Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

The Effect of Various Bleaching Agents on Surface Properties and Marginal Adaptation of Different Types of Resin Matrix Composites Restoration: A Review of Literature

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Bleaching treatments have always been one of the popular solutions for improving tooth aesthetics. The effects these bleaching treatments impart to composite restorations continue to be one of the most critical concerns in restorative dentistry. In this study, the action of different bleaching agents, hydrogen peroxide, and carbamide peroxide was investigated on the surface properties and structural integrity of composite restorations. Major parameters such as surface roughness, microhardness, and the tooth-restoration interface were evaluated. An electronic search of the MEDLINE/PubMed, EBSCO, and Web of Science databases was conducted. Conclusions: Bleaching agents affects the surface durability, physical properties and sealing adaptation of composite restorations.

Keywords: Surface roughness, Microhardness, Marginal adaptation, In-office vital bleaching, Resin composites.

1. Introduction

A considerable portion of restorative dentistry has been determined by aesthetic considerations. For numerous individuals desiring dental care, the shade and appearance of their teeth are essential concerns. The majority of individuals can now achieve lighter-colored teeth due to advancements in dentistry that have effectively preserved natural teeth, particularly in elderly patients.1 The bleaching procedure can be conducted at home by the patient, entirely under the dentist's supervision in the office, or through a combination of both methods. Besides these bleaching techniques, additional factors encompass the type of bleaching agent, the quantity and duration of application, and, more recently, the presence or absence of a light source.2

In-office bleaching employs a high concentration of hydrogen peroxide (ranging from 25% to 50%), which can be activated by a light source to improve and accelerate the bleaching process.3,4 The application of bleaching treatments may alter the clinical durability of dental composite restorations due to their chemical interactions. Bleaching agents adversely affect the surface morphology, chemical composition, and physical properties of dental restorative materials.5

Dental Composite

Ideal filling materials must have functional, aesthetic, and physical characteristics that resemble those of natural teeth. Over time, composite resins have outperformed traditional filling materials due to their ability to provide durability and aesthetic acceptance without compromising sound tooth structure and with little invasive preparation. Within each set of advantages and disadvantages, a variety of composite technologies were created, enabling dentists to select the system that best fit the clinical situation while simultaneously adding to their workload by requiring them to learn more about particular systems, their handling characteristics, and recommendations.6

Three fundamental components comprised resin composites: an inorganic filler, an organic matrix, and a coupling agent. For every composite system, the ratios of these elements were modified. The resin matrix contained monomers, stabilizers, initiator systems, and colors. Polymers like (bis-GMA) bisphenol-A-diglycidylmethacrylate and (UDMA) urethane dimethacrylate, along with fillers like glass, quartz, and colloidal silica, make up the majority of composites. Most of the mechanical properties of the composite resin were determined by both the matrix and the filler; for instance, the Bis-GMA component significantly enhanced polymerization shrinkage and color stability. However, the majority of the mechanical properties were typically determined by both the matrix and the filler.6 The durability against fracture was enhanced by the amount of inorganic loading by volume; the clinical and handling characteristics of a composite resin were greatly influenced by the type of filler used.7

Compositions of Dental Composites Resin

Resin composites consist of three components: inorganic particles enveloped by a coupling agent, distributed within an organic resin matrix.8 Inorganic Fillers: Composite strength is provided by these fillers. The size, shape, type, and volume of filler particles affect hardness, gloss retention, radio-opacity, fracture toughness, roughness, fracture behavior, elastic moduli, and water sorption. Different brands can have different filler compositions, such as silica, quartz, barium, zirconium, strontium, and others. The particle size of the filler can also be used to classify composites.9 Resin Matrix: In the resin matrix, organic monomers, photo initiators and inhibitors of polymerization, UV-stabilizers, as well as other components vary by manufacturer. Polymerization was used to convert organic monomers that were already in a fluid condition into rigid polymers.8

In dental resin composites, Bis-GMA is extensively used. Bis- GMA had a rigid bisphenol A core, which had a detrimental effect on the conversion degree, and strong hydrogen bonds produced by two hydroxyl groups, which caused the resin viscosity to be extremely high—

500–800 mPa. Because of its large molecular weight, BisGMA has greater mechanical properties and has little polymerization shrinkage than other monomers. Triethyleneglycol dimethacrylate (TEGDMA) seems to have a lower viscosity (100 mpa) than BisGMA due to the low molecular

weight structure and is often used as a diluent monomer in dental materials. Because TEGDMA was flexible and reduced BisGMA's stiffness, adding it to resins resulted in resins with a faster conversion rate but still enhanced water sorption as well as material shrinkage caused by the addition of TEGDMA to the resin formula.8 Although urethane dimethacrylate (UDMA) has a similar molecular weight to BisGMA, its viscosity is considered to be lower. The resin's ultimate properties are determined by the concentration and ratio of monomers used.10

