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Dental caries control using nanotechnology

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Abstract: In order to create new dental materials with cutting-edge qualities and anti-cariogenic potential, nanotechnology has been utilized in dentistry. Dentistry's current difficulties are with tooth decay prevention and cavity restoration. Due to their significant potential to limit biofilm accumulation, reduce the demineralization of the hard tooth tissues, and promote the remineralization process, recently discovered nanoparticles are now being used in preventative therapeutic agents and dental restorative materials. In this study, the advancement of nanomaterials for use in dental caries prevention and restoration is the main topic.

Keywords: Prevention dentistry; dental caries; nanotechnology.

The majority of adults and 60–90% of school-age children suffer from dental caries, which is the most common oral health condition impacting people globally throughout their lifetime. Small, chalky-white patches of demineralized, softened tissues on the enamel tooth surface are the first signs of dental caries and are typically difficult to discern because they are tucked away in fissures and grooves. The softer and more sensitive dentine layer is affected by untreated enamel caries, which causes more devastation. Periodontitis and gum recession may also be brought on by dental caries, which can similarly damage the root's cement [1].

Dental caries is caused by the action of cariogenic bacteria found in dental plaque on the tooth surface, which ferments carbohydrates found in foods and beverages and produces acids. The acids generated cause the calcium and phosphate in the tooth to become demineralized. In addition to buffering and neutralising the generated acids, normal saliva functions as a remineralizing agent, supplying a reservoir of minerals close to the enamel. Enamel undergoes numerous cycles of demineralization and remineralization every day. When this process is out of balance and demineralization occurs more frequently than remineralization, the enamel minerals are destroyed, which causes a cavity[2].

Dental caries prevention and minimally invasive treatment methods have taken centre stage in contemporary dentistry. Dental caries management entails both prevention and care for previously damaged and missing tooth tissue. Prevention is preferable to treatment. Fluoride and non-fluoride applications are just two examples of the many dental caries preventative treatments remineralizing chemicals that could be applied.

Enamel, dentin, or cementum of the tooth can be painted with fluoride varnish, which is normally a thick liquid that contains 5% sodium fluoride. Pit and fissure sealants, on the other hand, are a thin plastic coating applied to the teeth's occlusal surface to block plaque and acids from reaching the enamel. Fissure sealants and fluoride varnishes are regarded as successful occlusal surfaces caries prevention methods[3].

Unfortunately, dental caries is a condition that cannot be prevented, but it can be effectively minimised with dental and restorative care that closely adheres to approved caries prevention programmes. Removal of damaged tissue components and tooth replacement with suitable material are steps in the dental treatment of decaying teeth. Dental restorations are still required despite extensive efforts in oral health promotion and preventive measures. Due to the wide range of dental restorative materials currently on the market, several suitable materials, such as resin composite and glass ionomer and their variations [4], could be utilised to restore dental carious teeth. Lesions that develop caries at the borders of an existing restoration are referred to as recurrent caries. Recurrent caries is treated by replacing the compromised repair. It typically calls for prevention of both initial and recurrent caries. Therefore, great effort should be put into developing restorative materials that are highly effective and have anti-cariogenic qualities[5].

For the management of dental caries, nanotechnology, which deals with nanostructures at the nanometer scale (0.1–100 nm), offers novel methods. The biggest development in the therapeutic management of the missing enamel surface may come from remineralization. Nanotechnology was used to mimic the biomineralization process that naturally forms and repairs dental enamel. The main inorganic component of hard dental tissues is hydroxyapatite. The use of nano-hydroxyapatite as a preventive and therapeutic measure against tooth caries has significant potential. Dental materials' characteristics at the nanoscale are very different from those at the microscale. Newly developed nanoparticles can be employed to regulate the development of cariogenic biofilms and new tooth restorative materials [6].

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Assessment of optical and thermal degradation in dentistry

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Abstract: Analyzing the reasons for structural degradation and failure of the employed materials is crucial in order to forecast how well dental materials will perform clinically in the patient's mouth. The oral cavity is a challenging environment for bacteria to survive in because of the pH and temperature variations, as well as a range of challenges. The three most typical causes of dental material failure are poor material choice, poor design, or overuse. In addition, damage might happen while being repaired. Planning for failure, comprehending its causes, and taking the required steps are essential if you want to avoid material failure.

Keywords: *optical degradation, thermal degradation, dentistry.*

Introduction

To predict how well the clinical performance of the dental materials will perform in the patient's mouth, it is essential to analyse the causes of structural degradation and failure of the used materials. The mouth cavity is a hostile habitat with numerous stressors, pH and temperature variations, and pathogens. bad material selection, bad design, or overuse are the three most common reasons for dental material failure. Additionally, damage can occur while being corrected. It's essential to prepare to avoid failure, assess the causes, and put the required preventative measures into place in order to prevent material failure[1-4].

1) Optical degradation and assessment

1) Visual method

Subjective color identification involves visual color assessment. It is performed by reference color samples whose specification is known. In dentistry, shade guides are routinely used as standard color samples against the tooth to which it is compared. Some of the popular shade guides are Vitapan Classical, Chromascope, and Vita System 3D

Master. Visual methods are easier than instrumental measurements. However visual color perception may vary from one individual to another and might even vary. To have a realistic change of obtaining a color match, thousands of tabs are needed[5].

2) Instrumental color change

Instrumental color measurement uses the CIE system, where the color consists of three coordinates: L* ,a*, b*. Where, L* refers to the lightness coordinates, and a*, b* are the chromaticity coordinates in the red-green axis, yellow-blue axis.

$$\Delta E = \left(\Delta l^2 + \Delta a^2 + \Delta b^2\right)^{1/2}$$

Colorimeter: Colorimeter quantifies color by measuring three primary color components of light. Colorimeter has been shown to provide accurate and reputable measurements; however, they are not free of errors. Where, the spectrophotometer measures each wavelength of light. Spectrophotometer allows the integration of each wavelength. Digital imaging system allows appropriate calibration with object-camera distance, and digital camera settings), digital imaging method has been suggested as an alternative with reasonable accuracy and reliability. This is a more convenient and economical process than spectrophotometers or colorimeters[5].

5) Thermal degradation

Thermal analysis is a group of techniques that measures properties change as a function of temperature. These techniques are applied for the characterization, decomposition, thermal stability, and phase transition. The most commonly used methods are differential thermal analysis, differential scanning calorimetry, and thermo-gravimetric analysis.

1) Differential thermal analysis:

It measures the temperature difference of the sample under investigation and uses a thermally inert material as a reference against temperature or time. The temperature difference is then recorded while the sample and the reference are subjected to a controlled identical temperature program in an environment at a controlled uniform rate. It is used with materials of high melting points as metals, and ceramics[6].

2) Differential scanning colorimeter

It is a thermal analysis method that measures the difference in the amount of heat or the heat flow rate between the sample and an inert reference a function of time or temperature while both are subjected to controlled temperature, as seen in Figure 1. It measures the energy required to keep both the reference and the sample at the same temperature. It differs from the DTA that the sample and the reference are both at the temperature determined by the program. It is a qualitative method that measures temperature differences and has no quantitative data for energy. It measures the glass transition temperature, melting point, crystallization temperature, and the heat of crystallization[6].

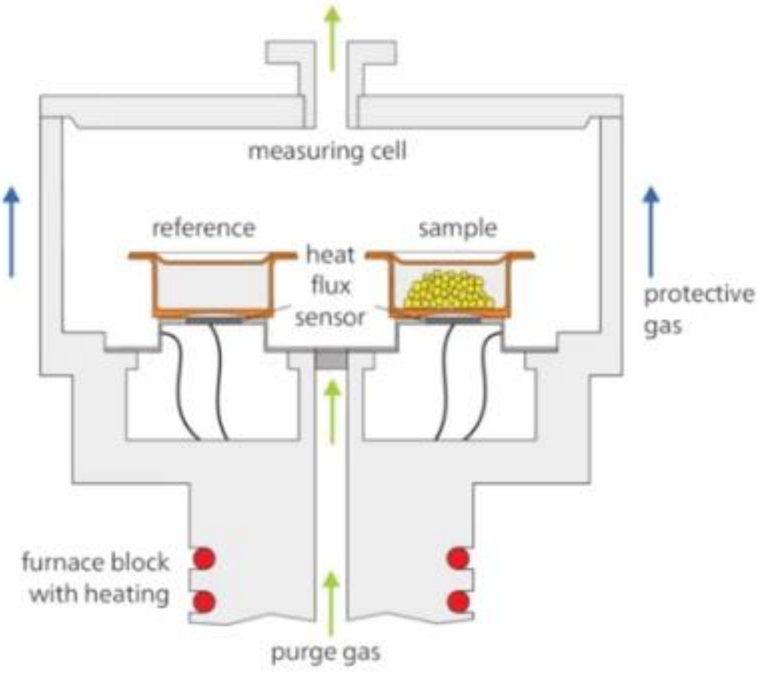

Figure 1: Differential scanning colorimeter

3) Thermo-gravimetric analysis

It is a technique where the mass of a substance is monitored as a function of temperature or time when the sample is subjected to a controlled temperature program. It measures the change in weight of the sample during heating or cooling. It is used to measure the glass transition and melting point including polymers and it also measures corrosion studies[6].

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Type of the Paper (Review Article)

Advanced In-Vitro Systems Mimicking the In-Vivo conditions

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Abstract: Our problem is that invitro and invivo systems are hard to compare due to the differences in their complexity, as invitro systems are very simple compared to invivo conditions. Where, there is only one cell type which is cultivated under two-dimensional conditions with an optimized culture medium. In contrast to invivo test where, there is always more than one cell type involved, and cells act in a three-dimensional environment in a dynamic fashion surrounded by different fluids. In case of Invitro tests this condition is considered pathological environment to which cells adapt and respond giving different response than that given to normal environment. Further research is conducted aiming to cross the gap between in vitro and in vivo tests.

Keywords: multiple cell types, cell aggregate, cell organoid and body fluid mimicry.

