Microleakage in Composite Resin Restoration- A Review Article

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ABSTRACT

BACKGROUND

The most important feature that a material must have is sufficient, long term sealing of the restorative margins. No restorative material developed to date is completely adhesive to the tooth structure. Every restorative material allows some degree of passage of fluids and micronutrients through it. It is termed as Leakage. By definition Micro leakage is "the clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material". It is the flow of a substance into a defect at the interface of restoration and tooth margin. Marginal leakage around restorative margins has been a concern with various clinical conditions. It includes quickening of the breakdown and dissolution of restorative materials. Marginal staining leads to collapse of margins, compromise in aesthetics and with time the need to substitute the restoration. Microleakage depends on several variables like dimensional change of restorative material mainly because of thermal contraction, polymerisation shrinkage, water sorption, mechanical stresses and dimensional changes of tooth. Almost all microleakage studies suggested that the majority of the materials accessible currently leak meaning that they allow penetration of dyes, radioisotopes, or bacteria. Microleakage can be calculated by various in vitro methods with or without thermocycling like staining, SEM, chemical agents, neutron activation analysis, ionization, autoradiography, radioisotope, and reversible radioactive adsorption. Reducing the marginal leakage and enhancing the marginal adaptation involves various factors like choice or combinations of materials, use of cavity liner or base, cavity design or configuration factor changes, acid etching and bonding, technique of restoration placement, direct or indirect techniques, sealing the marginal gaps, and different curing strategies. This article describes in depth the knowledge about various aspects of leakage such as sequelae and causes of microleakage, methods of detection of microleakage in vitro as well as clinically, and the measures taken to reduce or decrease the microleakage when restoring tooth with resin-based restorations.

KEY WORDS

Microleakage, Marginal Leakage, Composite Resin

BACKGROUND

The objective of restorative dentistry is to eliminate carious tissue and bacteria, and to fill the cavity with a suitable restorative material. It helps to re-establish the aesthetics and functionality of tooth.[1] Instead of gold and simply lathe cut amalgam, the pool of existing restorative materials has been extended to include flowable or packable composites, hybrid, macrofilled or microfilled or RMGIC and compomers in various viscosities. Superior aesthetics and shade-matching properties, with good strength have made Resin composites been widely used as preferred material in dentistry. The clinical achievement of a material depends on its durability in the oral environment.[2] Dentist thrive for achieving biocompatibility of restorations that will not be detrimental to pulp and also preserve the three dimensional seal.[3] The efficacy of restorative materials to seal cavity margins against the entrance of salivary constituents is of great importance. As early as in 1933, Fish showed that normal dentin would permit the inflow of dyes inside the dential tubules of human teeth.[4] The most important feature that a material must have is sufficient, long term sealing of the restorative margins. No restorative material developed to date is completely adhesive to the tooth structure. Every restorative material allows some degree of passage of fluids and micronutrients through it. It is termed as Leakage. On the other hand, the literature varies in terms of leakage. Various level of leakage are mentioned, like clearly clinically and non-clinically detectable leakage, but with improper adaptation. This "hidden leakage" is known as "microleakage". By definition Microleakage is "the clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material". It is the flow of a substance into a defect at the interface of restoration and tooth margin.[5] Leakage is associated with incursion from outer surroundings from the boundaries of restoration, although leakage may also occur from within. In the newer studies, newer form of leakage i.e. nanoleakage, have been introduced.[6] The term 'Nanoleakage' is category of leakage that occurs within dentinal boundaries of restorations. There is transport of fluid through resins and is visible only by advanced SEM techniques.[7]

Sequelae of Micro Leakage

Marginal leakage around restorative margins has been concerned with various clinical conditions. It includes quickening of the breakdown and dissolution of restorative materials. Marginal staining leads to collapse of margins, compromise aesthetics and with time the need to substitute the restoration.[8] These detrimental effects are owing to the bacteria, their nutrient products or hydrogen ions, that originate from plaque that leach out in the interfacial space.[9] The diffusion of organisms and the presence of a crevice also causes sensitivity on stimulus. Secondary caries can occur at every plaque retention site.[8] Secondary caries are very common and comprises of 40-70% of dentists' most common reasons for doing replacement of composite restoration.[9] Oral bacteria like Streptococcus mutans grow in the gap surrounding the restoration in a limited phase of, plaque retention site or smear layer. Later the bacteria and their noxious by-products can now spread through dentinal tubules and subsequently cause inflammation of the underlying Pulp.[10] Fluids within the margins causes hydrolytic degeneration of the resin along with collagen inside hybrid layer and therefore compromises the solidity of adhesive bond.[11] One of the other clinical consequence is cuspal deflection and increase chance of enamel fracture.[12]

