor and gingival seat are kept flat to provide resistance against occlusal forces.
- Rounded line angles are given unlike cast restorations
- The occlusal divergence of 5-6º is given with the help of tapered fissure bur. The occlusal divergence is necessary as it helps in easy removal of wax pattern and insertion of the final restoration.
- The axiopulpal line angle is rounded for the dissipation of stresses
- Also occlusal dovetail is given that prevents the displacement of the restoration.
- Sometimes shallow retentive grooves are given in the buccoaxial and linguoaxial line angles of about 0.3 mm in depth for additional retention especially in only box type of cavity.
- The grooves should always be in the sound dentin near DEJ.

*Bevels*

The tooth cement interface is known to be the weakest link in the indirect composite restoration. To reduce the marginal discrepancies between the restoration and the tooth interface, the cavosurface bevels are given an obtuse angle which provides the bulkiest and the strongest margins at the tooth and restoration interface. The bevels are important as they reduce the frictional component between tooth and the restoration.

Important to note is that they are not usually given in indirect ceramic restorations.

c) *Convenience form :*

- This type of form is required to provide accessibility and visibility for the completion of operative procedures.
- The final outline form should be designed in such a manner that it provides easy access and visibility for the final restoration and does not leave any carious dentin or any old restorative material.
- The final taper and flare of the cavity walls provides access for disking and placement of bevels.
- The buccal and lingual extensions of the proximal box provides for proper finishing and proper adaptation of the restorative material.

d) *Removal of secondary or remaining caries:*

- The remaining or residual caries have to be removed after the final cavity preparation with the help of hand instruments such as excavators or small round burs can also be used.

e) *Finishing of enamel walls and margins:*

- The preparation walls are finished in order to provide a good adaptation of the restoration in to the prepared cavity.

f) *Cleaning of the preparation:*

- After final finishing of the enamel walls are margins, the preparation is cleaned with water and dried with cotton pledges with gentle stream of air and carefully evaluated for any remaining undercuts.[24]

## Chapter 5:- Techniques used for restoring class II cavity

The impression techniques can be categorized into three groups:

1) The direct technique
2) The semidirect technique
3) The indirect technique

**Direct technique:**

Direct technique consist of intraoral procedures and the impression of the prepared cavity is made in a single appointment. There are various methods described by various authors. Simple methods include “bulk” restoration and little sophisticated method like the three sited light curing method.

The main disadvantage of the direct technique is the polymerization shrinkage especially in class I and class II cavities. Various other methods like placing the material in 2 mm increments and multi-layering, use of ceramic inserts to reduce the polymerization shrinkage were employed. [25]

The direct techniques are generally indicated for:

- As a preventive restoration: Generally, in small fissures and pits, the bulk technique is used and light cured.
- In small class I and class II restorations: Incremental technique by using multilayering and horizontal layering is done for such cavities. A metallic matrix band is used for the class II cavities which helps in better polymerization of the composite by reflecting the curing light. Generally, oblique layering technique is preferred in such cases, by placing 1 mm increment in gingival floor and 2mm

increments obliquely so that after removal of matrix band, they can be cured from both the sides.

The tunnel preparations are also restored with this technique.[26]

- For restoring medium class I and class II restorations. In such cavities, there is a lot of polymerization shrinkage and the horizontal and multilayering techniques cannot alone reduce the polymerization shrinkage stress. Hence placement of liner beneath the restoration such as traditional glass ionomer cement is generally recommended. Nowadays use of intermediate resin like flowable liner is used which will help in distribution of stresses. These materials act like stress breakers which absorbs the forces of polymerization shrinkage. A light transmitting wedge and a clear matrix band are used while restoring the proximal box. The first increment is placed on the bottom of the proximal box and is indirectly cured through the wedge and further increments are cured through the cusps. This type of technique helps in distribution of polymerization vectors towards the adhesive interface.

  But the main disadvantage of the clear matrix is that it does not provide tight contacts, therefore proper placement of the matrix and adjustment is necessary. The contact points can be improved by using other systems like Palodent System and CONTACT PRO, especially designed for class II cavities.

  The use of ceramic inserts are suggested for controlling the polymerization shrinkage. These inserts are composed of aluminoborosiliscate glass coated with silane. But the use of macrofillers like ceramic inserts were discredited as they were believed to cause cuspal flexure and microleakage. [27]

When the cavity walls are weakened, occlusally, the composite has to be applied in oblique layers and cured through the cusps. This is believed to limit the contraction forces between the opposing walls that are harmful for the restoration. [28]

**Semidirect Techniques:-**

When the proximal contacts are below the cementodentinal junction, the direct technique cannot be used to restore the cavity, hence semidirect technique are best indicated in such cases.

The rationale of using this method is to gain the benefit of luted restoration without the cost of lab made restorations. [29] The use of semidirect technique will totally depend upon the clinical situation, where large class I and two surface class II cavities could be restored by this method. For larger cavities where the width of the cavity is more, extraoral composite inlays are better preferred. [30]

*Intraoral composite Inlays*

These are prepared by placement of one or two increments inside the prepared cavity. The composite is cured inside the prepared cavity and is removed making it sure that the prepared cavity is free of any undercuts and has a proper taper. But this is a little problematic for MOD cavities because of the polymerisation shrinkage leading to the lock of the prepared composite inlay.

The cavity preparation is generally done with the help of diamond buns as these will create micro retentions which will help in the retention and locking of the composite inside the cavity. The tooth insulation has to be done with the help of special insulating gels. Glycerine containing gels like that of Air block (De Trey - Dentsply) can be used for this preparation. After the removal of restoration, further adjustments like proximal and occlusal adjustments can be carried out. [31]

Following criteria should be followed:

1) This can be only used in one or two surface restorations.
2) The preparation taper should be sufficient enough (10-15º).
3) The design should be even and the walls should be smooth.
4) The insulator should be used for the removal of restoration.

*Extra oral composite Inlays*

This procedure is not used nowadays as the materials had poor storage longevity but the technique is still in literature and is quite interesting. An impression has to be taken with alginate or condensation or addition silicone. In comparison to the intraoral inlays, the extraoral composite inlays have a higher esthetic potential because of their better layering methods. But the occlusal surfaces are built up without using antagonist tooth as a reference, hence the occlusal adjustments are to be done after the inlay has been luted in the oral cavity.