Our problem is that invitro and invivo systems are hard to compare due to the differences in their complexity, as invitro systems are very simple compared to invivo conditions. Where, there is only one cell type which is cultivated under two-dimensional conditions with an optimized culture medium. In contrast to invivo test where, there is always more than one cell type involved, and cells act in a three-dimensional environment in a dynamic fashion surrounded by different fluids. In case of Invitro tests this condition is considered pathological environment to which cells adapt and respond giving different response than that given to normal environment. Further research is conducted aiming to cross the gap between in vitro and in vivo tests. [1]

1. From single to multiple cell types.

Different cell types are cultivated in the same culture, either completely mixed or separated via membranes. It is known that an in vitro mixture of progenitor cells in different states of differentiation leads to more significant results than single cell types. If a material is placed in a multi-cell-type environment, each cell interacts with another in a synergistic way which is crucial for tissue formation and mainly for tissue repair. Different cell types affect cell proliferation, state of differentiation, and functionality of other cells.

The selected cell-type composition should depend on the application of the implant material. For example, if the tested material will be used in a bony environment. Then, the main cell types should include mesenchymal progenitor cells, osteoblasts, osteoclasts, fibroblasts and endothelial cells. **[1]**

Mohammadi et al., 2019 conducted a study to investigate if natural / synthetic polymeric nanofibers (Gel/PLCL nanofiber) can probably promote the proliferation of coculture (adipose derived stem cell ADS/ human fibroblast cells HFC). Where ADSs and HFCs were mixed and seeded on well plates coated with Gel/PLCL nanofiber and non-coated plates. Cell morphology and the interaction between cells and Gel/PLCL nanofiber were evaluated by field emission SEM & fluorescent microscopy. Fluorescence viability staining for detecting live cells was done after incubation of seeded samples with cells for seven days. Then, the samples were incubated by Calcein AM that stains alive cells in green for 30 min at 37°C and washed with PBS. The green- stained samples were subjected to fluorescent microscopy with a 490 nm excitation filter and a 520 nm emission filter. **[2]**

It was found that, nanofibers exhibited proper structural properties in terms of stability in cell proliferation and toxicity analysis processes. Gel/PLCL nanofiber promoted the growth and the adhesion of HFCs. Moreover, co-culture of ADSs/HFCs on the Gel/PLCL nanofiber increased cellular adhesion and proliferation synergistically compared to non-coated plate.[2]

2. **From 2D to 3D**

In invitro tests, single layer of cells is seeded on top of the tested material is done to evaluate its biocompatibility. While in in vivo conditions, an implant of the tested material is placed within a tissue. Thus, tissues will contact the implant. It is well known that cells in a 3D environment behave differently from those in a 2D environment.

Cell reaggregates are prepared of a defined cell number of one of the key cell types of the tissue that after implantation will contact the implant. it can be seen as a kind of organoid, that is placed on the test material and assessed. Growing cells in this situation have the choice to grow out vertically or laterally on the material. So, after placing the material in contact with the organoid, the cell expansion on the surface of the implant is measured. Moreover, cell morphology of the grown cells is assessed.

The point that might affect the outcome is the difference in the oxygen tension gradient. in vivo, oxygen tension probably has the lowest tension at the implant surface, while in this in vitro system, the lowest oxygen tension is in the centre of the reaggregate. Oxygen tension gradients may greatly affect cell migration activity and cell proliferation rate. **[1]**

3. **Oxygen tension**

Control and adaptation of oxygen tension in cell culture is hardly ever considered even though it is a very important factor in how cells react. For example, hypoxia is a pathological condition for most stem cell types, it is a key factor for chondrocyte development and behaviour. In native tissue, chondrocytes are exposed to oxygen concentrations ranging from 1–5%, since the distance to the vessels supplying the synovial membrane is exceptionally large compared to other tissues .

An elegant approach to mimic the in vivo oxygen tension gradient as in extracellular matrix environment is to place a **collagen gel layer** with embedded cells on top of the test material. With this set-up, another important in vivo aspect would be taken into consideration the dimensionality (3D instead of 2D). Collagen gels with embedded cells are currently used for various investigations including effects of matrix stiffness, mechanical load and tissue engineering. **[1]**

4. **From culture medium to body fluid mimicry**.

Culture medium contains a mixture of salts, amino acids, dilute quantities of serum proteins and specific growth factors. While, in in vivo conditions, the cell environment is crowded with proteins resulting in a reduction of diffusion and local high concentrations of released cell products. In this environment, nonspecific reactions play an important role. For example, it was found that collagen was formed by cells in in vivo conditions while absent in invitro conditions, this was solved by adding charged macromolecules to the cultured medium. Moreover, it was found that the addition of macromolecules promotes the differentiation of various cell types. So, by adding macromolecules the original microenvironment can be better mimicked. **[1]**

5. **From static to dynamic**.

The in vivo situation is characterized by the presence of microcirculation in the area of the implanted material. Dolder et al. reported that proliferation and differentiation towards osteoblasts of rat bone marrow stromal cells was increased in the presence of a fluid flow. [3]

All these are single attempts aiming to improve the invitro test system by applying at least one key issue of the in vivo conditions. However, combining different issues in one test system would certainly help better mimicing in vivo conditions and improves the test system.

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Principles of Adhesion to Tooth Structure

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Abstract: Adhesion or bonding refers to the forces or energies between atoms or molecules at an interface that hold two phases together. Adherends are the surface or substrate that is adhered. While, Adhesive/adherent is the material that can join substances together, resist separation and transmit loads across the bond. This article highlights the concept of adhesion, wettabiltity, factors affecting strength of the adhesive junction, then it focuses on the adhesion in dentistry, factors affecting bonding to tooth structure, Composition of dental adhesive Systems, Classification of dental adhesives and finally, degradation of the adhesive interface.

Keywords: *adhesion, dental adhesive, bonding to tooth structure, etch and rinse, self-etch and wet bonding.*

I. Adhesion

Adhesion or bonding refers to the forces or energies between atoms or molecules at an interface that hold two phases together. Adherends are the surface or substrate that is adhered. While, Adhesive/adherent is the material that can join substances together, resist separation and transmit loads across the bond.(1)

II. Adhesion mechanisms

Mechanical adhesion: It occurs when the solidified adhesive interlocks micro - mechanically with roughness and irregularities of the surface of the adherend (substrate).

Physical adhesion

- **Van der Waals interactions**: Attraction between opposite charges on ions and dipoles.
- **Dispersion forces**: Interaction of induced dipoles
- **Hydrogen bond:** It is a particularly strong bond and can be included among physical forces.(1)

Chemical adhesion: It refers to the forces or energies between atoms or molecules at an interface that holds two phases together. This can be formed by either Adsorption or Diffusion.

- **Adsorption mechanism**: It occurs when chemical bonds develop between the adhesive and adherend including ionic and covalent bonds.

Diffusion mechanism: It occurs when polymers from each side of an interface could cross over and react with molecules on the other side to allow disappearance of the interface.

Ideal requirement of adhesion is chemical affinity between the adhesive and the substrate.

III. Wettability

In order for the adhesive to create a bond between two materials, it must make intimate contact with the surfaces of the substrates such that no air voids (which would weaken the bond) are formed. The ability of an adhesive to contact a substrate depends on the ***wettability*** of the adhesive on that particular substrate. *Good wetting* is the ability to cover the substrate completely, so that the maximum benefit is obtained from whichever adhesive mechanism is activated.(2)

Wetting ability of an adhesive depends on 2 main driving forces.

- Forces that tend to spread the adhesive over the substrate; the surface energy of the substrate and surface tension of the adhesive.
- Resistance to spreading that depends on the viscosity of the adhesive, the surface irregularities and the presence of contaminants.

Surface energy & surface tension

In the bulk of a solid or a liquid, the molecules are subjected to attractive forces in all directions, such that the molecule is in dynamic equilibrium with its surrounding molecules. At the surface, this delicate balance is destroyed, resulting in a net inward attraction directed towards the large number of molecules in the mass of the material. It is this inward force that gives rise to the **surface energy** of a material. In liquids, the surface energy is known as the **surface tension**.

By increasing surface energy of a solid, wettability increases.

One of the effects of surface tension is the tendency for liquids to take up a spherical shape in preference to any other. This arises because a sphere has the minimum surface area for a given volume of liquid, allowing the total energy stored in the liquid to be a minimum. By increasing surface tension of a liquid, wettability decreases.

Contact angle

When a solid and a liquid make contact, the angle between the liquid surface and the solid surface is known as the *contact angle*, and is dependent on the surface tension of the liquid and the surface energy of the solid. For perfect wetting, which is the ideal situation for adhesion to occur, this angle should be 0°. In this case, the surface is completely covered with the adhesive and the maximum bond strength can be achieved.

Viscosity

For an adhesive to be effective, it must be able not only to make intimate contact with the substrate, but also to spread easily on it, Too high a viscosity is undesirable, as it prevents the fluid from flowing readily over the surface of the solid and penetrating into narrow cracks and crevices.

Surface roughness

The measurement of contact angles assumes that the surface of the substrate is perfectly smooth. In reality, the surface may be quite rough at a microscopic level. This roughness has the advantage of increasing the potential area for bonding, but can also lead to the entrapment of air. Such entrapment will significantly reduce the effective bonding area and result in a weak bond. Cracks and crevices constitute surface irregularities and the adhesive must be able to flow into them.

An irregular surface has a higher surface area than a smooth surface, so more chemical bonds can be created. If the irregularities are of a particular favorable morphology, such that undercuts are present at the microscopic level, the bond can be enhanced by the process of micromechanical interlocking.(2)

IV. Factors affecting the strength of the adhesive junction

- The thickness of the adhesive film: the thinner the adhesive film, the stronger the adhesive junction is.
- The degree of wettability of the adhesive to the adherend.
- Induced stresses:
    - Stresses due to setting contraction of the adhesive that results in creation of stresses at the interface. The less the contraction of the adhesive during setting the less will be the stresses and the stronger will be the joint.
    - Stresses due to large difference between the coefficient of thermal expansion and contraction between the adhesive and adherend. Close matching is required to minimize these thermal stresses.
- Type of bond. Ideal requirement of adhesion is chemical affinity between the adhesive and the substrate.
- Cleanliness of the surface is necessary to provide intimate contact which is necessary to produce adhesion.