As there was no chemical affinity between the resin matrix and the inorganic filler, a coupling agent was required to bind both the inorganic and organic phases (resinous matrix). Methacryloxypropyltriethoxysilane (-MPTS), a coupling agent, improves the inorganic particles' capacity to wettable interact with the organic phase. Methacrylate groups in the coupling agent copolymerized more with resin monomers during polymerization, increasing adhesion between the two phases and reducing deboning of inorganic particles, which impacted water absorption and wear resistance.8

Composite Resin Classification

-According to resin matrix.

1) Methacrylate based

Bisphenol Aglycidyl Dimethacrylate (Bis-GMA) is usually present in the resin matrix, but it is combined with triethelyneglycol- dimethacrylate (TEGDMA) because Bis-GMA has a high viscosity; the lower Bis-GMA, the higher the TEGDMA, resulting in more polymerization shrinkage. The tensile strength of the composite would be increased by substituting TEGDMA for Bis-GMA, but the flexural strength would be reduced.11

2) Ormocer based

Ormocers is a term for a type of modified ceramic. The matrix, unlike usual composites, was both organic and inorganic. As a result, Monomers were more firmly embedded inside the matrix, resulting in lower monomer release. Ormocers were made up of three main components: organic, inorganic, and polysiloxanes. The proportions of such components can have an impact on the material's quality: The polarity, Organic polymers influence crosslinking ability, hardness, and optical behavior, thermal expansion and chemical stability influenced by the glass and ceramic components (inorganic constituents) and the elasticity and interface properties influenced by the polysiloxanes; the inorganic components were bounded by multifunctional silane molecules to the organic polymers. A three-dimensional network is formed once the organic component of the methacrylate groups is polymerized.11 Taking into account all efforts to create a better restorative material using ormocers, cyclical loading in a laboratory test revealed that they had been inferior to hybrid composites.11 In a five-year clinical evaluation of these two composites, however, there was no statistically significant difference between ormocer-based and methacrylate-based composite.12

However, the difference was small. Ormocers were satisfactory in clinical applications, although there were concerns about marginal adaptation and their use in class V restorations due to weak adhesion. There was also a study that demonstrated no difference in restorative lifetime between ormocers and methacrylate-based resin composites. However, a five-year control study found that one of the two ormocer materials had a significantly higher tendency to discoloration than the other.12

3) Compomers:

It's a combination of composites and glass ionomers that takes use of the glass ionomers' fluoride release and ease of use, as well as the composites' superior material qualities as well as aesthetics. Compomers contain reactive fluoroaluminiumsilicate glasses which gain from the glass ionomer. The compomer's setting reaction is dependent on the polymerization of acidic monomers. Only after water absorption, acid-base interaction begins, and that was only localized to the surface layers. Because of its low abrasion, compomer is best suited for deciduous teeth, according to experts.12 The fluoride release from compomers rapidly increased within the initial twenty-four hours, followed by a swift decline. Additionally, compomers demonstrated that fluoride release into saliva was lower for young permanent teeth compared to deciduous teeth; thus, it is assumed that young permanent teeth may retain more ions within the enamel.11 Whenever traditional composite and compomer water absorption were evaluated, compomer outperformed traditional composite, simply result in little discoloration, and that was a consideration in the anterior restoration. Due to their limited abrasion resistance, compomers were also ruled out for substantial core build-up repairs.9

4) Silorane:

It is made up of Siloxanes and Oxirans, and its name refers to the chemical makeup of the substance. Siloranes exhibited properties such as less shrinkage, longer aging resistance, and less marginal discoloration. The silorane ring reaction, which was dependent on chain reaction, distinguished silorane from hybrid composite as shown.9

To initiate the polymerization of Siloranes, light-absorbing camphorquinon, an electron donor (e.g., amine), as well as an idonium salt were utilized as photoinitiators. The interaction between the excited camphorquinon and the electron donor opened the oxirane ring, which convert the idonium salt during this process to an acidic cation. The oxirane rings would be opened to compensate for some of polymerization shrinkage. Streptococci bacteria were less adherent to the surface of silorane restorations because to the siloranes' hydrophobic properties.9 Because of its low translucency, Silorane is normally only utilized on the back teeth, and an adequate adhesive system should be used in conjunction with it due to its hydrophobic nature. Furthermore, because to silorane's high viscosity and limited radiopacity, it is difficult to detect silorane restorations on radiographs.9

-According to the size of the filler particles.