**Post curing**

Before cementation of the semidirect restorations, these are preferably subjected to photocuring process in a special oven. This helps in a continuous conversion of resin as post curing photothermic treatment leads to polymerization spontaneously. This will create internal and marginal stresses in the material. The in vitro evaluation of such materials have shown to increase the hardness and wear resistance of these materials.

Another method is to immerse the restoration in boiling water and provide heat from a single thermic source. But clinical experience has shown that such restorations show more superficial staining than with dry heat polymerization. [32]

Hence it can be summarized that both the intaoral and extraoral techniques produce better marginal adaptation and anatomical contours than direct restorative method. The occlusal anatomy of the restorations made by semidirect technique has to be adjusted and reshaped after luting of the restoration. The adjustments can be done extraorally also. It should be kept in mind that only a little changes can be performed once the photothermal treatment has been done. And if any corrections are required, the micro retentions are to be created and then the bonding to these surfaces can be done.

Therefore, combining the advantages of indirect and direct method, the semidirect method offers better occlusal anatomy and function. But the semidirect method is a demanding method and the clinician's skill and experience will be an important factor in restoration's longevity and function.

**Indirect techniques:-**

These restorations are indicated when there are multiple restorations in the teeth or it is full mouth rehabilitation case. Such type of cases does not only involve aesthetics and function of a particular tooth but the restorations should restore the aspects of static and dynamic occlusion with the function and aesthetics. Hence, the indirect restorations like composite and ceramic are best indicated in these cases.

# Chapter 6: Class II composite restorations: direct and indirect technique

Class II Restorations: Direct Method

The direct technique is the most widely used method as it has certain advantages such as ease of application and cost effective and can be completed in a single visit. It is the treatment of choice for small and medium type of class II cavities. But the disadvantages related to the direct method include the polymerization shrinkage and restoration of the tooth in such a manner that it should follow the proper anatomical contours along with function and esthetics is quite difficult, especially in large class cavities.

*Polymerization shrinkage*

The polymerization shrinkage occurs because of the conversion of monomer into polymer network by exchanging van der Waals spaces in covalent bond spaces. This shrinkage leads to formation of contraction stresses within the restorative material and internal stresses inside the tooth structure. Shrinkage leads to poor marginal adaptation of the material progressing to post-operative sensitivity and recurrent caries. [33, 34]

Polymerization shrinkage leads to contraction stresses. These stresses produce deformation of tooth structure leading to enamel fracture, fractured cusps and cuspal deflection. It has the potential to create failures at the resin tooth interface and also in the restoration material itself. Also the shrinkage stress depends upon the size of the cavity. If there are more walls involved, such as in a large restoration, the resistance of the tooth to polymerization shrinkage decreases as there is less stress in the tooth resin interface as compared to the internal tooth structure. [34]

***Strategies to overcome polymerization shrinkage***

The various methods that will help in relieving the polymerization contraction stresses are:

1) Changes in the composition of resin matrix: Use of Silorane based composite resin help to reduce shrinkage by opening the cationic ring of the cycloaliphatic oxirane chain. E.g. Filtek$^{TM}$ Silorane (3M ESPE).
2) Changes in the placement technique: Use of incremental methods such as horizontal, vertical, oblique, wedge shaped, successive cusp build up method, centripetal technique and three sited curing method are used to reduce the contraction stresses in the composite resin.
3) Changes in the curing techniques: Use of soft start curing method or ramped curing method have shown less shrinkage. The curing lights designed for this show less intensity light for about 10 seconds and a high intensity light immediately. The fast setting resins show increase amount of polymerization shrinkage compared to slow setting and autocured resins. But the clinical efficacy of this method is not yet proven.
4) Changes in the material: The composite material has been modified to bring changes in the polymer matrix. They have been introduced with different formulations such as chemically cured resin based materials that offers a long time of pre gel phase and slow polymerization rate resulting in lesser shrinkage stress as compared to conventional light curing ones.
5) Changes in the filler: The use of ceramic or glass inserts reduce the shrinkage by reducing the overall volume of resin-based composites to be cured. But the disadvantage lies in the

procedure as it is technique sensitive and desilanization can occur, hence, these are highly discredited and not readily available.

6) Changes in the thickness of adhesives: The newer bonding systems exhibit better bonds between the tooth and the restoration. It has been found that a thickness of 125µm reduces the contraction stress. A thick adhesive layer will inhibit polymerization by oxygen and is highly susceptible to staining.

7) Changes in the cavity design: Newer designs for the cavity has been given by Luescher et al especially for class II composite restorations. This preparation has been termed as 'adhesive preparation'. In this preparation:
    - The occlusal carious dentin is removed either by round burs (diamond points) or hand excavators.
    - Beveled enamel margin and undermining of enamel has to be done
    - The proximal infected enamel and dentin has to be removed with the round burs in order to produce a round shaped or an ovoid cavity.
    - The elevation of enamel/dentin shoulder does not allow the overlapped cervical part of the restoration to be drawn away from the margins of the cavity be polymerization shrinkage stresses.

8) The use of a liner: The use of glass ionomer cement or use of flowable resin (sandwich technique) helps to reduce the stresses by acting as stress breakers. It absorbs the forces of polymerization shrinkage due to its elastic effect.

9) Sealing of margins (rebonding): The sealing of margins helps in sealing of the cervical marginal gaps. These are surface penetrating sealers and contain silicon dioxide filler,

clear, resin matrix that can be used as a protective layer over completed restorations. E.g. Fortify, Optiguard, Ultraseal.

These are several methods that can be utilized and has to be kept in mind before going for direct composite placement. Also the type of cavity and the C factor associated with it decides the amount of polymerization shrinkage in a restoration. [35]

*Type of cavity and C factors*

Feilzer and De Geea in 1987 has shown the relationship between cavity form and the shrinkage stress. They have demonstrated the C factor or the ratio of bonded to unbonded surfaces. Feilzer et al demonstrated that box like cavity as those in class I cavities have high C factor as there are 4 bonded surface and 1 unbonded surface. Similarly, for class II and III cavities, the C factor is 2, for class IV cavity, the C factor is least and around 0.5 whereas for class V cavities, the C factor is around 1.5 to 3.