V. Adhesion in Dentistry

Michael Buonocore is considered to be the first person to propose the application of adhesion technology in dentistry. His groundbreaking research in **1955** demonstrated for the first time that acid-etching of enamel could provide a surface suitable for bonding with resins. (3)

The functions of dental adhesives is to promote conservation of tooth structure and enable minimally invasive dentistry, reinforcement of weakened dentin or enamel, reduce marginal staining, reduce microleakag and may also reduce postoperative sensitivity when used properly.

The ultimate goal of a bonded restoration is to attain an intimate adaptation of the restorative material with the dental substrate. This task is difficult to achieve as the bonding process for enamel is different from that for dentin. Dentin has different composition than enamel, it has higher organic and water content. This humid and organic nature of dentin makes bonding extremely difficult.(4)

1. Bonding to tooth structure

Tooth composition is not homogeneous. Both organic and inorganic components are present in different amounts in dentin as compared with enamel. A material that can adhere to the organic components may not adhere to the inorganic components, and an adhesive that bonds to enamel may not adhere to dentin to the same extent. The instruments used to prepare the tooth for bonding leave a rough surface and debris, which promote air entrapment at the interface, prevent intimate contact between the tooth structure and the adhesive material in addition to dealing with saliva contamination.(5)

The fundamental mechanism of adhesion to tooth structure can be regarded simply as an exchange by which inorganic tooth material (hydroxyapatite) is replaced by synthetic resins. This process involves two parts: removing hydroxapatite to create micropores and infiltration of resin monomers into the micropores and subsequent polymerization. As a result, **resin tags** are formed that micromechanically interlock or interpenetrate with the hard tissue. There may also be chemical interactions with the tooth substrate if monomers having acidic or chelating functional groups are present. (5)

Whenever both enamel and dentin tissues are mechanically cut, especially with a rotary instrument, a layer of adherent grinding debris and organic film known as a **smear layer** is left on their surfaces and prevents strong bonding. Different quantities and qualities of smear layer are produced by the various cutting and instrumentation techniques. In dentin, the smear layer becomes burnished into the underlying dentinal tubules and lowers dentin permeability, which is a protective effect. However, it is also a very weak cohesive material and interferes with strong bonding. Therefore, various cleaning or treatment agents and procedures are employed to either remove the smear layer or enhance its **cohesive strength**. Application of acid is used to remove the smear layer from both enamel and dentin. Alternatively, in dentin the smear layer can be left partially in place and modified such that adhesive resins penetrate through it and bond to the intact dentin structures below. (5)

Bonding to enamel:

Composition: Dental enamel is composed of ~96% carbonated apatite, ~3% of water and less than 1% of organic matrix by weight. The basic building block of enamel is the enamel rod.

Acid etching: Phosphoric acid is the most widely used etchant for bonding to enamel. Depending on the concentration, phosphoric acid removes the smear layer and about 10 microns of enamel to expose prisms of enamel rods to create a honeycomb-like, high energy retentive surface.

Bonding agent: The increased surface energy ensures that resin monomers will readily wet the surface, infiltrate into the formed micropores aided by capillary action, and polymerize to form resin tags

Bonding to Dentin:

Dentin is a dynamic substrate and consequently a difficult substrate for bonding than enamel because of the complexity of the dentin structure.

Composition and challenges:

- Dentin composition is different than that of enamel. dentin consists of 50 vol% (volume percentage) of calcium phosphate mineral (hydroxy-apatite), 30 vol% of organic material (mainly type I collagen), and 20 vol% fluid. Acid etching removes hydroxyapatite almost completely from several microns of sound dentin, exposing a microporous network of collagen suspended in water.
- Dentin is heterogenous. Dentin contains a dense network of tubules that connect the pulp with the dentin-enamel junction. The tubules are lined by a cuff of hypermineralized dentin called **peritubular dentin**. The less-mineralized **intertubular dentin** contains collagen fibrils with the characteristic collagen banding. The intertubular dentin is penetrated by submicron channels, which allow the passage of tubular liquid and fibers between neighboring tubules, forming intertubular anastomoses.
- Movement of fluid present in dentinal tubules from the pulp to the dentin- enamel junction is a result of a slight but constant **pulpal pressure**.

○Dentinal tubules enclose cellular extensions from the odontoblasts and therefore are in **direct communication** with the pulp.

○When tooth structure is prepared with a bur or other instrument, residual organic and inorganic components form a "**smear layer"** of debris on the surface . The smear layer fills the orifices of dentin tubules forming smear plugs and decreases dentin permeability. The composition of the smear layer is basically hydroxyapatite and altered denatured collagen. Submicron porosity of the smear layer still allows for diffusion of dentinal fluid .The removal of the smear layer and smear plugs with acidic solutions may result in an increase of the fluid flow onto the exposed dentin surface. This fluid may interfere with adhesion, because hydrophobic resins do not adhere to hydrophilic substrates even if resin tags are formed in the dentin tubules.

○Dentin is a **dynamic tissue** which shows changes due to aging, caries or operative procedures.

○Several additional factors affect dentin permeability. Besides the use of vasoconstrictors in local anesthetics, which decrease pulpal pressure and fluid flow in the tubules, other factors such as the radius , length of the tubules and the viscosity of dentin fluid.

Acid etching: For removal or modification of smear layer, many acids or/and calcium chelators are used:

○*Acids:* Commonly used acid for conditioning dentin is 37% phosphoric acid. It not only removes the smear layer but also exposes microporous collagen network into which resin monomer penetrates. Usually, it forms exposed collagen fibrils which are covered with amorphous layer, a combination of denatured collagen fibers and collapsed residual collagen layer. This is collagen smear layer which is resistant to monomer penetration.

The amount of water left in etched dentin is critical. If insufficient water is present, the collagen network will collapse and produce a relatively impermeable layer that prevents resin infiltration and subsequent hybridization. If too much water remains, resin infiltration cannot fully replace the water in the collagen network and, consequently, sets the condition for later leakage into those locations. Therefore, a priming step is required to maintain a hydrated collagen network while removing excess water.

Other acids used for dentin conditioning are nitric acid, maleic acid, citric acid, oxalic acid and hydrochloric acid.

○*Calcium chelators*: These are used to remove and/or modify the smear layer without demineralizing the surface dentin layer. Commonly used chelator is ethylene diamine tetraacetic acid (EDTA). (1, 6)

Priming of Dentin

Primers are agents which contain monomers having hydrophilic end with affinity for exposed collagen fibrils and hydrophobic end with affinity for adhesive resin. Primers are used to increase the diffusion of resin into moist and demineralized dentin and thus optimal micromechanical bonding. For optimal penetration of primer into demineralized dentin, it should be applied in multiple coats. Also it is preferred to keep the dentin surface moist, otherwise collagen fibers get collapsed in dry condition resisting the entry for primer and adhesive resin. Commonly used primers have HEMA and 4-META monomers, dissolved in organic solvents.

Moist vs Dry Dentin

Collagen is one of the important factors in determining the dentin bonding. By etching of dentin, removal of smear layer and minerals from dentin structure occurs, exposing the collagen fibers. Areas from where minerals are removed are filled with water. This water acts as a plasticizer for collagen, keeping it in an expanded soft state. Thus, spaces for resin infiltration are also preserved. But these collagen fibers collapse when dry or when the organic matrix is denatured. This obstructs the resin from reaching the dentin surface and forming a hybrid layer. Thus, the desired effect of acid etching, which is increased permeability, is lost. So, it is advisable to have moist dentin for resin-dentin bonding, to achieve successful dentin bonding. (1, 6)

VI. Factors affecting bonding to tooth structure

There are different factors that affect bonding to tooth structure that could be classified into five main groups; tooth related, material related, cavity related, technique related and oral environmental factors.

Tooth related factors including:

- **Surface energy** of enamel and dentin surface as mentioned before. Increased surface energy is required for good adhesion.
- **Capillary attraction**. If there is good wetting, then capillary action will end to draw the material to the surface (irregularity or orifice). keeping in mind that the viscosity must be low enough for the material to penetrate into the defected site.

- **Compositional differences of tooth tissues**. Tooth composition is heterogenous. Both organic and inorganic components are present in different amounts in dentin & enamel.
- **Presences of smear layer** on surface of prepared enamel and dentin and how to deal with.
- **Contaminants** presence of contaminants that prevents the intimate contact between the tooth structure and adhesive affecting the bond strength negatively.

Material related factors

o **Degradation** of the adhesive junction in the oral fluids (that will be discussed later)

o **Thermal coefficient of expansion** as mentioned before the large difference between the coefficient of thermal expansion and contraction between the adhesive and tooth structure induce thermal stresses that affects the strength of the bond.

o **Modulus of elasticity and transfer of stress at interface.** The adhesive must have modulus of elasticity close to that of tooth structure to avoid stress shielding effect.

o **Dimensional stability** of the material used.

Prepared cavity related factors

All these factors should be considered during cavity preparation to maximize the achieved bond strength:

o Adhesive **cavity design** should be done.

o **Resistance and Retention** required should be estimated and built in preparation.

o All carious tissue should be removed.

o Adequate **finishing**, **debridement** and **toilet** of the cavity is required.

Technique of restoration and skills of the operator factors

o Avoid moisture contamination.
o Use of liner and bases.
o Constituents of temporary restorations.
o Post-operative and post restorative care.
o C-factor.

N.B: An important clinical consideration during the application of the adhesive to the prepared tooth structure is the **configuration factor (C-factor)**. The C-factor is the ratio of bonded surfaces to the unbonded or free surfaces in a tooth preparation. The higher the C-factor, the greater is the potential for bond disruption from polymerization effects (stresses are induced at the adhesive junction due to the polymerization shrinkage of the adhesive during setting, while the tooth structure is rigid).

