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Review Article

Pitfalls and their prohibition in composite restoration – A review

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ABSTRACT

Composite is always a preferred material of choice over amalgam because of better esthetics and ease of manipulation. But polymerization shrinkage is one disadvantage of this material which needs to be discussed as it effects the longevity of the restoration. More polymerization shrinkage results in microleakage and eventually the failure of the restoration. Therefore, the present article is aim to discuss in detail the causes and prevention of microleakage for better understanding.

1. Introduction

Composite as the restorative material was proposed in 1960s because of their convincing esthetics, conservative preparation technique, good physical and chemical properties with their compliant manipulation technique. Following their introduction, they are the first material of choice for restoration and they have completely replaced amalgam as the restorative material. However, the performance of the composite restoration depends upon the polymerization of resin component within it as it causes polymerization shrinkage upon setting.[1] The polymerization shrinkage of composite resins develops due to the transition of monomer molecules to a polymer structure caused by the replacement of van der Waals forces with covalent bonds, leading to a less free volume.[1,2] At present, the market is swamped with a variety of composites such as bulk fill, nanofill, microfilled etc. but composite resins continue to suffer from polymerization shrinkage, which can cause stress at the interface of the material and tooth structure. If shrinkage stress surpasses the bond strength, a marginal gap forms and leakage occurs at the interface generating marginal leakage.[2] Microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules or ions between cavity wall and the restorative material.[3] When the gingival margin of a preparation is in dentin, the chances of the microleakage gets increased. In recent past, many materials have been brought in to improve marginal adaptation and reduce microleakage in composite restorations at the gingival margin.[2] Therefore, the objective of the present article is to discuss the pathway, causes and prevention of microleakage including choice of composites, different types of base and liners for marginal adaptation and techniques of restoration.

2. Route of Microleakage

Step 1: Cariogenic bacteria especially streptococcus mutans and hydrogen ions originated from plaque gets diffused in the tooth – composite interface if lacks marginal adaptation and triggers degradation of restorative material, the margins get disintegrated causing poor esthetics.[3–5]

Step 2: Upon entering, bacteria grow within the gap, produce more contaminated by-products and then spread through dentinal tubules and consequently induce inflammation of the underlying pulp.[3–5]

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Step 3: Fluids present within the margins stimulate hydrolytic degeneration of composite along with collagen inside hybrid layer and thus effect the integrity of bond resulting in secondary caries and furthermore chances of enamel fracture.[3–5]

3. Rationale of Microleakage

1. Structural modification **in** restorative material - Due to thermal contraction, polymerization shrinkage, change in temperature, exposure to moisture, increase mechanical load and dimensional changes of tooth.[6]
2. Inadequate marginal adaptation – Polymerization shrinkage in resin reduce bonding to cavity walls lead to microleakage. It occurs due to macromolecules form during light curing causes volumetric reduction by 2% or more and hence leads to compromised integrity of the composite resin with tooth interface causing microleakage. Use of improper bonding agent or technique also results in decrease bonding and microleakage.[7–9]
3. Cavity design – It may also affect the integration of the restorative material to the boundaries of cavity.[10]
4. Orientation of enamel rods and dentinal tubules - In deep class II cavities, the cavity margins correspond with gingival margins where enamel is generally absent that provides weak interface for bonding. Additionally, the direction of dentinal tubules may alter the hybridization process. The micro-cracks, defects and fractures present in the enamel lead to microleakage after polymerization of composite resin.[10,11]
5. Coefficient of thermal expansion **-** The coefficient of thermal expansion of tooth ($8\text{-}11\times10^{-6}$/°C) is less as compared to composite resin ($20\text{-}50\times10^{-6}$/°C).[3,11]
6. Modulus of elasticity **–** There is a significant difference in the modulus of elasticity in enamel (84,000 Mpa), dentin (18,000 Mpa) and composite resin (21,000 Mpa).[3]
7. Inefficient bonding agent and curing – Demineralized collagen fibres, hydration level of dentin, partial evaporation of the solvent, discrepancy between composite and particular dentin bonding agent, inadequate curing - less time, depth and contraindication with photo initiator and instrumentation.[3]
8. Restoration technique - The type of material used for restoration (Bulkfill, Nanofill, Flowable) and poor handling technique by the clinician.[1,3,5]