C factor= bonded surfaces/ unbonded surfaces

The shape and form of the cavity walls also are an important factor in lowering the C factor, like if the two class I have the same volume but the designs of the cavity are different, the C factor will be higher for deeper and narrower cavity rather than larger and shallower cavity.[34, 36]

Table 1: C factor for different cavity forms

| Cavity pattern | C factor= bonded surfaces/ unbonded surfaces |
|---|---|
| Class I | 5 |
| Class II | 2 |
| Class III | 1 |

| | |
|---|---|
| Class IV | 0.5 |
| Class V | 1.9 |

***Clinical procedure***

A complete examination and diagnosis has to be done before going for the clinical procedure. Intraoral periapical radiographs to know the extent of the lesion should be taken and a detailed medical and past dental history should be recorded.

*Step 1: Administration of local anesthesia*

Administering anesthesia is important as it provides a comfortable environment for the patient uninterrupted procedure for the clinician as well. Also, it reduces salivation of the patient which is a contributing factor for the operative dentistry for bonding procedures.

*Step 2: Operation site preparation*

The patient should undergo oral prophylaxis before going for esthetic restorations.

*Step 3: Selection of shade*

Selection of shade should be done under daylight. The teeth are usually white with varying degrees of gray, yellow or orange tints. The standard shade guide for composite restoration is the Vita Classical and Vita 3-D Master. The other systems include Natural Color Concept system. Also various composite systems have their own shade guides in their kits. The sequence of shade selection is value, then chroma followed by hue.

Some of the principles that are to be followed are:

- → The shade selection is done under the daylight followed by incandescent and fluorescent lights.
- → The patient is also viewed at the level of eye so that the most color sensitive part of the retina is used.
- → The drape should not be very bright in color and lipstick should be removed.
- → The shade selection should be done for only 20 seconds. If more time has to be taken then, eyes should be rested by looking at a blue or a green object.
- → The patient should be asked to wet the tooth surface by his own saliva or sip water during shade matching as the dry tooth appears lighter than the wet tooth.
- → After selecting the shade, a little amount of the selected composite should be kept and cured on the surface to be applied without application of bonding agent to confirm the selected shade for the patient.

*Step 4: Isolation of the tooth*

Rubber dam application is the best method to isolate the tooth. Other methods include cotton rolls that re prefabricated with or without a retraction cord, if the cavities are not below the gingival margin. The isolation is an important aspect in composite restorations as the efficacy of bond gets affected if the prepared cavity gets infected with saliva.

*Step 5: Cavity preparation*

The cavity preparation according to the principles are discussed in the previous chapter with cavity design and features.

*Step 6: Restoration Technique*

Matrix application

The most important step in restoring class II cavities is the application of matrix and wedges to produce proper contacts and contour. Class II composite restorations are totally dependent upon matrix placement as these cannot be condensed like amalgam to produce the proper contacts.

For class II composite restorations, sectional matrix systems are indicated. These are made up of nickel and titanium alloy that helps to offer a consistent force to the separation of teeth and then come back to their original shape after removal. These help in producing good anatomical contours and tight gingival seal.

Examples are: Palodent Plus Sectional Matrix System, Composi-Tight 3D Sectional matrix system, Triodent V3 Ring matrix system.

*Step 7: Etching and Bonding*

Depending upon the type of cavity, different available bonding systems are used. These are total etch systems and self-etch systems. Depending upon the clinical situation, ease of placement and site of placement, different bonding agents are being used. For deep dentinal cavities, self-etching agents are preferred.

*Step 8: Composite placement and light activation*

The proximal part of the restoration is cured first. Also the composite placement is dressed in incrementally. The different layering techniques can be used for restoring different forms of class II cavity preparation.

*For restoring small class II restorations*:

Horizontal layering techniques are used for restoring small class II cavities in 2mm increments with the help of metal matrix band which helps in the reflection of light and helps in curing of the composite.

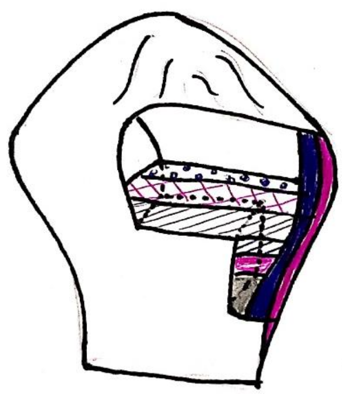

Fig 5. Horizontal layering technique

*Medium class II restorations*:

For medium class II restorations, a three sited curing method is used. This method uses a clear matrix and reflective wedges. The curing gun is first directed through the clear matrix and the reflective wedges so that the polymerization vectors are directed towards the gingival margin. This is followed by placement of wedge shaped increments to prevent distortion of the cavity walls and reduces the C factor. The procedure first directs the polymerization towards the cavity walls and then the occlusal surface in order to direct the vectors of polymerization towards the adhesive interface. [37]

*Medium class II cavities*:

Oblique layering technique and polymerization through the cusps: this is done by placing wedge shaped increments in the cavity. The increments placed are cured twice through the cavity walls followed by the occlusal surface, for directing the vectors towards the adhesive interface. This reduces the C factor and cavity wall distortion.

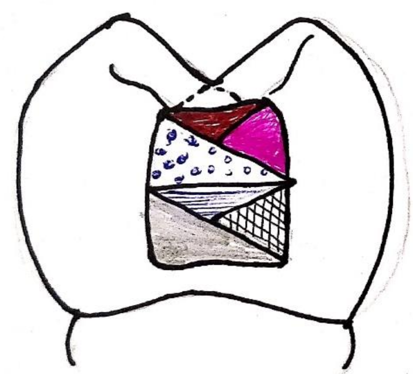

Fig 6. Oblique layering technique

*Medium class II restorations*:

Four increment method: According to Spreafico and Krejici, curing should be done from the occlusal surface with soft start curing.

The first increment has to be placed in the interproximal marginal ridges, followed by second increment of flowable composite to cover the dentinal surface. The third increment is placed in the dentin mass and fourth increment is placement of enamel mass and occlusal shaping is done thereafter.