Oral environmental factors

o Occlusal loads.
o Chemical degradation.
Oral microorganisms.
o Humidity.
o Chewing habits.

All these factors have negative impact on the strength of the adhesive junction and its durability.

VII. Composition of dental adhesive System

☐ Etchant:

In etch and rinse technique the etchant used is 30% - 40% phosphoric acid gel (pH = 0.1–0.4). In enamel phosphoric acid etching removes the smear layer and approximately ≅ 10 μm of the enamel surface, creating a porous area with increased surface energy and wettability. This enables fluid resin infiltration, forming resin tags.

However, etching dentin surfaces with phosphoric acid leads to a complete removal of the smear layer and demineralizes the intertubular dentin, leaving a 3D microporous mesh of exposed collagen fibrils, devoid of hydroxyapatite making chemical bonding with is unlikely. Hence, the primary bonding mechanism of etch & rinse adhesives to dentin depends on infiltration of resin within the exposed collagen fibril scaffold. However, complete infiltration of monomers into the wet and demineralized dentin is not consistently achieved, leaving incompletely infiltrated zones along the bottom of the hybrid layer in the form of “nanoleakage” phenomena. (12)

Even after the air drying , dehydration of the demineralized dentin leads to the collapse of the exposed collagen mesh, reducing the spaces between the fibrils and preventing them from acting as channels through which monomers may penetrate and spread.

In self-etch adhesive, the etchant is typically an acidic monomer that also serves as the primer so the previous problem does not exist.

☐ Primer:

The main aim of the priming step is to alter the hydrophilic dentin surface into a hydrophobic phase. The primers, adhesion promoting agents, contain amphipathic monomers dissolved in organic solvents. These monomers have hydrophilic properties with affinity for the collagen fibrils and hydrophobic properties to co-polymerize with the adhesive resin. The (HEMA) monomer is the most frequently incorporated in primers. However, the incorporation of HEMA to adhesive–resin makes dental adhesives too hydrophilic and thus more susceptible to hydrolysis.

Self-etch adhesive systems utilize primers that are acidic monomers. Examples of acidic functional resin monomers are (10-MDP). Overall, 10- MDP is the most popular and highly stable acidic monomer; its stability is attributed to the long carbonyl chain (spacer) between the functional and the polymerizable groups in the monomer structure. Additionally, the phosphate functional group is capable of forming strong ionic bonds with hydroxyapatite, due to the low solubility of the resulting calcium salts. (13)

☐ **Resin components:**

In order to assure a good covalent bond between the adhesive and resin composite, dental adhesives contain resin monomers that are similar to those in resin composite. They act as a backbone providing structural continuity and thus mechanical properties such as strength. Monomers are the key constituents of adhesives. Two kinds of monomers can be distinguished:

- *Cross-linkers hydrophobic monomers* (have two polymerizable groups) which is responsible for its biomechanical properties and co-polymerization with the restorative material as (BisGMA).
- *Functional hydrophilic monomers* (commonly have only one polymerizable group) used for different actions, such as increasing the wettability (e.g. HEMA); provide anti-bacterial properties (e.g. MDPB & 10-MDB).(14)

☐ **Initiator systems:**

Adhesive systems should be cured before the application of the composite, to obtain an optimal degree of conversion, thus good mechanical strength of the adhesive layer.

- **Photo-initiators:** Many compounds can dissociate into free radicals upon absorption of light energy, such as camphorquinone (**CQ**), 1-phenyl-1,2 propanedione (**PPD**) both are hydrophobic. so, may be subjected to phase separation resulting in poor polymerization of the hydrophilic part of the adhesive systems. The use of alternative photoinitiator systems 2-hydroxy-3-(3,4dimethyl-9-oxo-9H-thioxanthen-2-yloxy)-N,N,N-trimethyl-1 propanaminium chloride (**QTX**). The QTX is a water soluble photoinitiator, that improve the polymerization of the more hydrophilic components of the adhesive resin. However, it has very short absorption peak, so need special LED light curing unit.
- **Chemical-initiators:** The use of chemical initiators is usually restricted to cements and resin that cannot rely on light curing for polymerization. The most common initiator in self-curing resins is benzoyl peroxide (**BPO**) in conjunction with co-initiator **tertiary amine**. (14)

☐ **Inhibitors:**

Inhibitors added to dental resins are actually **antioxidants** that are able to scavenge free radicals originating from prematurely reacted initiators. The most frequently used inhibitors in adhesives are butylated hydroxytoluene.

☐ **Fillers:**

Fillers are added to modify the strength and viscosity of adhesives. Depending on their chemical composition, fillers can also provide **fluoride release** and **radioopacity**.
P.S., particle size affects penetration ability.

☐ **Modifiers:**

Manufacturers sometimes add specific ingredients such as: glutaraldehyde, which have desensitizing effect results from denaturation of collagen in dentin and the occlusion of dentinal tubules, in addition to strong antibacterial activity.
Methacryloyloxydodecylpyridinium bromide (MDPB) monomer with antibacterial effect, N-methacryloyl-5-aminosalicylic acid (5-NMSA) monomer has a salicyl group that is intended to chelate with calcium in order to obtain a desensitizing

☐ **Solvent:**

The addition of solvents to resin is essential. The wet nature of dentine only allows good wetting when a hydrophilic bonding is applied. Their main function is to promote good penetration of the monomers in the collagen network of the demineralized dentin, thus improve the diffusion ability of resin.

- **Water:** Water-containing adhesives are capable of expanding the collapsed and shrunken collagen network. Water takes a longer time to evaporate when compared to alcohol.
- **Ethanol:** Its higher vapor pressure compared to water allows faster evaporation by air-drying thus added to water.
- **Acetone:** Its high vapor pressure, which is about **four times** as high as that of ethanol. However, its high volatity reduces shelf life of acetone-containing adhesives, by rapid evaporation of the solvent.

Wet bonding technique

Solubility parameter for hydrogen bonding forces (δh) is used to predict how any solvent or adhesive resin can re-expand a collapsed dried, acid-etched dentin. To re-expand matrices, a solvent or resin monomer blends must have hydrogen bonding force higher than 14.8 $(Jcm^3)^{1/2}$. Ethanol ($\delta h = 20.0\ [Jcm^3]^{1/2}$) and water ($\delta h = 40.4\ [Jcm^3]^{1/2}$) are successful in breaking interpeptide hydrogen bonds allowing the matrix to re-expand. (15)

Traditional **water-wet-bonding** technique is used to improve initial bond strength of etch-and-rinse adhesives. Water is an excellent solvent to re-expand collapsed demineralized dentin matrices prior to resin infiltration. However, excess water often causes **suboptimal polymerization** of infiltrated resin monomers. Moreover, water is not a proper solvent for resin monomers, as their miscibility is limited in the water, resulting in **phase separations** of hydrophobic resins as Bis-GMA. Resulting in poor quality hybrid layer that is quite susceptible to biodegradation over time in a harsh oral environment.
Ethanol wet-bonding enhances resin infiltration promoting higher quality hybrid layers in comparison with conventional water wet-bonding. The crucial aim of ethanol wet-bonding is to infiltrate the interfibrillar spaces and dentinal tubules with hydrophobic dimethacrylate resins.
Ethanol is used to chemically dehydrate the exposed collagen matrices without causing their collapse. For maximum collagen re-expansion water is added (28-45 vol%) to ethanol without detection of phase separation.

However, remaining solvent within the adhesive layers may impair adhesive polymerization. Therefore, thorough and careful air drying of the adhesive is necessary to remove excess solvent before the light curing of the adhesive. (15)

VIII. Classification of dental adhesives

Different classifications have been introduced over the years for adhesives; according to generation, method of etching and the number of bottles involved or the number of individual steps necessary for the entire bonding procedure.

- **According to Chronology**

Dental adhesives can be categorized chronologically into generations. The generation simply refers to when and in what order this type of adhesive was developed by the dental industry, ranging from 1st generation in the 1960s to modern 8th and 9th adhesives. 1st and 2nd generation bonding agents are no longer used. They achieved poor bond strengths and failed to prevent marginal gaps. However, 3rd, 4th, 5th and 6th generation adhesives are popular and offer various advantages depending on the clinical situation and the clinician's personal preferences and experience. (4)

- **According to clinical application steps**

Modern dental adhesives can be classified into two basic types: etch-and-rinse (total etch) and self-etch adhesives. These systems can then be sub-classified based on the number of clinical steps included into: three-step and two-step etch and rinse systems. Self-etch system is classified into two-step and one-step self-etch systems.

- **According to adhesion strategy**

Smear layer removing adhesive systems (etch and rinse approach), smear layer dissolving adhesive systems (self-etch approach) and Glass-ionomer approach self-adhesive‖ due to the ionic interaction of polyalkenoic acid with calcium in hydroxyapatite forming submicron hybiridization.

  - **Etch and rinse or total etch approach**
    (Smear layer removing adhesive systems)

The **etch-and-rinse system** has a separate etch-and-rinse step before the priming and bonding steps. The 3-step etch-and-rinse (total-etch system) (using fourth generation adhesives) follows the conventional "etch-rinse-prime-bond" approach. The two step etch-and-rinse system (using fifth-generation adhesives) combines the primer and the bonding agent into one application. (4)

These bonding agents completely remove the smear layer employing the total etch concept. It works on the principle of hybrid layer and resin tags. Enamel and dentin are etched simultaneously using an acid (preferably

37% phosphoric acid). After washing and drying the tooth surface, primer and bonding agent are applied either separately or in combination.