The evolution of dental composites continues to be marked by changes in filler size, shape, morphology, as well as loading efficiency. Flame pyrolysis, flame spray pyrolysis, and sol-gel techniques are among the many ways used to make nanofillers. The phenomenon of scattering or absorbing visible light for nanofillers is important for achieving outstanding cosmetic features and can be used to restore anterior teeth. Because of the small size, the filler loading efficiency can be improved. Filler wettability is influenced by a direct correlation between filler loading as well as filler particle surface area. The purpose of nano-based filler particles (40 nm to 0.7 nm) is to make the normal tooth structure as well as the nano-sized filler particle more compatible. As a result, an even more refined and natural interface appears.13 Nanofills and Nanohybrids are two forms of nanocomposites that are increasingly generally available. Nanofills are dominated by particles with a diameter of 0.1 to 100 nm, whereas nanohybrids are made up of larger particles with a diameter of 0.4 to 5 µm. As a result, they are not fully nanofilled and are referred to as hybrids.13

1) Macro-filled composites

Large inorganic quartz or glass fillers are used in macro-filled materials. The macro-filled particles varied in size from 1 to 10 µm. Excessive wear and difficulties polishing to a smooth finish are regarded drawbacks related to the dislodgment of the filler from the filling surface. The most prevalent fillers in macrofilled composites (density of 2.2 g/cm2) were ground quartz and strontium glasses.14

2) Micro-filled composites

When compared to macrofilled composites, microfilled composites had inorganic silica filler particles (40 nm) that were substantially smaller. The purpose of microfilled composite was to make a more polishable composite. In 1977, Isopaste (Vivadent) was the first microfilled composite to come to market. Microfillers are created from silicon dioxide smoke (ash) or colloidal silica, which is sodium silicate colloidal particles added to water and hydrochloric acid.15

The two types of microfilled composites were homogeneous and heterogeneous. Microfiller particles are put directly onto the resin in homogeneous materials, and this approach is rarely used. Heterogeneous microfiller was the most common, and sintering, precipitation, condensation, or salinization were all used to compress it into clumps. At a filler loading of about 70% by weight, the heated resin combined with the fumed silica resin. In microfilled composites, particle sizes varied from 30 to 65 nm. Pre-polymerized resin fillers were the filler particles in consideration, and the inorganic filler makes about 35 to 72 percent of the final product manufactured using pre-polymerized resin fillers and nonpolymerized resin filled with microfiller.6

3) Hybrid Composite

Hybrid composites were created to merge the advantageous physical and mechanical qualities of traditional composites with the smooth surface characteristic of microfilled composites. They comprise approximately 75% conventional-sized particles (1-3 microns) and around 8% submicron-sized particles (0.02-0.04 microns).16

4) Micro-hybrid composite

The particle size of microhybrid composite resins was reduced to a range of 0.04 µm to 1 µm. Microhybrid composites polish and handle superior than hybrid composites due to the use of very small particles.

5) Nanohybrid composite

Nanohybrid composites were marketed as universal composites, as well as being suited for anterior buildups, because they had better esthetic and wear properties, handling, and polishability. The agglomerated nanoclusters interleaved with micro sized particles in the nanohybrid composite produced acceptable wear characteristics. This category's fracture resistance and compressive strength were regarded similar to or stronger than those of the composites stated before, and nanohybrids had a higher surface hardness than those composites, making them ideal for later applications.14

6) Nanofilled composite

Nanoclusters and 5 nm to 75 nm particles (nanomers) appear to have been used as fillers in nanofilled composites; At the points of contact, agglomerates (0.6-1.4µm) of zirconia/silica nano-particles (5-20 nm size) crosslinked with each other to create nano-clusters. Porous structures penetrated by silane are eventually created, which have good esthetics, are incredibly easy to polish, and have better wear resistance and fracture toughness.17

Tooth Whitening (Dental Bleaching)

The aesthetic of teeth influences personal appearance. Numerous factors influence the appearance of teeth, including color, form, position, and the quality of dental restorations.18,19 The color of teeth is a significant element influencing individual satisfaction with dental aesthetics. In response to the significant public demand in the twenty-first century, aesthetic dentistry has developed. Clinicians and scientists were prompted by societal concern with smile aesthetics to create minimally invasive methods like tooth bleaching as an alternative to cosmetic veneer or crown placements that could be harmful and destructive. 20,21