Causes of Micro Leakage

Microleakage depends on numeral of variables like dimensional change of restorative material mainly because of thermal contraction, polymerisation shrinkage, water sorption, mechanical stresses and dimensional changes of tooth.[13] The main reason is inadequate adaptation at tooth and restoration interface. The contraction forces are created due to polymerization shrinkage of resin that leads to disruption of bond to cavity walls, leading to microleakage.[14] Shrinkage means densification or volume loss. The formation of macromolecules during light curing is associated with the shrinkage of the organic material that is being polymerized; hence intermolecular distance (Van Der Waals distance) of a monomer ranges from 0.3 nm to 0.4 nm. When the material polymerizes, a 0.15 nm long covalent bond forms, resulting in a 2 % decrease in intermolecular distance. This volumetric contraction of the composite material compromises the integrity of the composite resin-tooth interface, and can lead to the gap formation.[15] Newer composite resins shows volumetric contraction in range of 2.6% to 4.8 %.[16] Although the contraction stresses generated due to polymerisation shrinkage (13-17 MPa) may result in marginal opening.[17]

Adhesive failure results in loss of marginal seal, creating a gap between the tooth and the restoration. The type of cavity may also affect the integration of the restorative material to the boundaries of cavity. Undeniably, the Configuration-factor of cavities is also one of the major factors, mostly with a composite resin.[18] In class II composite restoration common occurrence is at gingival margins. This is because of loss of enamel at the margins of the gingiva, leading to a unstable interface for bonding.[19] The direction of the tubules may alter the superiority of hybridization thus enhancing leakage.[20] It is suggested that the micro-cracks and fractures present in enamel lead to microleakage after polymerization of composite resin.[21] Another causative factor is the coefficient of thermal expansion.[22] Guzman and co-workers reported that the occurrence of leakage or " marginal percolation" ascends with theory that mismatch between coefficients of thermal expansion of tooth and restorative material. The coefficient of thermal expansion of tooth is less as compared to composite resin.[23] Lastly, along the walls of a cavity there occurs micro movements of the restoration due to difference in elastic modulus also contribute to the bond failure which promotes leakage.[24]

Other probable cause for microleakage are based on orientation of dentinal tubule to the cervical wall (CEJ), organic matter of dentine and fluid movement among dentin, improper alteration or incomplete removal of smear layer. Also, inefficient infiltration of primer into the collagen fibres which are demineralized after etching, hydration level of dentin substrate, partial evaporation of the solvent, incompatibility of the composite with respective or particular dentin bonding agent, source of polymerization - incompatibilities with photo initiator and instrumentation.[3]

Microleakage can also occur because of poor marginal intimation of the restorative material and restoration to the

walls of the cavity. The leakage pattern in teeth is influenced by the material that is used to restore the teeth as well as by the operator's care in placing the material. Poor manipulation, filling and condensing of materials promotes dimensional changes on polymerization. Microleakage around such restorations penetrates the margins nearly unrestrictedly.[25]

Measurement of Microleakage

About all microleakage study suggested that the majority of the materials accessible currently leak meaning that they allow penetration of dyes, radioisotopes, or bacteria. These all penetrate through enamel margins, dentin and subsequently to pulp. In vitro studies result put a question around the amount of leakage which may or may not either happen in vivo. Usually, there is difference between the degree of microleakage found in study and the clinical success of a material. Though, if a material is placed in vitro do not exhibit microleakage, there are superior chances of clinical success as compared to leakage in vitro.[26] Various laboratory techniques have been introduce to study microleakage tooth- restoration interface. Microleakage can be calculated by various in vitro methods with or without thermocycling like staining; SEM; chemical agents; neutron activation analysis; ionization; autoradiography; radioisotope and reversible radioactive adsorption. The outcome of most of the studies highlight that the margins of the restoration are not predetermined, inert and impassable boundaries, excluding 'dynamic micro-crevices which enclose a busy traffic of ions and molecules' (Myers, 1966).[27] Most common method is dye penetration. The teeth are sectioned following immersion in dye and seen under microscope. This technique is lesser reliable than the three-dimensional techniques. This method is mostly qualitative. A quantitative method is a practical method to demonstrate the outline of dye permeation and may specify where the leakage occurs. Thus, it was concluded that so far, no available method is gold standard.[28,29]

Methods to Reduce Microleakage

Reducing the marginal leakage and enhancing the marginal adaptation involves various factors like choice or combinations of materials, use of cavity liner or base, cavity design, acid etching and bonding, technique of restoration placement, direct or indirect techniques, sealing the marginal gaps, and different curing strategies.