The advantage of this system is that, it provides the highest enamel bond strength. However, this technique results in low dentin bond strength, it is technique sensitive, and results in post-operative sensitivity and nanoleakage. While, with sclerotic dentin, etch and rinse system is better, because, the hyperminerialization of dentin and reduced size of dentinal tubules. (4)

- **Self-etch approach (Smear layer dissolving adhesive systems)**

The **self-etch adhesive system** eliminates the rinsing phase after etching by using non-rinse acidic monomers to etch and prime dentin simultaneously. The two-step self-etch system (involving sixth generation adhesives) uses **hydrophilic acidic monomers** as self-etch primers in the initial step and an **adhesive hydrophobic resin** in the second step. The one-step self-etch system (using seventh generation adhesives, also known as all-in-one adhesives) combines the (self-etch) acidic primer with the adhesive resin in one application step. This allows for simultaneous infiltration of adhesive resin to the depth of demineralization, which decreases the discrepancy between the depth of demineralization and the depth of resin infiltration resulted with etch and rinse system. (4)

These agents partially demineralize the smear layer and the superficial dentin surface without removing the remnants of smear layer or the smear plugs. They make use of acidic primers also termed as self-etch primers or self-etch adhesives which provide simultaneous conditioning and priming of both enamel and dentin. After this, adhesive is applied without washing the tooth surface. The basis for use of these systems is to condition the dentin and to simultaneously penetrate to the depth of demineralized dentin with monomers which can be polymerized.

As one-component self-etch bonding systems mix hydrophilic and hydrophobic agents in the same bottle, they are generally **not as acidic as** other adhesives and can therefore **bond poorly** to enamel and sclerotic dentin. In addition, a difficulty with formulating one-bottle systems is **maintaining stability** with a mixture of components and avoid the phase sepration. In order to solve such a problem, one-step self-etch adhesive systems are supplied as two bottles or unit dose that require mixing just before application.

The etching aggressiveness of self-etch adhesive systems can also be classified into:

- **Strong (pH<1)**: At enamel, “strong” self-etching shows good bonding performance. While, at dentin, “strong self-etching” dissolves nearly all the smear layer but does not remove the dissolved calcium and phosphates ions. These loosely embedded calcium phosphates are hydrolytically unstable, thereby weakening the interfacial integrity on the long-term.
- **Intermediately strong (pH≈1.5):** It has typically a hybrid layer with demineralized top layer and partially demineralized base.
- **Mild (pH≈2):** partially dissolves the smear layer, forming a thin hybrid layer. It has a great advantage of leaving significant amount of hydroxyapatite- crystals around collagen fibrils, which may form chemical bond with carboxylic or phosphate groups of functional monomers. Furthermore, less amount of MMPs will be released form collagen.
- **Ultra-mild (pH≥2.5):** can only expose superficial dentin collagen, producing a nanometer interaction zone.

Advantages of self-etch adhesive:

1. Improve technique sensitivity and control the tooth wetness issue.
2. Better protection of collagen fibrils compared to the E&R technique.
3. Less post-operative sensitivity

Limitations of self-etch adhesive:

Chemically cured composite resins that use tertiary amine as activator do not bond well with self-etch adhesives. This is because the acidic monomers in the self-etch adhesives deactivate the more basic tertiary amines. This problem is overcomed by an additional bottle of chemical co-initiator containing sodium benzene sulphinate.

- **Universal “multi-mode” adhesive systems**

These products are known as multi-mode″ as it can be used as: self-etch (SE) adhesives (one step), etch-and-rinse (E&R) adhesives (two step) and in selective enamel etching.

Most of the formulations of universal adhesives include a chemical bonding capability due to presence of functional monomers that chemically bond to hydroxyapatite, which has been proven to be important for the stabilization of the bond over time.

Among the currently used functional monomers, 10-methacryloy- loxydecyl dihydrogen phosphate (10-MDP) demonstrated a very effective and durable bonding to dentin. (7)

10-MDP can ionically bond to calcium (Ca++) ions and form stable MDP-Ca salts. These salt deposits at the adhesive interface form self-assembled nano layers. When the MDP-containing adhesive is applied onto the dentin covered with a smear layer, the surface is partially demineralized up to a nanometer in depth. Ca++ ions released by the partial dissolution of dentin diffuse within the hybrid layer and form MDP-Ca self-assembled nano layers.(8)

In vitro studies have shown that the use of a multimode universal adhesive in either the etch and rinse or self-etch application mode did not result in significant difference in dentin bond strength. (9, 10, 11)

Examples: Scotchbond Universal (3M ESPE) & All-Bond Universal (Bisco Dental) (7)

Disadvantages of universal adhesive:

- Universal adhesives cannot infiltrate to the full depth of demineralized dentin created by phosphoric acid in case of E&R strategy.
- The complex formulation with high content of solvents may impair complete solvent volatilization and consequently lead to inferior adhesive polymerization.

IX. Degradation of the adhesive interface

☐ Nano-leakage

Nano-leakage is the presence of porous zones beneath or within the hybrid layer that allows penetration of small molecules. It is created by the discrepancy between dentin demineralization and resin infiltration in etch and rinse adhesive systems. The hybrid layer act as a permeable membrane, allow water movement through the bonded interface that plasticizes the polymer chains as shown in Fig. 1.

Self-etch procedures use acidic adhesive resin monomers to simultaneously demineralize and infiltrate the bonding substrate. Thus, theoretically avoiding incomplete infiltration aiming to minimize nano-leakage.

Simplified one-step self-etching adhesives are highly hydrophilic and form hybrid layers that have been found to behave as permeable membranes after polymerization, permitting water movement throughout the bonded interface. Moreover, the retention of residual water in etched dentin and/or adhesives may result in regions of incomplete polymerization or increased permeability within adhesive resin matrices resulting in nano-leakage.(16)

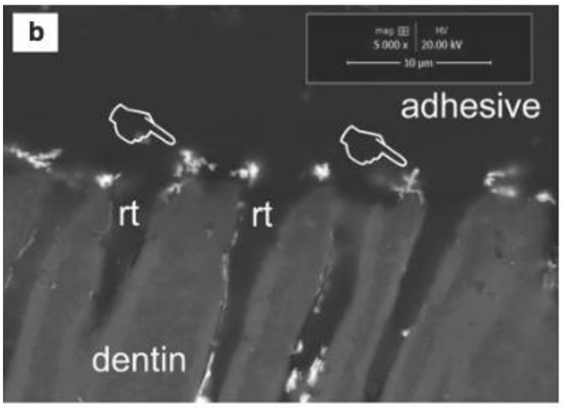

Fig. 1. SEM image of a specimen created with the ethanol wet-bonding technique in dentin pretreated with oxalic acid and submitted to simulated pulpal pressure. Very little nanoleakage can be appreciated within the resin-dentin interface. (14)

☐ Degradation of the Resin Matrix

Most adhesive systems produce very good immediate bond strengths, but the long-term strength is questionable. Adhesive systems are not able to infiltrate completely the demineralized collagen matrix in the acid-etched dentin due to the inability of resin monomers to displace water. This leads to micro- and/or nano-phase separation within the hybrid layer (nano-leakage). These represent the **critical sites** where the hydrolytic degradation can occur causing decrease in the durability of the resin-dentin bond.

However, hydrolysis of resin matrices occurs in both self-etch (SE) and etch-and-rinse (ER) adhesives. Moreover, it is related to their **degree of hydrophilicity** and the amount of water sorption within the hybrid layer. Subsequent to water sorption, these materials are subject to hydrolytic effect, which influences their mechanical properties, dimensional stability and biocompatibility.

Polymer chains within light-cured adhesives absorb water and undergo volumetric changes such as swelling and physical changes such as plasticization and degradation. Degradation occurs through two main mechanisms: (1) passive hydrolysis and (2) enzymatic reaction.

Dental polymer networks may undergo hydrolytic reactions that cause scission of the polymer chain (breakdown of double covalent bonds).

Saliva contains several **esterases** that may cause esterification of methacrylates. The degree of enzymatic degradation is related to the degree of cure of resin monomers at the resin-dentin interface. Loosely cross-linked resin networks are characterized by the presence of ester groups that may be more susceptible to degradation.

The degradation of the polymer matrix is also related to **the chemical composition** of the adhesive. The higher the amount of hydrophilic monomers, the greater the water sorption and hydrolysis.

It is widely accepted that 3-step ER and 2-step SE adhesive systems can be considered as the ‘gold standard’ in dental adhesion. The reason being that is the placement of a hydrophobic adhesive over a primered dentin that reduces water sorption within the resin-dentin interface. While, adhesive systems with fewer application steps, such as all-in-one SE, 2-step ER and universal adhesives exhibit lower bond strength over time and less predictable clinical results compared to the more complex adhesive protocols. Such simplified adhesives are too hydrophilic and allow water sorption, which leads to more drastic hydrolytic degradation of the resin matrix (14)

- **Enzyme-Mediated Collagen Degradation**

The bulk of the tooth is made of dentin, which is constituted by a **mineral component** of up to 70 vol% calcium-deficient/carbonate-rich hydroxyapatite and 30% of **organic content** (90% collagen fibrils and 10% water-rich non-collagenous proteins (NCPs) such as proteoglycans, glycosaminoglycans, phospholipids and enzymes). The enzymes are mainly endogenous MMPs and cysteine cathepsins (e.g. cathepsin K) proteases bonded to the collagen matrix as inactive enzymes proforms and fossilized within the mineralized dentin.

- When MMPs (e.g. MMP-2, MMP-9) are exposed and **activated during restorative procedures** using acid etchants (ER bonding approaches) or acidic resin monomers (SE bonding approach). Moreover, it has been demonstrated that acidic resin monomers contained in mild SE adhesives can **inhibit tissue inhibitors of metalloproteinases** (TIMPs) thus allow MMPs activation. The optimum pH for MMPs to function is between 7.2 and 7.5.
- Cathepsin K has proteolytic activity that leads to collagen degradation within the hybrid layer. The optimum pH for cathepsin K is around 5.0.