As early as 1877, a vital tooth bleaching procedure using oxalic acid was reported by Chappel.' In 1884, after experiments with various forms of chlorine, Harlan described what may have been the first use of hydrogen peroxide, calling it hydrogen dioxide (Zaragoza, 1984). Although this was followed by Taft and Atkinson in 1889 using chlorine, it was ultimately generally accepted by dentists that hydrogen peroxide is the most effective vital tooth bleaching agent.22 Then in 1918, Abbot reported on what continues to be the basic combination for tooth bleaching: high-intensity light that generates a rapid rise in the temperature of the hydrogen peroxide, accelerating the chemical bleaching process. 22,23

To meet the overwhelming public desire for beautiful white teeth. At the end of the 1980s, tooth whitening agents were launched to the US market.24,25 Peroxide's lightening effect on enamel was discovered by accident in 1962 after Klusmier's orthodontic therapy, using a carbamide peroxide containing gel to treat inflamed periodontium, indicating its potential for usage as tooth whitening agents. However, Klusmier's personal message to the Arkansas Dental Society went unreported until Haywood and Heymann published a description of the approach in 1989.25,26 Dental bleaching is regarded as a successful treatment, employing varying doses of carbamide peroxide or hydrogen peroxide in both at-home and in-office procedures. The immediate outcome of tooth bleaching is closely correlated with the concentration of the chemical and the duration of exposure, however the final result post-treatment is comparable both clinically and in vitro.27

Tooth Bleaching Chemistry

Carbamide peroxide has a more complicated structure than hydrogen peroxide, which breaks down into its active components after reacting with water. Hydrogen Peroxide (HP) is more prone to break down at pH values above 7, generating hydrogen and perhydroxyl, resulting in superior whitening outcomes than free oxygen species.25,28

Carbamide peroxide has a longer active whitening procedure in comparison to HP due to the structural stability of Carbamide peroxide that make it degraded slowly. Water and reactive oxygen radicals are formed when hydrogen peroxide decomposes. It's highly soluble, resulting in an acidic environment with a pH which further varies depending on concentration; a 1 percent hydrogen peroxide solution, for example, had found to have a pH around 5-6. Bleaching preparations for teeth contain hydrogen peroxide as the active ingredient, glycerin as a carrier, Carbopol as a thickener, and a variety of flavoring ingredient.27,29

Types of Vital Tooth Bleaching

- In-office tooth bleaching

According to General Dental Council (UK) rules, only a professional dentist under the close supervision as well as direction of a dentist can perform in-office bleaching. 30 It cannot be done by beauty therapists, for example. For a brief length of time, in the past, a bleaching gel was employed with high amounts of chemically as well as light activated HP (45min-1hr). Because in-office products have a high concentration of HP (30-38 percent), significant amounts of free oxygen radicals can form in a shorter amount of time, resulting in quick whitening Effect.31,32

In an office bleaching procedure, a gel containing 35–38% hydrogen peroxide is wiped onto the teeth and left on for 30–45 minutes. One way to speed up the bleaching process is to employ a chemically activated bleaching product. Another option is to utilize a visible light curing lamp.33

- At-home tooth bleaching

Dentists typically advocate night-guard vital bleaching as the gold standard in tooth whitening. It's a less expensive whitening treatment that can be used by the patient, with fewer reported negative effects.34 This whitening method involves putting 10% CP in a tray as well as wearing it about 2-6 weeks at a time.35 According to the evidence, the overall whitening effect of at-home whitening with 10% CP for eight to ten hours nightly for 14 days is approximately doubled (ΔE) ($\Delta E = 12.3$) of a 35 percent hydrogen peroxide gel performed in-office once a week for two weeks ($\Delta E=5.3$).36 A clinical trial demonstrated no significant difference in whitening efficacy between a 10 percent CP gel utilized about two hours, overnight, for 21days as well as a 35 percent of hydrogen peroxide gel utilized about three 8-minute sessions, once 7 days, for 21 days.37 The median shade change from baseline for both procedures were 4-7 Vita-shade guide units. This study's subjective color change assessment may have had a larger margin of error over objective colorimeter findings.36–38

Day whitening at home can take from around 2-4 hours per day for 2 weeks on average. After two weeks of therapy with a 15% CP gel that applied for two hours daily, the reported ΔE varied between 4.6 to 5.3, which is less than that reported for tooth bleaching with a night guard using a lower CP concentration.39 This is most likely due to the variation in whitening time between day and night, During the day, it's 2-4 hours, and at night, it's 8-10 hours. After two hours of therapy, only half of the CP is broken down to its active components, which is important to note.40 For brightening discolored teeth, the use of hydrogen peroxide or peroxide releasing agents, such as carbamide peroxide or sodium perborate, has become a popular treatment modality.