4. Prevention of M icroleakage

1. Choice of composite material- Light-activated composite has more polymerization shrinkage as compared to chemically-activated composite as the later polymerizes more slowly compared to light cure, thus less chances of microleakage.[2,3]
   Microfilled composite resins has more flexibility due to less particle size, less contraction as compared to macrofilled composite resin restorations. Additionally, microfilled has more tendency for water absorption resulting in expansion which counteracts the polymerization shrinkage. The polymerization shrinkage of the nanocomposites is less than that of the conventional composite and they show higher modulus of elasticity than those of universal and microfilled composites.[2–4]
2. Cavity Design – Conservative approach towards cavity preparation should be implemented always for composite. Bevelling of cavity margins in posterior restorations is recommended because it increases the surface area for bonding, enhances bond between restoration and tooth surface so making it difficult for the fluids to permeate through the tooth-restoration interface. Other than that, modified cavity designs, reduced depth and rounded internal line angles are also effective in providing good marginal adaptation and reducing microleakage. Many studies have reported higher leakage in dentin margins than enamel margins because dentin is less mineralized than enamel and contains more water content comparatively which makes it less favourable for bonding.[2,3,10]
3. Configuration Factor - It is defined as the ratio of the bonded to the unbonded surfaces of a cavity preparation. It is directly proportional to the polymerization shrinkage and hence more chance of microleakage if gets increased.[3] C-factor is an important aspect of cavity design because cavities with high C-factor have more shrinkage forces which cannot be eased by the flow of composite resin, resulting in the debonding of one or more walls.
4. Use of Cavity Liner or Base – Bonded base restorative technique - An intermediate layer of GIC or flowable composite or RMGIC is applied between the restorative material and cavity floor as the primary layer of the restoration. This layer soak up the stress caused and hence reduce the effects of polymerization shrinkage. Open sandwich technique - When GIC or RMGIC is used as an intermediate material and is left open at the margin.[2]Many studies have proved that the least microleakage was reported in the open‑sandwich technique if RMGIC is used as the material of choice for the intermediate layer because it has less modulus of elasticity so less polymerization shrinkage and lesser microleakge. Additionally, the less amount of composite volume in this technique also a major reason for less microleakage.[1,4,5]