*Step 9: Final Contouring and Polishing*

The final occlusal adjustments are made with the help of egg shaped or a round oval diamond point with water spray. The excess composite form the proximal surface is removed by the help of flame shaped diamond point. Overhangs in the proximal surfaces are removed with the help of a 12B scalpel blade. Proximal surfaces can also be finished with the help of proximal finishing strips. The final finishing and polishing of the restoration is done with the help of polishing disks and rubber cups. [37]

*Drawbacks of the Direct composite technique:*

- → The main disadvantage of direct resin restorations is the polymerization shrinkage.
- → The bond is difficult to achieve in areas where the cavosurface margin is in the dentin.
- → In deep interproximal areas, it is difficult to achieve the proper polymerization in that area.
- → Decreased wear resistance in stress bearing areas.
- → Increased water sorption
- → Interproximal contacts and contours are difficult to achieve.

Indirect technique

Adhesive inlays can be fabricated by composite and ceramics. Touati and Mormann were the first to describe the posterior indirect restorations for inlays and onlays. The first generation indirect resin restoration has composition as same to that of direct resin. But there were certain disadvantages associated with first generation indirect resins as there was wear resistance was too low and there was a high degree of bulk fracture. Marginal gap formation, microleakage and failure of adhesion led to the development of second generation indirect resins.

In the second generation indirect resins, microhybrid fillers of around 0.04-1µ are incorporated. The volume of filler is twice from that of first generation indirect resins. Also, the ceramic inlays can also be used inspite of composite inlays due to their excellent wear resistance and longevity. [38]

Indications for composite inlay:

1) As a replacement for preexisting metallic restorations. When there are more metallic restorations in the mouth and the patient wants to get them replaced into esthetic restorations.
2) These are used in restoration of large defects as direct method will lead to polymerization shrinkage and also due to poor wear resistance, indirect composite resins are preferred.
3) Patients have habits like bruxism and clenching are indicated for indirect restoration
4) For achieving proper contacts and contours.

Contraindications:-

1) If there is hypersalivation or inability to maintain a dry field as this will cause poor bond.
2) In deep subgingival preparation, the impression taking becomes difficult and the restoration becomes difficult to lute in the prepared cavity.
3) The patients who do not have a good oral hygiene.
4) The procedure is costly and hence cannot be given to the patients who cannot afford it.

***Clinical Procedure:***

It involves

- → Cavity preparation
- → Fabrication of inlay
- → Luting or cementation

Cavity preparation for composite inlay:-

- ✓ The walls should be divergent with well-defined margins and sufficient strong walls.
- ✓ The thickness of the wall should be around 1.5 mm
- ✓ A thin layer of flowable resin is applied over the dentin about 0.5mm
- ✓ The margins are well defined and unchamfered.
- ✓ The proximal, cervical, vestibular and lingual separations are provided

Fabrication of inlay (Composite inlay):-

→ In office fabrication

The steps are:-

- The fabrication of the composite inlay is done over the prepared cavity in the mouth and then the inlay is removed and is heat treated in an oven. This procedure is done under complete isolation. E.g. Brilliant Direct Inlay System (Coltene- Whaledent)
- The tooth and cavity preparation is painted with the lubricant for easy removal of inlay.
- A clear matrix is kept around the tooth without retainer and clear reflecting wedge is used at the interproximal area.
- The increment of the composites are placed in the proximal box first and is gently condensed with the help of a resin adhesive coated ball burnisher followed by occlusal portion.
- The end of the curing light is placed in the interproximal area and is cured for 60 seconds from facial to lingua surface and the occlusal portion is cured for 60 seconds.
- After the light curing, the inlay is removed from the prepared cavity.

- A lubricant is applied over the inlay surfaces. The lubricant will exclude air and will allow for the removal of oxygen inhibited layer and allows complete curing of the inlay. The inlay is light cured for 60 seconds again and then placed in an oven at 110º C for seven minutes. The combination of light curing and heat curing results in better polymerization of composite with increased wear resistance. It also minimizes the polymerization shrinkage.

This is the in-office method of fabrication of composite inlay and can be restored in a single appointment.

→ Laboratory fabrication

The laboratory method involve the fabrication of inlay on a die. The inlay is fabricated outside the oral cavity in a laboratory and the fabricated inlay is bonded inside the prepared cavity.

*Step 1: Impression making*

The various impression materials are available for recording the impression of the prepared cavity. The choice of the material and the technique will vary according to the clinician's choice and the clinical situation. Most commonly used materials are rubber base elastomeric impression materials and irreversible hydrocolloids. [24]

Table 2: Impression Materials: Composition, Advantages and Disadvantages

| Impression materials | Composition | Advantages | Disadvantages |
|---|---|---|---|
| Polysulfide impression | The base contains polysulfide polymer , fillers | Working time is more, has a tear | Requires fabrication of |

| | | | |
|---|---|---|---|
| material | and dibutyl phthalate and the catalyst paste contains lead dioxide | resistance, the margins are easily visible and is economic | custom tray, overstreching leads to distortion and it can stain clothes, has a very bad odour and has to be poured within 1 hout |
| Condensation silicone | The base and the catalyst paste contains α-ϖ-hydroxyl-termianted polydimethyl siloxane. | It provides good working time, margins are seen clearly, clean and pleasant for the patients. | High rate of polymerization shrinkage is seen, it has a volatile by product, has low tear strength, is hydrophobic and has to be poured immediately. |
| Addition silicone | Consists of base and catalyst paste.<br>Base paste has polymethyl hydrogen siloxane and catalyst contains | It provides automix dispense, clean and pleasant for patients, margins are easily seen | It is hydrophobic in nature, has a low tear strength, putty has the tendency to displace wash, the |

| | | | |
|---|---|---|---|
| | divinylpolydimethylsiloxane | and elasticity is sufficient enough. | wash has low tear strength and a high cost also. |
| Polyether | The base paste consists of polyether polymer, colloidal silica and accelerator consists of alkyl aromatic sulfonate | The advantages are moist field is okay, it is hydrophilic, has low cost with long shelf life. | Impressions are not accurate by this material, has to be poured immediately. |
| Agar | Consists of agar, borates, sulfates, waxes and thixotropic materials. | Moist filed is compatible, accurate and pleasant to taste, it has a low cost and long shelf life. | It requires special equipment and it tears easily and has to be poured immediately. |
| Alginate | Consists of potassium alginate, calcium sulfate, zinc oxide, potassium titanium fluoride, diatomaceous earth and sodium phosphate | Moist field is okay, clean and pleasant, hydrophilic, low cost, and long shelf life. | It is not accurate, tears easily, pours immediately, it can also retard settings of gypsum. |

*Step 2: Provisional Restoration*:-

After the tooth preparation, it becomes very important to protect the rest of the tooth structure from the thermal and chemical insults and also to restore the relationship between the prepared tooth and the antagonist tooth. These temporary restorations have to stay in the mouth for a short period in order to maintain the form and function of the lost tooth structure. The temporization is only needed for short periods. The method of temporizing can be either by direct or indirect method.