The Toxicity of Bleaching Agents

Oxidizing chemical, that's according to Agency for Toxic Substances and Disease Registry (ATSDR), can cause irritation to skin, eyes, and mucous membranes when concentrations are high (>10 percent). According to Public Health England’s Centre for Radiation, Chemicals and Environmental Hazards (CRCE), HP produces hydroxyl radicals, which cause peroxidation of lipid, damage of DNA, as well as cell death. The highest concentration of Hydrogen Peroxide that did not produce mucosal irritation was 5%, while the highest concentration that caused harm was 8%. HP can be manufactured at considerably higher concentrations, and it is considered corrosive at concentrations above 50%. The toxicity of whitening chemicals is affected by hydrogen peroxide concentration, the type of the bleaching material, as well as the length of application.41 It can reach the dental pulp chamber as well as periodontal ligament due to its low molecular weight, causing an inflammatory response that may result in cervical root resorption as well as damaging pulp, fibroblasts, even DNA.42,43 Despite their ability to cause genotoxicity and cytotoxicity, free radicals of oxygen are thought being unable to get through cell membranes as well as cause harm unless supplied in extremely high concentrations 30 % HP (hydrogen peroxide). According to previously published investigations, the concentrations of commercially available whitening materials were reported to vary by up to 40%. To date, no reports of whitening chemicals used within accordance with policies and standards were found to produce long-term negative.41,44

Adverse Effect of Tooth Bleaching

- Tooth sensitivity

Tooth sensitivity manifests in two-thirds of patients utilizing home bleaching methods. A majority (55%) may encounter mild sensitivity, while 10% may suffer strong sensitivity, and only 4% may face severe sensitivity.45 Symptoms often manifest early in the treatment, generally within 2 to 3 days, and may last for 3 to 4 hours post-removal of the tray, dissipating shortly after the completion of the treatment.46 The etiology of tooth sensitivity following bleaching treatment is multifactorial and is poorly understood. The causes of post-bleaching dental discomfort is various and inadequately comprehended. Sensitivity is believed to result from the diffusion of by-products generated during the breakdown of HP and CP through dentinal tubules.47 Glycerine, utilized as a carrier in numerous bleaching treatments, is hydrophilic and induces dehydration of dental structure during bleaching procedures. This may also lead to tooth sensitivity.48 The application of bleaching agents with higher peroxide concentrations also enhances the possibility of tooth sensitivity.49

- Gingival or mucosal irritation

Certain individuals may encounter gingival or mucosal discomfort during at-home bleaching methods. Irritation of soft tissue may result from a poorly fitting tray that exerts pressure on the gingiva and/or the application of excessive material.46 Management involves only refining the tray and/or advising the patient to utilize a reduced quantity of substance. In an in-office bleaching technique, a higher concentration of hydrogen peroxide is typically employed. HP is a corrosive agent that can induce burns to the gingival or mucosal tissues.50 Consequently, a rubber dam or manufacturer-supplied light-cured resin must usually be utilized to safeguard sensitive tissues during in-office bleaching treatments.

- Effects on tooth structure

The bleaching of vital teeth requires prolonged direct contact with the enamel surface, varying according to the specific materials used. This feature enhanced concerns regarding the potential harmful effects of such a potent oxidizing agent on the enamel or dentin. The current research is inconsistent. Certain scanning electron microscopy investigations indicated alterations in the surface morphology of enamel subsequent to bleaching with CP and/or HP products.51

- Effect on dental composites

Tooth-colored restorative materials, particularly composite resins, are a significant element of modern dentistry. Composite resins have greater susceptibility to chemical alterations compared to metallic restorative materials and neutral ceramics owing to their organic matrix. The utilization of bleaching treatments poses a risk of damaging the surface of composite resin restorations, leading to bacterial adherence.52 The final impact of these chemical agents on composite resins is based upon the type and resistance of the resin matrix, the filler content of the composite resin, the bleaching gel, and the time of their application.53 Increasing use of peroxide bleaching agents has raised concerns about their effects on different restorative materials. Numerous studies have reported that tooth bleaching may adversely affect physical and/or chemical properties of restorative materials, including increased surface roughness, crack development, marginal breakdown, release of metallic ions, and decreases in tooth-to-restoration bond strength.54–57