However, there is an agreement in adhesive dentistry that collagen degradation is more evident with ER approaches, as the use of phosphoric acid-etchant demineralizes more dentin compared to other approaches, leaving collagen matrices exposed and making them more susceptible to proteolytic degradation by endogenous enzymes . (17)

While, In SE adhesives etch and resin infiltrate the dental substrate simultaneously preventing complete exposure of collagen fibres and preventing also removal of smear plugs from dentinal tubules. Thus, collagen fibrils remain protected by HAP crystallites and less water sorption from the pulpal chamber. (17)

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Types of Dental Veneers and Bonding of Veneers to Tooth Structure

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Abstract: Veneer is a thin sheet of material placed on the facial surface of anterior teeth, for aesthetic purposes and protection. It is a thin layer of restorative material that replaces the enamel. Veneers are the restoration of choice for a conservative and esthetic approach as they give the patient a perfect smile. The following article highlights the history of dental veneers, Indications and contraindications of dental veneers, Classification of dental veneers according to the preparation type, application method & the material used, Advantages & Disadvantages of dental veneers, Treatment required for the fitting surface of veneers & tooth surface before cementation and finally Cementation.

Keywords: *dental veneers, ceramic Veneers, thineers, Lumineers and composite veneers*

I. Introduction

Veneer is a thin sheet of material placed on the facial surface of anterior teeth, for aesthetic purposes and protection. It is a thin layer of restorative material that replaces the enamel. Veneers are the restoration of choice for a conservative and esthetic approach as they give the patient a perfect smile.

Lumineer is an exceptionally thin shell like structure (0.3 mm thickness), placed on the tooth structure with a permanent bonding agent. This is one of the most conservative procedures and only a maximum of 0.3mm of tooth structure is removed if required. Lumineers are also called thineers / ultra-thin veneer / no-prep veneers.(1)

In 1928, **Dr Charles L Pincus** introduced the concept of veneering anterior teeth with laminates in Hollywood. This was to enhance an actor’s appearance for close-ups in movie industry. Dr Pincus attached these thin veneers temporarily with a denture adhesive powder.

In 1970, after the introduction of light cured composites. Dentists have the necessary working time to properly shape direct laminate veneers.

In 1979, the "Mastique laminate veneer system (caulk)" the pre-fabricated composite veneer. The first commercial veneering system. These veneers were fabricated using indirect acrylic resin and were bonded to the etched enamel using an ultraviolet light–cured resin composite as the cementing layer.

The use of resin composite veneers presented several problems such as loss of luster over time and staining, biological incompatibility, these restorations did not employ any tooth preparation, a bulk of material was necessary to obtain a pleasing appearance thus leading to gingival inflammation due to overcontoured restorations.

In 1975, Rochette explained the concept of acid etching porcelain and bonding to the tooth, and described a technique for making ceramic restorations. Next in evolution came the procedure referred to as 'laminating' where veneer facings were bonded to etched tooth structure. Porcelain veneer was a definite improvement over resin veneers but poor bond between the veneer and the tooth still persisted.

In the early 1980s a method of bonding porcelain to acid etched enamel was developed. Etching the porcelain with hydrofluoric acid or a derivative increases the shear bond strength between composite resin luting agent and the porcelain veneer by a factor of four when compared to unetched porcelain.(2)

With the significant improvement in ceramics, luting composites and successful bonding to the tooth structure, this directed clinicians towards minimal invasive dentistry. One such recent modality in veneer is Porcelain Thineer. Porcelain Thineers can be as thin as 0.1 mm and it offers a predictable and successful treatment option in certain cases such as tetracycline staining or mild fluorosis. The aim of the Thineers is to avoid extensive tooth preparation and reinforce the remaining tooth structure present. The advantage of Thineer is preserving the natural tooth structure as much as possible and yet achieving the cosmetic needs of the patient.(1)

II. General indication and contraindication of veneers (3)

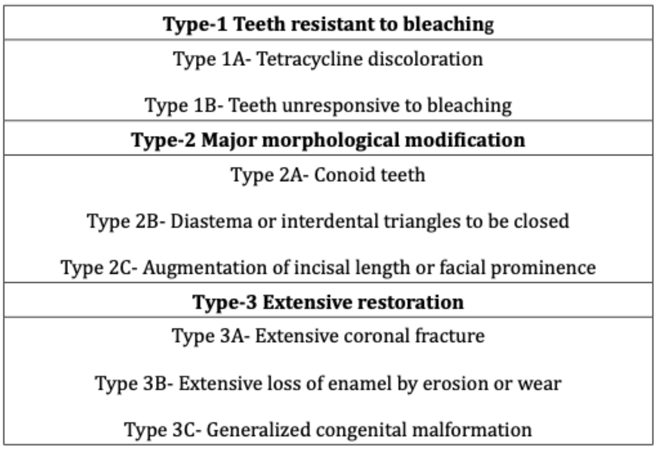
Indications:

1. Extreme discoloration that cant be treated by bleaching
2. Small enamel defects as enamel cracks
3. Diastema & multiple spacing between teeth
4. Mal-positioned teeth or tooth shape anomalies.

Contraindications:

1. Insufficient tooth structure
2. Actively erupting tooth
3. Parafunctional habits
4. Endodontically treated teeth

Magne and Belser classification for the indication of ceramic veneers (3)



Type-1 Teeth resistant to bleaching
Type 1A- Tetracycline discoloration Type 1B- Teeth unresponsive to bleaching
Type-2 Major morphological modification
Type 2A- Conoid teeth Type 2B- Diastema or interdental triangles to be closed Type 2C- Augmentation of incisal length or facial prominence
Type-3 Extensive restoration
Type 3A- Extensive coronal fracture Type 3B- Extensive loss of enamel by erosion or wear Type 3C- Generalized congenital malformation

Type I patients are candidates for conventional ceramics, whereas type II patients require high-resistance ceramics. Type IB patients require simple esthetic facets, although in this case the substrate teeth present color alterations. Therefore, independent of the need for shape modifications, the selected ceramic material must be able to hide the underlying substrate color. In these cases, both the porcelain and cement must present various degrees of opacity to hide the color alterations. In Type II patients, feldspate or alumina ceramics of high resistance, and oxide ceramics are indicated.(4)

III. Classification of dental veneers

III.A) According to type of preparation (3)

1. Window preparation: the incisal edge of the tooth is preserved

2. **Feather preparation**: The incisal edge of the tooth is prepared, but incisal length is not reduced.

3. **Bevel preparation**: The incisal edge of the tooth is prepared Bucco-palatally and the length of the edge is reduced to 0.5 to 1 mm.

4. **Incisal overlap preparation**: The incisal edge of the tooth is prepared Bucco-palatable, and length is reduced to 2 mm; in this case, the veneer is extended to the palatal aspect of the tooth. This places the veneer under compression thus gives better results. Moreover, it allows easier seating of multiple veneers and minimize the risk of fracture. (4)

III.B) According to the application method: (3)

- **Direct laminate veneers**

Laminate composite veneer restoration can be directly applied. In a direct composite technique, the material is directly applied onto the prepared tooth surface followed by intraoral polishing. The disadvantage of the direct composite is its inferior mechanical properties, low resistance to wear, discoloration with time, and fracture.

- **Indirect laminate veneers**

This technique could be done using resin composite or ceramic materials. The indirect composite veneers have advantages of having high resistance against attrition, fracture and discoloration as compared to direct composite veneers but come with a disadvantage of increased dental visits and cost.

- **The direct-indirect technique**

This technique is done using resin composite. It combines both the above technique in which the first layer of high-value opaque hybrid of the resin followed by the second layer of translucent hybrid resin and final layer of translucent microfill composite resin is applied onto the tooth surface and sculpted to desired morphology. It is then teased-off at the veneer-tooth interface and is polished and heat-treated for improving physical properties. After the tooth preparation, veneers are restored onto the tooth using an appropriate luting agent.

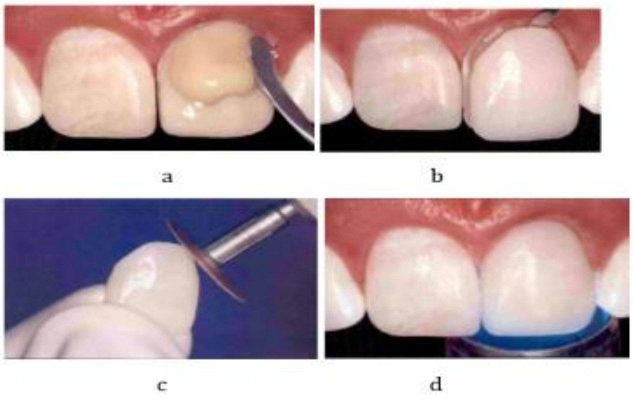
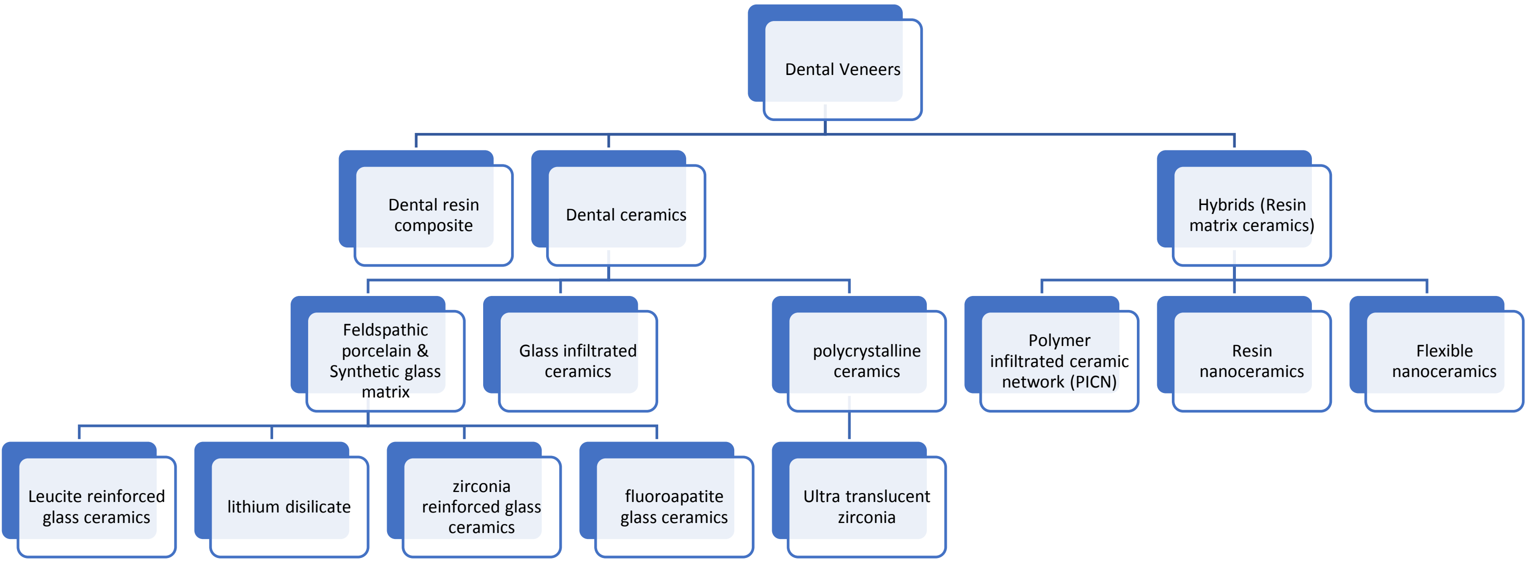