The indirect method is used when one or more teeth are involved. This can be done by making the impression of the tooth to be restored preoperatively by polyvinylsiloxane impression material. The temporization material is being injected on to the teeth that are being restored. The material is allowed to set for 1 to 2 mins. This temporary restorations are removed from the impression and checked intraorally for occlusion followed by finishing and polishing. These are cemented with the help of non eugenol containing temporary cements.

The indication for direct method includes

1) Small and narrow preparations, specially inlay.
2) Onlay with a single cusp coverage.
3) Decision to provide temporary restoration is made after the initial preparation.

The direct technique involves tooth preparation and impression making of the tooth to be restored. This is followed by placement of wedges interproximally. The temporary material is placed into the preparation and condensed. The patient is asked to bite down and occlude onto the uncured material. The opposing tooth is lubricated to remove any uncured material from its surface. The material is then light cured for 20 to 30 seconds and is followed by finishing and polishing. [39]

*Step 3: Fabricating composite inlay*

The impression made is poured with die stone. After setting of the die stone and the cast is mounted and is sectioned. The contact at the gingival area is remained intact. The margins of the preparation are marked by a red pencil. Separating media is applied over the die. The composite resin of correct shade is selected and the incremental buildup of enamel and dentin shades are being done. These composites have usually good viscosity for manipulations which help to develop a proper proximal and occlusal anatomy. All the surfaces are light cured for 40 seconds. The prepared inlay is then removed from the die.

This inlay is heat treated in an oven for 20 minutes at 100º C. the inlay is then carved on the die and is finished and polished with diamond points and composite finishing kit. The inlay is cleaned ultrasonically in a water bath and the process of characterization of stains around pits and fissure are done in order to bring the natural appearance to the tooth with the help of resin based colorants. This stain is light cured for 40 seconds and now this is ready to be cemented into the prepared cavity. The restoration is finally finished and polished with the help of multifluted finishing burs in the sequence. Polishing of the restoration is done with the help of aluminium oxide containing composite polishing paste. The removal of the rubber dam is done followed by verification of the occlusion with the help of articulating paper in centric and excursive occlusion.

*<u>Step 4: Final Cementation</u>*

The final cementation process is carried out after isolation of the operative site with the help of rubber dam. The prepared cavity is first cleaned with fluoride free prophylactic paste or an air water jet of bicarbonate with a diffuser. The inlay is placed in the cavity and is evaluated for its passivity, accuracy and effectiveness of the contact points of the contact points. The adhesion process is facilitated by sand blasting the prepared inlay with alumina particles, silane coupling agent is being applied over the inlay to provide micromechanical and chemical adhesion of the inlay with the cavity. The cavity is treated with the adhesives and without curing it, the prepared inlay is being seated inside the preparation. The various types of luting agents that are available are: chemical, dual and light cured resins. The excess material is removed before final light curing. After light curing the restoration is again finished and polished intraorally. [24]

Which technique is better?

The clinician should always know the advantages and disadvantages of a technique before choosing it.

The direct technique offers the main advantage of being performed in a single appointment. Also the procedures are very less invasive and cost effective for the patients. But the disadvantages include high chances of polymerization shrinkage especially in cases of large cavities. Also the occlusal and proximal anatomy are less well defined as compared to indirect composites.

This is the advantage for the indirect technique which offers excellent occlusal and proximal anatomy and control over the polymerization shrinkage stress. But the disadvantages are that the material is costly and the patient has to come in two sessions. Also the preparation design is more invasive than the direct methods.

All of these benefits and drawbacks should be kept in mind before opting for the technique.

## Chapter 7:- Ceramic Restorations for Class II Cavity

Indications for ceramic inlay:-

- → It has all the indications for cast metal inlay with the added advantage of tooth colored material.
- → It is used in place of metal inlay or an amalgam restoration in class II cavities in which the buccal and lingual walls remain intact.
- → As a viable alternative to a direct posterior composite restoration where excessive isthmus width is present.
- → As a replacement for pre-existing metallic restorations.

Contraindications:-

- → Patients with high caries index and poor oral hygiene are not indicated.
- → Porcelain fracture is one of the biggest failure with these kind of restorations and hence, heavy occlusal loading should be avoided.
- → In presence of unfavorable occlusion, such as presence of group function occlusion and in patients having parafunctional habits like bruxism, clenching.

*Material for fabrication of ceramic inlay*

The various types of ceramics are available in the market for fabrication of ceramic inlay. These can be broadly classified as

Silica based and non-silica based.

Silica based consists of:

- ✓ Feldspathics: Multiple

- ✓ Leucite reinforced porcelain: Empress (Ivoclar), eMax empress (Ivoclar), OPC (pentron), Finesse (Dentsply)
- ✓ Lithium disilcate glass ceramic: Empress 2 (Ivoclar), G3 (Pentron), eMax CAD (Ivoclar).

Non silica based consists of:

- ✓ Glass infiltrated Zr, Alum; Spinell : INceram (Vita/ Vivadent), WolCeram (Vita)
- ✓ Dentsply sintered $Al_2O_3$: Procera (Nobel Biocare)
- ✓ Densely sintered ZrO: eMax ZirCAD (ivoclar), CEREC (sirona), Cercon (dentsply), Lava (3M/ESPE).

The current choice of material includes feldspathic porcelain, leucite reinforced, lithium disilicates and glass infiltrated porcelain. But the disadvantage of feldspathic porcelain is that it has less strength as compared to other available materials. The glass infiltrated porcelain has an aluminium core made from an aluminous slip applied to a refractory die. These porcelain have less pores and defects in comparison to previous ceramics with improved strength i.e. 3-4 times more than that of traditional alumina cores.