1) Surface Roughness

It’s the smoothness of the surface of the material. Roughness of composite surface may be mechanically irritating and facilitates adhesion of dental plaque which leads to staining and recurrent caries.14 The size and composition of the filler particles primarily determine the smoothness of restoration58,59, composite material in which the inorganic filler particle size is between 1-8µm are only semi polishable. They present a duller, less reflective surface after finishing. Materials with inorganic filler particle size are greater than l0µm are considered to be non-polishable since they present a dull, non-reflective surface after finishing.60

Surface roughening can be caused by wear and chemical deterioration, and this roughening can decrease gloss, which can promote extrinsic staining. Water sorption, resin breakdown, stain resistance reduction, and changes in translucency can also induce softening of the resin matrix. Furthermore, Extrinsic discolorations can be caused by dietary and smoking habits, poor oral hygiene, as well as the adsorption or absorption of water-soluble pigmentation throughout the resin matrix.61

Surface Roughness Tests

- Profilometers

Roughness readings derived by profilometers provide a quantitative assessment of surface irregularities. Surface roughness (Ra) is regarded as an inadequate measure of surface texture; yet, it is the most commonly documented value for assessing surface topography in dental materials. Surface topography possesses a three-dimensional character. Therefore, the assessment of 2D surface topography fails to precisely represent the fundamental features of a surface.62 Stylus type profilometers provide definitions of surface features for a scale size related to the probe dimensions and because of its size, 2D profilometer cannot penetrate certain micro-irregularities and could not represent surface features, which were narrower than the stylus.62,63 A diamond stylus usually in contact with a sample moved across the sample for a specified distance and specified contact force.64 Optical profilometry techniques, utilizing numerous optical principles like as interferometry, light scattering, and focus detection, possess an enhanced effective range for amplitude measurements and are widely employed to assess the surface roughness of dental materials.65,66

- Atomic Force Microscopy (AFM)

Average roughness commonly represents the AFM 3D parameter of the texture surface topography by the symbol (Sa). The AFM is an effective instrument for examining site-specific structural topography of enamel and the alterations in enamel following application of materials. The main advantage of this technique compared to the other technologies are that it is the provision of extensive qualitative and quantitative characterization data. Additionally, it facilitates enamel pore depth assessment which reveals details of the ultra-structure of the enamel surface. Meanwhile, the size of the scan area is one of the disadvantages of the AFM; commonly it cannot exceed more than 100 μm x 100 μm.67

Qasim et al.68 assessed the impact of two distinct bleaching agents on the surface roughness characteristics of dental resin nanocomposites and dental porcelains through diverse strategies. The study found no significant variation in surface roughness among the bleaching chemicals used to the evaluated dental materials. Bleaching agents can be utilized without damaging ceramic, nanofilled, or nanohybrid resin restorations. Nonetheless, the presence of microhybrid or microfilled composite restorations in the oral cavity may result in surface finish deterioration due to bleaching, necessitating restoration replacement.

Pradeep et al.69 evaluated the effects of bleaching agents on the surface roughness of bulk fill composites. They found the surface roughness of the bleached composite resins surfaces increased significantly. Also, Wongpraparatana et al.70 examined the effect of simulated bleaching with a 10% carbamide peroxide or a 40% hydrogen peroxide system on surface roughness of resin composite. They conclude simulated bleaching with 10% CP or 40% HP increased both surface roughness.

Chakraborty et al.71 compared the surface roughness of different restorative materials after in-office bleaching with Pola office. They conclude the surface roughness is not affected in both nanohybrid and nanofilled composite resin materials. Hence, the effect of the bleaching agent on the existing composite resin restorations must be considered at the time of selection of the bleaching agent and the regimen for clinical use.

El-Rashidy et al.72 evaluated the effect of finishing and polishing and an in-office bleaching gel on the surface roughness of single-shade and group-shade resin composites. They conclude the surface roughness of resin composites is material dependent. single-shade demonstrated lower initial Ra value than group-shade. However, single-shade showed significant increase in surface roughness following finishing and polishing, unlike group-shade. Bleaching with 38% H2O2 showed no effect on the surface roughness of both materials.

Popescu et al.73 studied the progression of surface roughness in various completed and polished composites upon the application of bleaching agents. Their findings indicate that the bleaching techniques altered the surfaces of the samples, resulting in increased roughness relative to the control samples.