Choice of composite material- It was observed that microleakage in light-activated composites was more as compared to chemically-activated resins. The chemical-activated resin composites polymerize more slowly compared to light cure, thus a higher capacity to flow at the time of longer gel stage and, generating lesser stresses on development of the adhesive bond. [30] Microfilled composite resins provide a better marginal adaptation compared to macrofilled composite resin restorations. This can be attributed to the greater flexibility of the microfills during polymerization shrinkage that decreases the contraction forces. Also, microfilled shows more absorption of water resulting in expansion which counteracts the polymerization shrinkage. Nanocomposites have been introduced and the polymerization shrinkage of the nanocomposites is less than that of the conventional composite and they show higher elastic modulus than those of universal and microfilled composites.[31] Greater depth of cure was achieved in silorane-based posterior composite than in methacrylate-based posterior composite resins.[32]

Cavity Design

Cavity designs for composites should be as conservative as possible to overcome the disadvantages of polymerization shrinkage. Modified cavity designs, placement of bevels, reduced depth and rounded internal line angles are very effective in providing good marginal adaptation and reducing microleakage. The role of bevels on cavosurface margins in reducing microleakage remains controversial. Bevelling provides exposed enamel rod ends to be obtainable for bonding. Bowen et al. found that the bevel compensates for polymerization shrinkage. This might be because bevel increases the surface area of cut enamel thereby making it more tough for fluids to permeate in the restoration-tooth interface. The enamel margins when bevelled it produces oblique sections of prisms, and the strength of the bond between enamel and resin increases. Also, the bevel area is more tightly bonded to resin which reinforces the enamel margins, resulting in an decrease in polymerization shrinkage in this area. On the contrary Retief et al. found no advantages of bevelling to reduce microleakage in anterior teeth, while various other have reported less leakage with the tooth having bevel.[33]

Configuration Factor

The preparation factor that is "Configuration-factor" may affect stress on posterior composites restorations. It is defined as the "ratio of the bonded to the unbonded surfaces of a cavity preparation".[34] Higher "C-factor" is suggestive of a higher potential for bond disruption because of the forces acting from polymerization shrinkage, which result in formation of gaps and, therefore leakage.[35] Highest C-factor is possessed by Class 1 cavity; therefore, they have the increased tendency for the unfavourable effects of polymerization. Other cavity preparations have low "C-factor" and thus, dispose the restoration to lower risk for breakdown. Though C-Factor for class 1 cavity was high (five), they exhibit less leakage compared to Class II cavities. The Class II (MOD) cavity shows a "C-factor" of 3. From the above values, it seems that not only the configuration of cavity, but the bonding surfaces that is enamel and dentin or cementum also influence microleakage.[36]

Use of Cavity Liner or Base

To minimize the stress factors in resin composite restoration, the layer of a flexible material is placed in between the restoration and cavity walls to amplify the compliance of bonding substrate. Along this low elastic modulus layer, the stress distribution is more even and uniform. This technique of using intermediate layer of low viscosity flowable material is called elastic cavity wall and it helps to reduce microleakage[37] The commonly used materials as intermediate layers are glass ionomer, self-cure composite resins, and flowable composites.[38] Simi and Suprabha stated that the marginal integrity of a composite is enhanced when used along with a flowable composite. Chuang et al stated that microleakage is significantly reduced when a thin 0.5–1.0

mm layer of flowable composite liner is used under packable or condensable composite. A composite of low viscosity can be used as a liner. The injectable composite recently entered into field of aesthetic dentistry has claim to have a low modulus of elasticity and prepolymerised filler i.e. organic fillers along with inorganic fillers. The prepolymerised fillers decreases the volumetric shrinkage by increasing the accessible sites for composite flow with no effect on mechanical properties.[39] The glass ionomer‑composite resin interface bond is found to be stronger than the glass ionomer‑dentin bond. Hence, cement liner tends to detach from the dentin wall during polymerization shrinkage process.[40] Consequently, few researchers advise against practicing glass ionomer as an intermediate liner.

Bulk vs Incremental Curing

Many investigators attribute the reduced polymerization shrinkage to the incomplete polymerization of the composite at a deeper layer. The incomplete polymerization leads to compromised mechanical properties and leaching of monomer. Eakle and Ito concluded that the incremental curing was more efficient than bulk curing in controlling microleakage. The other investigators like Coli et al, and Manuel et al. Found no influence incremental or bulk filling technique on microleakage. [38] Oblique layering method with increments of 1 to 1.5 mm in depth of wedge- or triangle-shaped causes lowest C factor and decreases stress formation. The incremental placement techniques (occluso‑gingival, oblique, facio‑lingual, or U‑oblique) have been recommended because they may reduce polymerization shrinkage stress due to; (1) the small volume of material that is polymerized at one time, (2) the reduction in the cavity configuration factor, and (3) the minimal contact of the restorative material with the opposing cavity wall during the polymerization process.[41] Although it is generally accepted in the literature that the incremental placement techniques are desirable, the role of these techniques in reducing interfacial stress build‑up in composite restorations has been questioned previously.[42] In a study using finite element analysis, it was observed that all the incremental techniques for the placement of resin composite restorations (occlusal‑gingival, oblique, U‑oblique, and facio‑lingual) caused more inward deformation of the cavity walls compared to the bulk placement technique. The incremental placement techniques resulted in cavities that were volumetrically filled with less composite resin compared to their original volume. It might be due to the fact that increased cavity wall deformation in an incrementally‑placed resin composite restoration resulted in a more stressed tooth‑ restoration complex compared to the bulk‑placed restoration. Therefore, any benefits of placing resin composite restorations in increments may get cancelled by the progressive deformation of the cavity wall. Although the incremental placement of resin composite has obvious benefits including thoroughness of light polymerization, allowing bond maturation, and ease of adaptation; its role in the total stress relief has not been demonstrated. polymerization shrinkage occurs immediately after light activation.[41] 70% to 85% of the shrinkage could occur immediately after polymerization while up to 95% only occurs after 5 minutes. From this it becomes evident that as polymerization shrinkage of the last increment occurs,