Magnesium and zirconium based In ceram materials are also introduced which are reported with good marginal adaptation. The heat pressed ceramics are leucite based and lithium silicate based materials. The leucite based is usually used for fabrication of inlays whereas latter are usually used for fabrication of crowns. These type of porcelain has a fracture resistance and good marginal adaptability.

Machinable lithium disilicate is also available in a lot of shades. The inlays fabricated by this material have excellent strength and marginal adaptation. [40]

*Preparation design for ceramic inlays*

The cavity preparation depends upon the material selected for the fabrication of inlay and the method of fabrication. There are other factors such as aesthetics, fracture resistance and the edge strength of the selected restorative material. The tooth preparation guidelines are as follows:

- The retention form is not very critical as it is dependent upon the bonding mechanism.
- The cavosurface angle is kept at 90º and the preparation must be smooth enough for the fabrication of inlay.
- Rounded line angles are recommended.
- There should be no undercuts and a minimum taper of 10-12 º is generally suggested.
- The pulpal floor depth is kept around 1.5-2 mm, 1-1.5mm of axial reduction and the isthmus width shall be 2mm.

  The width of the isthmus and the depth of the cavity along with the taper of 10º or more is needed for the proper bulk of this material to withstand the forces of occlusion which are more in the posterior region.

  The dimensions of the cavity mentioned above are usually given for lithium disilicate porcelain and leucite based porcelain material. With other materials like zirconia, the cavity dimensions are likely to be less than mentioned above. [41, 42]

*Fabrication of ceramic inlay*

Fabrication can be done by laboratory method or by using CAD/CAM. Different types of ceramic materials require different types of fabrication methods. In the laboratory, firing of dental porcelain done either on a foil or a refractory die system, the lost wax technique is usually used for pressed glass ceramic. The restorations are also milled from prefabricated ceramic blocks. All these materials are fabricated with the help of special furnace designed for the individual material. [43, 44]

*Cementation / Luting of the ceramic restoration*

Luting or cementation of the inlay is done under isolation. Use of rubber dam is generally indicated. The cavity preparation is cleansed with pumice, it is rinsed and then dried. The prepared inlay is etched with hydrofluoric acid to create microporosities. Silane coupling agents are also used, which promote the adhesion of the porcelain to the resin by wetting the surface of ceramic allowing the resin to flow freely into those areas.

The commonly used cements are glass ionomer cement and resin based cements (self-cure and dual cure types) the glass ionomer has the advantage of establishing a chemical bond to the enamel and dentin, fluoride release. [45] But this cement has a low solubility and the restorations cemented by GIC are weak and have poor resistance to fracture. The resin composite cement are mostly used. These have high strength and are less soluble in oral fluids as compared to GIC. The dual cure and self-cure cements are generally preferred as the curing light cannot penetrate in the deeper areas. [46]

Procedure of placement:-

- The cavity to be restored is isolated with the help of rubber dam, preferably.
- The prepared cavity is cleaned with pumice and rinsed with water and dried.
- The inner surface of the restoration is luted with 8-12%of hydrofluoric acid for 1-3 minutes. After etching with HF, the inner surface is rinsed with water and air dried.
- Then the silane coupling agent is applied.

- The prepared cavity is etched with 35-37% orthophosphoric acid for 10-15 seconds and is rinsed with air water spray. The cavity is dried with the help of cotton pellets.
- A thin layer of adhesive cement is applied inside the cavity and restoration is seated into the prepared cavity.
- Patient is asked to close their mouth in functional occlusion and the excess of cement is removed from the margins.
- Light curing is done for 30-40 seconds from all the sides.

Finishing and polishing is generally less required in porcelain restorations. If polishing is needed, it can be done using diamond impregnated finishing points and polishing gels.

## Chapter 8:- CAD / CAM for Fabrication of Composite and Ceramic Inlays

In the early 1970's, Duret introduced the use of CAD/CAM in dentistry. [47] About 10 years later, Mörmann et al developed CEREC system which was the first chair side computer aided fabrication system for inlays and onlays from the available ceramic blocks.

CEREC 1 was developed by Dr. Mörmann and Marco Brandestini, who was an electrical engineer in the year 1983. This system allowed the dentists to fabricate and design the in-office restorations. Then the system was improvised and CEREC Bluecam Scanner was introduced that had accuracies of around 17 microns for a single tooth. CERECOmniscan was introduced that produced true color digital impressions without requiring any contrast medium.

The CEREC In Lab CAD software was recently introduced with the wide range of capabilities. This system has a Sirona inEOS X5 scanner for designing and scanning the restoration. Once this is completed, the file is sent for the copy milling process to a milling machine having wide range of materials. [48]

The Procera system was introduced in the year 1994. This was the first system to use network for the fabrication of restorations. [49] Cicero system was introduced in1999 by Denison et al. This system allowed semifinsihed crowns and rapid custom fabrication of high strength alumina coping to dental labs for ceramic layering and finishing. [50]

The Celay system was also introduced years ago to fabricate feldspathic restorations by copy milling process. In this system, acrylic resin patterns were used for fabrication of the restoration. Zirkozahn had developed a similar system in 2003 called Zirkograph. This system was used for milling zirconia restorations out of a replica.

The Cercon system introduced by Dentsply Ceramco also designs Zirconia restorations out of wax impression. [51] The Lava (3M ESPE) was introduced in 2002, can fabricate Yttria-tetragonal-zironia polycrystal (Y-TZP) cores and frameworks for all ceramic restorations. The LAVA system has an optical scanner that designs and fabricates the restoration or the framework. Other systems for zirconia restorations include DCS Zirkon (DCS Dental) and Denzir. [52]

Cavity preparation for ceramic inlays by CAD/CAM:

- → The cavity preparation should always be defect oriented, and hence, all faults should be included.
- → The rounding of all the edges inside the cavity is done. The transformation from preparation walls to the floor of the cavity and all the line angles are kept rounded.
- → A minimum taper of 6 to 10º is aimed.
- → A minimum thickness of 1.5mm is kept occlusally at the fissure region. This can be evaluated with the help of periodontal probe.
- → The recommended occlusal width thickness is around 2.5mm.
- → The minimum wall thickness of 1.5-2mm is needed, if the defect leads to decrease in wall thickness, then subsequent shortening of the cusps is done to achieve the minimum wall thickness of the cavity.
- → The overall cavity preparation should be box shaped, slight divergent with cavosurface angle that run out at 90º, this provides high strength to the ceramic and the tooth structure.
- → Bevels are not given in the preparation as the retention is dependent upon the adhesive bonding.