2) Surface Microhardness

Hardness may be defined as the resistance to permanent surface indentation. Therefore, it is a measure of resistance of plastic deformation and is measured as a force per unit area of indentation.74The microhardness test based on micro-plastic deformations after removal of a loaded indenter.75

When choosing a restorative material, one of the most important factors to consider is the mechanical qualities. Because it is used to restore missing tooth structure, restorative materials must be strong enough to resist the forces involved with mastication.76 One of the mechanical properties can be evaluated by using microhardness test. As it is directly linked to the composition properties of the materials examined, microhardness is modified by aging, water absorption, and material surface interactions.77 Indentation tests (with Vickers or Knoop indenters) are used to determine microhardness, which can provide a good indication of the resistance to localized plastic deformation. This is critical in dentistry because surface behavior is linked to usury and scrape, implying that resistance is linked to clinical long-term efficiency.78

Surface Microhardness Tests

In materials science, hardness is a fundamental feature of a solid material that indicates its resistance to permanent deformation and is strongly correlated with atomic bond strength.79,80 The ratio of load area is used to describe the hardness measurement where the load is applied. There are several designs for the load application instrument, such as a sphere, a basic elongated pyramidal base, and among others, also the area of brand impression is also important as the hit value.81,82 The hardness testers under 1kgf are used during indentations due to changes in testing techniques and materials with increasingly smaller particles. Vickers and Knoop are two alternative microhardness testing procedures that are used for restorative materials.83 Vickers hardness is a classifying system based on the hardness of materials tested in a laboratory.84,85A diamond pyramid with a dihedral angle of 136 is utilized in this procedure, and it is compressed with an arbitrary force "F" to the material's surface. Calculate the printed area "A" by measuring its diagonal surface, after applying the force on the material as in Figure (1-4a).86 Knoop, on the other hand, with a diagonal ratio of 7-1, is used to evaluate the behavior of a flexible material capable of shrinking the smaller diagonal after the stress is removed.87,88

The Vickers hardness number (VHN) is determined by dividing the applied load by the surface area of the indentation. The lengths of the diagonals of the indentation are measured, mean values are calculated, and the Vickers Hardness Number (VHN) is referenced from a table. The disadvantage of this test is its unsuitability for measuring resilient materials, since they tend to recover, resulting in erroneous indentations.89,90

The Knoop hardness test is a widely utilized method for assessing resin composites due to its ability to reduce the impact of elastic recovery. A study comparing the Knoop and Vickers hardness methods for composite placement techniques indicated that both measurement approaches yielded statistically comparable results and strong correlation, however with Vickers values being elevated: VHN = 14.7 + 0.954 x KHN. These authors' conclusion was that both tests can be used for the indirect evaluation of degree of polymerization of composites.90

The indentation of microhardness is a generally non-destructive, straightforward, and quick method for classifying materials and conducting comparative analyses of their characteristics. This investigation employed the Vickers method to quantify surface microhardness, a technique utilized in several studies due to its accuracy, accessibility, and simplicity. The Vickers hardness test is more reliable than Knoop's due to the square configuration of its indenter, and any errors in hardness measurement are readily identifiable due to the slight elongation of its diagonal impression. Consequently, it is advised that the Vickers indenter be utilized consistently in material hardness assessments.

The microhardness of composite resin surfaces is contingent upon the material's mechanical qualities and its degradation. Multiple aspects associated with composite resin formulation, such as monomer type, size, and filler content, might influence their mechanical properties. Taking into account the influence of several elements, an augmentation in surface microhardness and enhancement of the physical properties of composite resins by extended curing time may enhance their clinical durability and resistance to chemical agents, including bleaching agents.

Leal et al.91 evaluated the microhardness of composites after different bleaching techniques. They conclude that surface hardness of nano-hybrid and nano-filled composite resins was unaffected by whitening solutions based on carbamide and hydrogen peroxide.

Bahannan et al.92 studied the effects of different bleaching agent concentrations on microhardness of esthetic restorative materials. They conclude when resin composites were bleached, the findings for surface microhardness were variable. When subjected to a bleaching agent, several researchers noticed a decrease in surface microhardness.

Bahari et al.93 Investigated the impact of bleaching compounds on the surface and mechanical properties of restorative materials is critically essential. The study concludes that 15% carbamide peroxide and 35% light-activated hydrogen peroxide considerably reduced the microhardness of a silorane-based composite resin. Light-activated 35% hydrogen peroxide reduced the microhardness of silorane-based composite resin to a lesser extent than 35% hydrogen peroxide and 15% carbamide peroxide. Nonetheless, no substantial variations in microhardness were seen between 15% carbamide peroxide and 35% hydrogen peroxide.