considerable strain could still be under way from the first layer. Therefore, the combined simultaneous shrinkage of the different layers may result in much more shrinkage stress compared to the shrinkage stress from a single bulk cured layer.[42] The thought that a successive increment can compensate for polymerization shrinkage could only be applicable if the additional increment is placed in all areas where volume reduction had occurred. The least microleakage values were seen in incremental technique and the more values with bulk placement technique. Since none of the placement techniques could totally eliminate microleakage, additional measures that could reduce microleakage such as application of a surface sealer or a layer of dentin bonding agent over the restoration margins would be beneficial.[43]

Curing Modes and Direction of Light Source

A current method planned to diminish shrinkage stress includes to reduce the initial conversion by means of using various curing modes. A sudden increase of intensity over a given phase of time in ramped or soft start curing technique provide the slightest shrinkage stress and potentially the optimized polymerized state.[9]

Pre-Polymerized Composites

Recently available quartz-beta glass ceramic inserts and pre-polymerized composite inserts in the mass of restorative material is one of the methods to decrease polymerization shrinkage. The most powerful factors for microleakage is the alternating contraction and expansion of the restorative material when subjected to variation in temperature. Also using a precured composite insert decrease the quantity of uncured composite within the restoration, thus reducing the largely the polymerization shrinkage and its stress. Additionally, the placing the pre-cured composite insert within a cavity already partly filled with composite may have enhanced the adaptation of the composite to the walls of cavity.[44] Glass and polyethylene fibers helps in reinforcement of composite restorations. A lesser amount of polymerization shrinkage can be obtained if the whole of composite material in class II restoration is reduced. The Insertion of polyethylene fibers in composite restoration can diminish the total amount of resin matrix necessary for restoration and lessen the shrinkage as well as microleakage.[45]

Finishing and Polishing

Finishing and polishing do affect the marginal integrity of resin restorations. Finishing and polishing procedures helps to maintain the seal of the restoration and prevent the microcracks. Finishing techniques and their timings have shown to affect the ability of restorative materials to resist leakage. Most of the authors advocate finishing after 24 hours, until the polymerization is complete. If done before it seems to break the resin-tooth bond. If done before the initial setting, it seems to break the resin-tooth. However newer composites sets faster and thus can be finished at the same time after the restoration.[46]

Other Techniques

It was seen that additional film of hydrophobic resin significantly reduce the leakage of the universal bonding type

with the self-etch mode at margins of dentin, and have no consequence with the etch rinse mode. The etch rinse mode is more useful in the margins of enamel to that compared with the margins of dentin; and the Self etch mode provide improved results in the margins of dentin as compared to the enamel margin.[47] The 8th generation bonding agent shows less gingival microleakage in deep class II cavities when compared with 7th generation bonding agent.[48] To minimize polymerization shrinkage and increase the degree of conversion, multilayer technique is recommended for ultimate success of composite.[49]

Conditioning the Dentin Surface

Conditioning the dentin surface after acid etching with ethanol or chlorhexidine, can be effective in decreasing the leakage, especially over time.[50]

Re-Bonding of Composites

Re-bonding technique can substantially minimize marginal leakage of composite restorations when a flowable sealant is applied over cavosurface margins of finished restorations (Dickinson & Leinfelder). These materials enter into the structural micro-defects and marginal gap by capillary action which seal them and thus improving marginal sealing. In addition, they would fill or repair the pores and structural defects formed during the finishing and polishing processes. These materials are commercially available in a range of monomer combinations, including BisGMa, TEGDMA and UDMA.

Immediate Dentinal Sealing

Marginal sealing is crucial for long-standing success of direct or indirect restoration. In disparity, adhesive breakdown at the restoration margins can affect the durability of a restoration. Studies have shown that although immediate dentin sealing improved bond strengths for adhesive, it did not decrease the marginal micro- leakage for restorations.[51]

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