- → The undercuts or the rough surfaces present in the pulpal floor can be flattened using base materials like Glass Ionomer cement.
- → Cavity convergence of the buccal and lingual walls are unique for the CEREC inlay preparation which facilitates the automatic design feature of the ceramic restoration by CAD/CAM.

*Fabrication Technique*

- ✦ Impression and die fabrication
- ✦ Provisionalization
- ✦ Optical impression
- ✦ Milling procedure
- ✦ Cementation
- ✦ Finishing and polishing

Impression making and die fabrication: impressions can be made by reversible or irreversible hydrocolloids, polysulfide, polyvinylsiloxane and polyether. The opposing arch impressions are not required. The interocclusal records are also not necessary. The impression is poured in die stone and the cast is sectioned proximally with the help of the saw, still maintaining the proximal relationship.

This is followed by providing temporary restoration to the patient. This process is called provisionalisation or temporization. The rationale is to provide a temporary seal for a short period of time to the prepared tooth in order to protect it from thermal and chemical insults. DuraSeal is a self polymerizable polymethylmethacryalte material, is available as powder and liquid applied directly onto the tooth surface and is retained onto the tooth surface without any cement.

Optical impression: the die which is prepared is being correctly positioned on a flat surface and is uniformly coated with a special reflective powder. This is done to enhance the reading capability of the miniature infrared camera that records the preparation surfaces in three planes. This can be observed on a monitor screen. The impressions can be recorded again and again till the perfect image is obtained. Once the optical impression is completed, the command for computer assisted manufacturing is given for milling of the ceramic block.

The ceramic block of appropriate shade is selected and is sent for the milling process. The diamond coated wheel is driven electrically under continuous stream of water. The three axis rotational cutting is performed in following way:

- → Rotational movement is done by the block
- → There is a horizontal movement of block into the wheel
- → The wheel moves in a vertical motion.

Once the milling process is completed, the prepared ceramic restoration can be checked on die for proximal contours and proper fit of the restoration.

Finally, cementation of the prepared inlay is done. This is done under complete isolation for which rubber dam is the best. The surface of the prepared inlay is etched with hydrofluoric acid or ammonium biflouride. This is done to achieve microporosities which will help to achieve microretentions by formation of microtags. This is followed by application of silane coupling agent to enhance adhesion.

After the surface preparation of the restoration, the cavity is etched with 35-37% orthophosphoric acid for 15-20 seconds and is rinsed with air water spray. This is followed by application self-cure or dual cure resin cement which is gently applied with the help of applicator tip on to the prepared cavity and on the inlay. The inlay is seated in the prepared cavity and is checked for occlusion by asking the patient to close the mouth in functional occlusion. Mylar strips and light transmitting wedges help in controlling excess cement during the luting procedure. The curing is done for 40 to 45 seconds from all the sides. This is followed by finishing and polishing with the help of diamond points and finishing strips. The polishing is done with the help of flexible polishing disks (Sof- Lex, 3M) and polishing paste. [53]

## Bibliography

1. Newbrun Ernest.3rd Edition. Chicago, IL, Quintessence Publishing Co. Inc., 1989. Cariology.Pg. 13-27.
2. Aristotle. Opera Omnia.Paris: I. Billiane, Simon Piget, Frederic Leonard, 1654. 4 vols. Vol. 4, P 182. Problemata. Section 22, Eorum ad fructus arborum, question 14.
3. Aslander, A. 1961. Lifetime teeth, NY*J Dent* 31:346-348.
4. Black G.V. 1st edi. Vol.2. Chicago, Medico-Dental Publishing Company, 1908. Operative Dentistry.
5. Heymann H, Swift E, Ritter A. Sturdevant's Art and Science of operative dentistry, 6th edi. St. Louis: Elsevier, 2013. Page 287.

6. Letzel H, Van't Hof MA, Marshall GW, Marshall SJ. The influence of the amalgam alloy on the survival of amalgam restorations: a secondary analysis of multiple controlled clinical trials. Journal of dental research. 1997 Nov; 76(11):1787-98.
7. Plasmans PJ, Creugers NH, Mulder J. Long-term survival of extensive amalgam restorations. Journal of dental research. 1998 Mar; 77(3):453-60.
8. Major IA. Amalgam and composite resin restorations: Longevity and reason for replacement. In: Anusavice KJ, editor. Quality evaluations of dental restorations. Criteria for placement and replacement. Chicago: Quintessence Publishing Co. Inc; 1989. Pg. 61-8.
9. From amalgam to composite: selection of restorative materials and restoration longevity in Finland. Acta Odontol Scand 2001; 59:57-62.
10. Goldstein GR. The longevity of direct and indirect posterior restorations is uncertain and may be affected by a number of dentist, patient and material related factors. J Evid. Based Dent. Pract. 2010; 10:30-31.
11. Antony K, Genser D, Heibinger C, Wendiech F. Longevity of dental amalgam in comparison to composite materials. GMS health technol Asses 2008; 4: Doc 12.
12. Bergman M. the clinical performance of ceramic inlays; a review. Aust Dent J. 1999; 44(3):157-168.
13. Dietschi D, Spreafico R. Adhesive metal-free restorations: current concepts for the esthetic treatment of posterior teeth. Chicago, Ill, USA: Quintessence; 1997.
14. Dunn JR. iBond: the seventh-generation, one-bottle dental bonding agent. Compendium of continuing education in dentistry (Jamesburg, NJ: 1995). 2003 Feb; 24(2 Suppl):14-8.

15. Virgillito A, Holz J. Produits adhesifs dentinaires et de scellement soumis au contrôle biologique in vivo. J Biol Buccale. 1989; 17:209-4.

16. Elbaum R, Remusat M, Brouillet JL. Biocompatibility of an enamel-dentin adhesive. Quintessence International. 1992 Nov 1; 23(11).

17. Dietschi D. De Siebenthal G, Neveu-Rosenstand L, Holz J. Influence of the restorative technique and new adhesives on the dentin marginal seal and adaptation of resin composite class II restorations: An in vitro evaluation. Quintessence Int. 1995 Oct; 26(10):717-27.