Figure: *Showing a) layer of translucent microfill composite b) teasing off the composite veneers c) polishing and adjustment d) light curing of composite veneer post etching and bonding agent application*

III.C) According to the material used (4)



<u>Dental Resin Composite</u> (5)

Resin-based composites are restorative materials that have mainly the following three compositions: 1) resin matrix 2) inorganic filler 3) coupling agent. The most commonly used monomer in the resin is Bis-GMA which has a higher molecular weight than methyl methacrylate resins. Therefore, the polymerisation shrinkage of Bis-GMA (7.5%) is significantly less than that of methyl methacrylate resins (22%).

The bonding between the resin and the filler is achieved by the use of coupling agents i.e. salines, the most commonly one that is used in resin composite is γ- MPTS.

New generations of composites are introduced by the dental company through the years, aiming for better aesthetic and physical properties as nanosized particles (nanomers 20-75nm and nanoclusters 0.6 µm). This small sized nanoparticles with high filler loading (80%) improved mechanical properties (flexural strengths, elastic modulus, fracture toughness and hardness), reduced polymerization shrinkage, high translucency, better polishability and gloss retention.

- **Advantages**
    - It can be used directly, resulting in less chair time.
    - Composite veneers do not require heavy preparations. Therefore enamel can be preserved for good adhesion.
    - Easier to repair than ceramic veneers
    - Lower cost than ceramics.
- **Disadvantages**
    - Prone to discolouration and wear.
    - The clinician skills in placing, finishing and polishing of the composite plays a major factor in the aesthetic outcome.
    - Needs to be replaced more frequently than ceramic veneers.

Dental Ceramics

1. **Feldspathic veneers** (6, 7)

Composition and microstructure:

Feldspathic porcelains are composed mainly of feldspar (potassium aluminum silicate and sodium aluminum silicate as glassy phase (55–65%) responsible for the translucency of the restoration and silica as crystalline phase. Feldspar is a greyish mineral that can be found in rocks rich with iron and mica.

Properties

Feldspathic porcelain provides great aesthetic value and demonstrates high translucency, just like natural dentition.

Feldspathic porcelain’s mechanical properties are low, with flexural strength usually from **60 to 70 MPa**. Due to the nature of the glass matrix materials and the absence of core material, the veneering porcelains are much more susceptible to fracture under mechanical stress.

Clinical considerations:

Good bond, in combination with a stiffer tooth substructure (enamel), is essential to reinforce the restoration. Currently, requests for less-invasive treatments and higher levels of aesthetics have enhanced the indication of feldspathic veneers.

It is possible to have a thickness of less than 0.5 mm, with or without preparation in the enamel.

Advantages (5)

- Could be used in **very thin** thickness so it can be almost translucent which result in an appearing natural restoration.
- It requires **minimal tooth preparation**. Therefore enamel can be preserved.
- It is possible to etch feldspathic porcelain with hydrofluoric acid which gives a great bonding strength to the remaining enamel.

Disadvantages.

- Layering method is technique sensitive
- Masking heavy discoloured teeth can be difficult because the porcelain is very thin and highly translucent.

Fabrication method:

- By using a **layering and firing process**, ceramists developed veneers that could be made as optically close to natural teeth as possible.
- **CAD/CAM** method
  - VITABLOCS® are the most used feldspar-based CAD/CAM ceramics with an average grain size of 4µm and flexural strength of **154MPa.**
  - VITABLOCS® TriLuxe (2003) and TriLuxe forte (2007). VITABLOCS® TriLuxe includes three, while TriLuxe forte four layers of different shade intensity from the cervical to the incisal edge, especially suitable for veneers.
  - VITABLOCS® RealLife (2010), multichromatic feldspar ceramic with different colour intensity in three dimensions

2. Synthetic glass-based ceramics (6)

Composition and microstructure:

The glassy phase possesses the usual properties of glass such as translucency, brittleness and non- directional fracture pattern. The crystalline phase improves light scattering and opacity, and provides the ceramic material with strength and stability.

The crystals are "artificially" created by controlled nucleation and crystallisation. The size and distribution of the crystals are determined by the composition and processing of the base glass and the subsequent heat treatment. This process allows “tailor-made” materials to be produced, which exhibit homogeneous structure, good optical properties, appropriate wear characteristics, as well as optimal strength.

Increased strength in glassy ceramics is achieved by adding appropriate fillers that are uniformly dispersed throughout the glass, such as leucite, lithium disilicate, zirconia, and fluorapatite. (6)

- **Leucite-reinforced ceramic** (IPS Empress CAD, Ivoclar Vivadent) consists of leucite crystals (35–45 vol%) that are homogeneously distributed into the glassy matrix.

Properties

Due to the high silica content (60–65 wt%) this ceramic has improved translucency, fluorescence and opalescence, while the crystalline content is responsible for the flexural strength of **160 MPa** and ability to absorb the fracture energy that results in arrested or slowed down crack propagation.

- **Lithium disilicate ceramic** (IPS e.max CAD, Ivoclar Vivadent) is comprised of approximately (70 vol%) of crystalline phase incorporated in the glassy matrix. Which are randomly-oriented, densely distributed, elongated fine-grained lithium disilicate crystals (1.5 µm in length)

Properties

It has excellent mechanical properties and fracture toughness. Flexural strength **360 ± 60 MPa.** It also has a high esthetic due to the relatively low refractive indices of the crystals and good bonding strength.

- **Zirconia-reinforced lithium silicate** is glass-ceramic material enriched with highly dispersed zirconia (Celtra Duo and VITA Suprinity®). The crystalline phase consists of 25 % lithium metasilicate (Li_2SiO_3) and 11% lithium disilicate ($Li_2Si_2O_5$) crystals. zirconia (8–12 %) acts as a nucleating agent but remains dissolved in the glassy matrix.

Properties

Flexural strength of **370-420 MPa** after glazing, due to the lithia and particularly zirconia content.

Zirconia reinforced lithium silicate shows higher translucency when compared to lithium disilicates due to the addition of zirconia that ensures nucleation process, resulting in more homogenous, finer crystals of size (0.5 μm) compared to the needle-shaped coarser crystalline structure (1.5 μm) of lithium disilicate glass- ceramic. (8)

Moreover, natural opalescence & fluorescence are achieved. As crystallites have size of 0.5- 0.7 μm corresponds to the wavelength range of natural daylight thus mimicking the opalescence behaviour of the tooth enamel, and together with the high glass content are responsible for the fluorescence of the restoration.

Fluorapatite glass-ceramics (IPS e.max Ceram and IPS e.max ZirPress, Ivoclar Vivadent) contain fluorapatite crystals $Ca_5(PO_4)_3F$ in various sizes embedded into the glassy matrix. The crystals, responsible for material's opalescence.

Properties

The flexural strength is approx. **120 MPa**.

The flexural strength of IPS e.max Ceram is significantly lower than IPS e.max ZirPress due to the pores present in the material, result of an air-bubbles' incorporation during mixing the ceramic powder with the mixing liquid (due to different fabrication methods).

Fabrication method:

IPS e.max Ceram is a nano-fluorapatite layering ceramic in the form of a powder, used for the production of veneers or as veneering material for glass or oxide ceramics.

IPS e.max ZirPress are pressable ingots suitable for the production of veneers and veneering of zirconia substructures using press-on-zirconia technique.

3. Glass-Infiltrated ceramics (7)

Composition and microstructure

The glass-infiltrated ceramics belong to a group of ceramic-glass interpenetrating phase composites as they have at least two interpenetrating phases intertwined throughout the material. The porous ceramic skeleton is infiltrated with lanthanum glass in a second firing, thus increasing the strength of the restoration. (VITA In-Ceram^{TM} SPINELL).

Properties

Flexure strength (**400 MPa**) with very high translucency.

Fabrication method

The ceramic material is fabricated utilising **the slip-casting** or **CAD/CAM** technique.

N.B. The use of this class of materials is abandoned due to the complexity and sensitivity of the manufacturing process, as well as the increased popularity of lithium disilicate ceramic.

4. Cubic (Ultra-translucent) Zirconia (7)

Composition and microstructure

Utra-translucent multilayer katana Zirconia blocks

The material shows nano sized crystals with grain sizes ranges from 50 nm to 400 nm contains approximately 95 wt. % ZrO_2 and 0.11–0.26 wt. % Al_2O_3.

Advantages

- The flexural strength approx. **557 MPa**
- It is more translucent than tetragonal zirconia. This is due to the isotropic optical properties of cubic crystals that enable a more uniform transmission of light, in addition to reducing the amount of alumina in the material and decreasing grain size.