5. Bulk vs Incremental Method - Incremental curing is considered more efficient than bulk curing because less volume is polymerized at once which reduces the bonded/unbonded ratio thereby reducing the configuration factor and hence lesser polymerization shrinkage. The polymerization shrinkage (70-85%) in composite restoration occurs instantly after curing while remaining happens post 5 minutes. Therefore, in incremental curing there is progressive polymerization shrinkage in one layer after another while in bulk fill there is simultaneous combined shrinkage in all layers which produce more shrinkage and more microleakage.[2,6,7] Various incremental techniques have been discussed in the literature namely horizontal layering, oblique layering, vertical layering, stratified layering, centripetal build up and many others. Horizontal layering technique increases the configuration factor which further causes greater polymerization shrinkage. Buccolingual incremental technique induces least strain because cuspal tension is minimized in this technique as composite is applied to a single dentin surface without touching the opposing cavity wall. In centripetal buildup technique, as an initial vertical composite increment is placed in contact with the matrix band, class II cavities are converted to class I cavities so lesser shrinkage. Any of the technique can be used by the clinician to reduce polymerization shrinkage and enhance the longevity of composite restoration.[12]
6. Finishing and Polishing - It aids in securing the seal of the restoration and prevent the microcracks. The composite resin is generally polymerized at the wavelength of 450-500 nm and the complete polymerization occurs in 24 hrs approximately. Thus, immediate finishing and polishing can deform the restoration as only 75% of the resin is polymerized which leads to the formation of microcracks, which hampers the marginal integrity. It is advised to do finishing and polishing after 24 hours as the polymerization is complete.[9,11]
7. Surface sealant and re - bonding – The surface sealant and bonding agent helps in creating a bond between restoration and tooth surface to close the gap and prevent microleakage of composite restoration. The bonding agent consists of monomers namely bisphenol glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA). These sealants when applied enter into the micro-gaps present between restoration and tooth interface through capillary action and repair the deformation or cracks formed post finishing and polishing.[3,11]
8. Curing Method and Modes – There is a direct relationship between polymerization shrinkage and the intensity of curing light, it means that the higher light intensity results in greater polymerization shrinkage when exposure time is constant as compared to lower light intensity. It is due to the greater degree of conversion of carbon double bonds into carbon single bonds. A newly introduced method named as soft-start mode of curing is the best alternative to deal with the polymerization shrinkage associated with the high intensity curing light. In this method, low light curing intensity is used initially which increase the time to reach the gel form and also increase the flow capability of the material. Afterward high intensities are used to achieve complete polymerization.[3,12,13] Now-a-days, light-emitting diode (LED) has replaced the conventional halogen lights used for the polymerization of resin composite restorations. LEDs possess several advantages over halogen-based curing units because it has long shelf life, more light efficiency, no filter is required, and having higher resistance to shock and vibration.[14]
9. Fillers in composite - The composition of the composite possess great influence on the polymerization process and the degree of the volumetric shrinkage. Furthermore, there is a direct connection between the increased number of fillers and reduction of polymerization shrinkage. Accordingly, the presence of pre-polymerized resin fillers particles decreases the volumetric reduction of polymerized resins and the subsequent polymerization shrinkage. The volumetric shrinkage of composite resins relies on influences namely the amount, type, and size of filler particles. Therefore, more the number of fillers in the resin matrix less chances of overall shrinkage of composite resins as lesser quantity of monomers are present in the resin for the curing reaction. But the greater number of filler particles adversely affect the modulus of elasticity of composite and can generate more polymerization shrinkage. It also not believed to be an efficient and appropriate approach to reduce the polymerization shrinkage rather chemical alteration is believed to be an alternative method through which the rate of polymerization shrinkage can be delayed and hence the subsequent chances of high polymerization shrinkage will be less.[14,15] In flowable composites, the filler content is less than the conventional composites so less shrinkage is reported in the latter. In homogenous micro-filled composites, the volume percentage of filler is less than 50 % with consequential shrinkage of 5%, whereas the shrinkage in heterogeneous micro-filled composite and hybrid composite is approximately similar which is reported to be 3% because of high volume percentage of i.e. 60% of filler.[16]

10. Degree of conversion of resin matrix - It indicates the number of double carbon bonds converted to single carbon bonds resulting in long-chain polymers. The volumetric shrinkage is directly proportional to the degree of conversion. The viscoelastic behaviour of the composite is determined via its modulus of elasticity and flow which in turn determines the polymerization shrinkage. The degree of conversion varies with different monomers based on its high molecular weight and initial concentration of double carbon bonds. TEGDMA is known to have higher degree of conversion than BIS-GMA. In conventional composites, the final degree of conversion is between 55% and 75%. As the degree of conversion increases, the modulus of elasticity of resin increases, which ultimately increases the shrinkage stress. Therefore, the degree of conversion is an important factor in determining the polymerization shrinkage.[13,16]

5. Conclusion

Polymerization shrinkage is an inevitable factor in composite since its introduction. Many advancements have been done and varied techniques have also been introduced to reduce its impact. The current article summarizes different types and techniques and other ways to reduce polymerization shrinkage and microleakage.

6. Conflicts of Interest

The authors declare that they have no conflict of interest.

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