18. Lutz F,Krejci I,Luescher B, Oldenburg TR. Improved proximal margin adaptation of class II composite restorations by use of light reflecting wedges. Quintessence Int 1986; 17:659-664.

19. Tyas Mj. Glass Ionomer (polyalkeonate) cement restorations. Curr Opin Periodontal Res Dent 1992; 137-131.

20. Mitra SB. Adhesion to dentin and physical properties of a light-cured glass-ionomer liner/base. Journal of Dental Research. 1991 Jan; 70(1):72-4.

21. Denry IL, Rosenstiel SF. Flexural strength and fracture toughness of Dicor glass-ceramic after embedment modification. Journal of dental research. 1993 Mar; 72(3):572-6.

22. Bertolotti RL. Posterior composite technique utilizing directed polymerization shrinkage and a novel matrix. Practical periodontics and aesthetic dentistry: PPAD. 1991; 3(4):53-8.

23. Swift EJ, Heymann HO, Ritter AV, GopiKrishna V. Sturdevant's Art and Science of Operative Dentistry–South Asian Edition.

24. Sikri V K. Edition 1st. Amritsar. Quintessence Science communications Pvt. Ltd. Indirect Restorations.

25. Lutz F, Kull M. The development of a posterior tooth composite system, in-vitro investigation. Schweizerische Monatsschrift fur Zahnheilkunde= Revue mensuelle suisse d'odonto-stomatologie. 1980 May; 90(5):455-83.
26. Kays BT, Sneed WD, Nuckles DB. Microhardness of class II composite resin restorations with different matrices and light positions. The Journal of prosthetic dentistry. 1991 Apr 1; 65(4):487-90.
27. Bichacho N. The centripetal build-up for composite resin posterior restorations. Pract Periodontics Aesthet Dent. 1994 Apr; 6(3):17-23.
28. Weaver WS, Blank LW, Pelleu JG. A visible-light-activated resin cured through tooth structure. General dentistry. 1988; 36(3):236-7.
29. Blankenau RJ, Kelsey 3rd WP, Cavel WT. A direct posterior restorative resin inlay technique. Quintessence international, dental digest. 1984 May; 15(5):515.
30. Mormann WH, Brandestini M, Lutz F, Barbakow F. Chair side computer- aided direct ceramic inlays. Quintessence Int 1989; 20:329-339.
31. Peutzfeldt A, Asmussen E. A comparison of accuracy in seating and gap formation for three inlay/onlay techniques. Operative dentistry. 1990; 15(4):129-35.
32. BAUSCH JD, Delange C, Davidson CL. The influence of temperature on some physical properties of dental composites. Journal of Oral Rehabilitation. 1981 Jul;8(4):309-17.
33. Bowen RL. Adhesive bonding of various materials to hard tooth tissuesñVI. Forces developing in direct-filling materials during hardening. J Am Dent Assoc 1967;74(3):439-45

34. Giachetti L, Scaminaci Russo D, Bambi C, Grandini R. A review of polymerization shrinkage stress: current techniques for posterior direct resin restorations. J Contemp Dent Pract. 2006 Sep 1; 7(4):79-88.
35. Malhotra N, Acharya S. Strategies to Overcome Polymerization Shrinkage− Materials and Techniques. A Review. Dental update. 2010 Mar 2; 37(2):115-25.
36. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 1987; 66:1636-9.
37. Ac I. Restorative Dentistry-E-Book. Elsevier Health Sciences; 2013 Dec 1.
38. Nandini S. Indirect resin composites. Journal of conservative dentistry: JCD. 2010 Oct; 13(4):184.
39. Sturdevant CM, Roberson TM, Heymann HO, et al. The Art and Science of Operative Dentistry. 3rd ed. St. Louis, Mo: Mosby; 1994.
40. Hopp CD, Land MF. Considerations for ceramic inlays in posterior teeth: a review. Clinical, cosmetic and investigational dentistry. 2013; 5:21.
41. Yang S, Cook N, Paddock C. All-ceramic inlays and onlays. Clin Update. 2005; 27(2):1–2.
42. Heymann H, Swift E, Ritter A. Sturdevant's Art and Science of Operative Dentistry, 6th ed. St Louis: Elsevier; 2013. Page 287
43. Giordano R. Materials for chairside CAD/CAM produced restorations. J Am Dent Assoc. 2006; 137 Suppl 1:14S–21S.
44. Hayashi M, Miura M, Nishimura N, Takeshige F, Edisu S. Effects of cavity form and setting expansion of refractory dies on adaptability of fired ceramic inlays. Oper Dent. 2000; 25(1):33–39.

45. Van Dijken JWV, Örmin A, Olofsson AL. Clinical performance of pressed inlays luted with resin-modified glass ionomer and autopolymerizing resin composite cements. J Prosthet Dent. 1999; 82(5): 529–535.

46. Söderholm KJM, Shang SW. Molecular orientation of silane at the surface of colloidal silica. J Dent Res. 1993; 72(6):1050–1054.

47. Duret F, Blouin JL, Duret B. CAD-CAM in dentistry. The Journal of the American Dental Association. 1988 Nov 1; 117(6):715-20.

48. Mormann WH. Chairside computer-aided direct ceramic inlays. Quintessence Int. 1989; 20:329-39.

49. .Gehrt, M. Wolfart, S. Rafai, N., Reich, S. Edelhoff, D. (2013). Clinical results of lithium-disilicate crowns after up to 9 years of service. Clinical Oral Investigations. 17(1), 275–84

50. Neves F, Prado C, Prudente M, Carneiro T, Zancope K, Davi L, Mendonçe G, Cooper L, Soares C. Marginal fit evaluation with micro CT of lithium disilicate crowns fabricated by chairside CAD/CAM systems and the heat-pressing technique. J Prosthet Dent. 2014.

51. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mat Journal 2009. 28: 44–56.

52. Hertlein G. Kramer M, Sprengart T, et al. Milling time vs marginal fit of CAD/CAM manufactured zirconia restorations. J. Dent Res 2003. 82:194.

53. Nathanson D, Riis DN, Cataldo GL, Ashayeri N. CAD-CAM ceramic inlays and onlays: using an indirect technique. Journal of the American Dental Association (1939). 1994 Apr; 125(4):421-7.