Hybrid (Resin-Matrix Ceramics) (7)

1. Resin nanoceramic

Composition and microstructure

Lava Ultimate from 3M ESPE has been marketed as ‘Resin Nano Ceramic’ (RNC) as it contains 80% by weight nanoceramic particles (nanomer 4-20 nm in diameter and nanocluster 0.6-10 μm particles) bound in a highly cross-linked polymeric matrix. Both nanomers and nanoclusters are treated with a silane coupling agent so that chemical bonds can be provided between ceramic particles and the resin matrix. The material is processed several hours in a special heat treatment process, which results in highly cured material, so there is no need of further firing after milling.

Properties

Flexural strength (**200 MPa**)

Resin Nanoceramic has flexure strength, fracture strength and wear resistance higher than composite materials (provided by nanoclusters), and with significantly improved polishability and optical properties.

The polymeric resin as a matrix contributes to some properties that composites have: the material is not brittle and is fracture resistant, with shock absorbing characteristics.

2. Polymer Infiltrated Ceramic Network (PICN).

Composition and microstructure

VITA Enamic has two 3- dimensional network structures interpenetrating one in another; the dominant fine-structure feldspar ceramic network (86 wt %) is strengthened by a polymer network consisting of methacrylate polymer (14 wt %). Both of the networks are interconnected through the chemical bonds obtained by the coupling agent.

Properties

The flexural strength of this two-phase material can reach a value of about **150–160 MPa,** significantly higher than that of a porous ceramic (below 30 MPa) and polymer (135 MPa) alone.

3. Flexible Nano Ceramic

Composition and microstructure

CERASMART from GC, referred to as “Flexible Nano Ceramic”, as it has the highest flexural strength in its category. It is composed of nano-sized, uniformly distributed particles of alumina-barium-silicate embedded in a polymer matrix.

Properties

The flexural strength is approx. **242 MPa**

Advantages of hybrid resin matrix ceramics:

- All hybrids have a modulus of elasticity similar to dentin
- Resilience is significantly higher than feldspar-based and glass-ceramics, thus significantly higher energy can be absorbed without permanent deformation or failure.
- Milling time in the CAM unit is shorter compared to other ceramic materials,
- Longer lifetime oF the milling burs.
- There is no need for sintering or crystallization firing after milling.
- Final gloss and smoothness of the restoration can be achieved by surface polishing.
- Hybrids are wear resistant and “gentle” to the opposite dentition
- Restorations can be easily repaired in the mouth, although these materials are characterized by virtually no chipping.

IV. Advantages of ceramic veneers (9)

- **Color:** Porcelain offers natural look and more color stability.
- **Resistance to abrasion**: Porcelain is exceptionally high wear and abrasion resistance as compared to composite resins.
- **Strength:** Porcelain veneer restorations develop high shear and tensile strengths.
- **Periodontal health**: Highly glazed porcelain surface resists plaque accumulation thus maintaining periodontal health

V. Disadvantages of ceramic veneers (9)

- **Cost:** It has higher cost than direct composite veneers
- **Time**: Veneering is a highly technique sensitive procedure and require multiple visits.
- **Brittleness:** Veneers are extremely brittle and difficult to manipulate during try-in and cementation stages.
- **Repair:** difficult once veneers are cemented to the enamel.
- **Color:** is difficult to modify once the veneer has been cemented to the enamel surface.

VI. Treating the Fitting Surface of the Veneer

The enhancement of bonding through modifying the internal veneer surface is advocated in order to increase the intimacy of the bond; this may be achieved by different methods. The aim of pre-cementation surface modification is to increase the surface area available for bonding and to create irregularities that increase the strength of the bond to the resin luting cement.

The treatment of the veneer fitting surface is different according to its composition.

A. Surface treatment of resin composite veneers:

Roughening the internal surface of indirect resin composite veneers with **sandblasting** or a **diamond bur** is effective to create micro-mechanical retentions. This is followed by cleaning with alcohol.

B. Surface treatment of glass based veneers and Silanization (6)

Feldspathic ceramic, leucite, lithium disilicate, and zirconia-reinforced ceramic. All of these must be conditioned with hydrofluoric acid and silane. Acid conditioning with hydrofluoric acid dissolves the glassy matrix surrounding the crystalline phase,leaving retentive areas between the acid-resistant crystals. It also allows a micro-mechanical bond with resin cement. Moreover, it is efficient in removing superficial defects and rounding off the remaining flaw tips, thereby reducing stress concentrators and increasing the overall strength. The difference between these systems is the period of acid conditioning with hydrofluoric acid.

N.B. The acid should be thoroughly cleansed with air–water spray and ultrasonic distilled water bath for 5 minutes to remove any residues remaining on the surface then dried before silanization step. (10, 11)

Silanization of etched porcelain with a bifunctional coupling agent provides a chemical link between the luting resin composite and porcelain. A silane group at one end chemically bonds to the hydrolyzed silicon dioxide at the ceramic surface and a methacrylate group at the other end copolymerizes with the adhesive resin.

Restorations are dried and silane primer is applied to the fitting surface, which helps provide a chemical covalent bond to the ceramic.

C. Surface treatment of cubic zirconia veneers

Since cubic zirconia is a polycrystalline structure, it cannot be etched by HF as it shows less effective adhesion when compared to silica-based ceramics. Hence, other surface treatments have been offered to modify its surface and optimize the adhesion to resin cements such as; gritblasting with aluminum oxide, and etching with hot strong acids to produce surface roughness, or tribochemical silica coating followed by silanization aiming to obtain chemical bond.

N.B. Thorough cleansing should be done after surface treatment with air–water spray and ultrasonic distilled water bath for 5 minutes to remove any residues remaining on the surface then dried before silanization step. (10, 11)

D. Surface treatment of hybrid ceramic veneers

Most of the currently available in vitro studies revealed that hydrofluoric acid etching with silane application are the ideal pretreatment. The hydrofluoric acid partially dissolves the glass phase and provides micromechanical interlocking with the composite cement.

VII. Tooth preparation

The preparation of teeth greatly influences the durability and color of the ceramic restoration, since the tooth preparation will determine the inner superficial contour and the thickness of the ceramic material. This stage is determined by the tooth condition, the indications of the clinical situation, and the chosen material. Although early concepts suggested minimal or no tooth preparation, current belief supports removal of varying amounts of tooth structure. Enamel reduction is required to improve the bond strength of the resin composite to the tooth surface. In doing so, the aprismatic surface of mature unprepared enamel, which is known to offer only a minor retention capacity, is removed. In addition and when possible, care must be taken to maintain the preparation completely in enamel to provide an optimal bond with the porcelain veneer. Although the results of the newest generation dentin adhesive systems are very promising, the bond strength of porcelain bonded to enamel is still superior when compared with the bond strength of porcelain bonded to dentin. Thus, one of the main objectives of the technique is to maintain the entire contour in intact enamel whenever possible, because the better the adhesion between the veneer and the prepared tooth, the better the stress distribution in the system enamel–composite–ceramic.

VIII. Treatment of Tooth Surface (Enamel and dentin)(2)

The enamel surface must be conditioned with phosphoric acid (37%) for 20 seconds. This procedure increases the surface energy of the enamel structure and surface roughness, which leads to a perfect wetting of the surface with the bond.

Incase of exposed dentin within the preparation, sealing this structure with a dental bonding agent is suggested immediately after the completion of tooth preparation and before the final impression, because the newly prepared dentin is ideal for the adhesion. This technique is called "**resin-coating technique**," . it is done by adding a layer of low viscosity resin on the dentin immediately after tooth preparation. This procedure increases the **bond strength** and reduces **crack formation**, **bacteria infiltrations**, and **postoperative sensitivity**. Moreover, it allows enamel acid conditioning while avoiding the conditioning of the dentin.(6)

IX. Cementation (4, 6)

The success of the porcelain veneer is greatly determined by the strength and durability of the bond formed between the three different components of the bonded veneer complex: the tooth surface, the porcelain veneer, and the luting composite.

For cementation of porcelain veneers, a **light-curing luting composite** is preferred. A major advantage of light-curing is that it allows for a longer working time compared with dual- cure or chemically curing materials. This makes it easier for the dentist to remove excess composite prior to curing and greatly shortens the finishing time required for these restorations. In addition, their color stability is superior compared with the dual-cured or chemically cured systems.

Nevertheless, it is important that there is enough light transmittance throughout the porcelain veneer to polymerize the light-curing luting composite. The porcelain veneer absorbs between 40% and 50% of the emitted light. The thickness of the porcelain veneer is the primary factor determining the light transmittance available for polymerization. The color and the opacity of the porcelain would have less influence on the amount of absorbed light.

The opacity of porcelain became more important for facings with a thickness of 0.7 mm or more. Consequently, the presence of a porcelain veneer increases the setting time of the resin composite used beneath the veneer.

In case of porcelain with a thickness of more than 0.7 mm, light-cured resin composites do not reach their maximum hardness. A dual-cured luting composite, which contains the initiation systems for both chemically and light-cured composites, is advisable in these situations. With these latter luting agents, a stronger bond can be obtained with the porcelain. Furthermore, higher values of hardness were reported for the dual-cure resin cements than for the light-cured luting composites, because of their higher degree of polymerization.

X. **Clinical Evidence** (4)

The success rate of Ceramic Veneers has been clinically evaluated through a time range up to 20 years. The rate of success reported in these studies varies between 75% and 100%. Fracture, microleakage, and debonding are types of failures seen in Ceramic Veneers. (12-15)

Burke et al reported that survival rates of CVs are **rarely 100%**. The preparation of the teeth greatly influences **the durability** and **color** (translucency and tonality) of the ceramic restoration.

Veneer **preparation into dentin** adversely affects survival.

Tooth preparation will determine the **inner contour** and the **thickness** of the ceramic material.

A veneer requires a minimum of 0.1 mm to 0.3 mm of thickness for each shade change, thus affecting the amount of reduced tooth structure. (16)

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