Fernandes et al.94 evaluated the effect of dental bleaching on the microhardness of sealed composite resins. They conclude that enamel microhardness was influenced by both dental bleaching procedures used. Also, Mohammadi et al.95 evaluate the effect of curing time and bleaching agents on microhybrid composite resin surface microhardness. They conclude application of both bleaching methods decreased the surface hardness of microhybrid composite resin.

Hassan et al.96 examined the influence of dental bleaching systems (home bleaching system and two in-office bleaching systems) on the surface microhardness of the two resins composite restorative materials. They conclude regarding the physical properties of composite resins; the microhardness may be compromised by bleaching treatments.

3) Marginal Adaptation

The marginal adaptation refers to the relationship between the restoration and the tooth structure. Inadequate marginal adaptation may lead to postoperative discomfort, recurrent cavities, pulp irritation, and marginal discolouration.97 Consequently, replace or repair an adhesive restoration due to these predominant causes.98

Along with advancements in restorative materials in recent decades, the marginal integrity of restorations continues to be a difficulty for dentistry. Inadequate marginal adaptation can lead to marginal discoloration, postoperative sensitivity, and secondary caries.99 These are predominant reasons for replacing or repairing an adhesive restoration.100,101 The marginal failure of composite resin restorations mostly corresponds to the quality of adhesion to tooth structures and the force exerted on the restoration.99

Furthermore, the literature indicates that the bleaching treatment may contain substances capable of degrading the adhesive contact, potentially diminishing the restoration's lifetime.102 The capacity of the restoration to seal the surrounding tissues is critically important during and after this invasive treatment. 103–105 Consequently, it is essential to evaluate if dental bleaching adversely affects the sealing capabilities of bonding systems to determine if these materials sufficiently preserve the teeth during bleaching and whether these restorations should be maintained or changed post-procedure.

Factors That Affecting on Marginal Adaptation Evaluation

- Adhesive systems

The adhesion to the tooth structure is achieved through phosphoric acid etching, followed by rinsing and the application of an adhesive agent. The development of self-etching primers and adhesives eliminates the phases of conditioning, washing, and drying that are necessary for the adhesion system; yet, this simplification has not demonstrated any enhancement in bonding performance. Furthermore, the substrate to which the adhesive is applied can affect the efficacy of certain adhesive systems.106 A gap that forms between the restoration and tooth wall occurs when the binding strength of most composite resins is inferior to the concentration forces. The primary shortcomings of contemporary adhesive restorations are their limited endurance within the oral cavity. Adhesive restoratives maintain optimal quality for around 3 to 5 years.107 The primary causes for the failure of adhesive restoratives placed with prior adhesives are inadequate marginal adaptation and loss of retention.108,109

- Occlusal loading

Upon submission of the restoration to loading, the formation of a loading gap subsequent to debonding can be detected. Following the polymerization of the composite, a decrease in the intermolecular distance among the monomers leads to resultant shrinkage.110 The adhesion of composite resin to the cavity walls restricts material deformation and induces shrinkage stress at the bonding surfaces. A contraction gap will occur if the tension passes the bonding strength between the adhesive system and the dental substrate, hence impacting the restoration's durability.97,111

- Temperature

Variations in oral cavity temperature induce stress on restorations and can disrupt marginal adaptation due to discrepancies in the thermal coefficients of tooth structure and composite materials.112

- Polymerization shrinkage

Polymerization is a chemical phenomenon in which tiny molecules transform into extensive chains of polymers. Intermolecular lengths measure approximately 3-4 Å; however, upon polymerization, the distance between the resultant polymer units is merely 1.5 Å. This is attributable to the contraction occurring during polymerization, generally ranging from 1.5% to 5%.113 The extent of polymerization shrinkage is influenced by the quantity of the covalent bonds established, which is contingent upon the molecular size, as well as the degree of conversion of the monomers' double carbon bonds. As the size of the molecules increases inside a given material volume, the quantity of formed bonds diminishes, resulting in reduced polymerization shrinkage.114

Composite polymerization occurs either during the pre-gel or post-gel phases. During the pre-gel phase, the reaction types exhibit significant mobility for reorganizing and compensating for volumetric shrinkage without generating substantial interfacial and internal stress.115,116 After gelation (post gel phase), the producing of a semi rigid polymer network restrains the plastic deforming.117 As long as the system remains in a liquid state, it undergoes rapid deformation. When the conversion degree nears 10-20%, the network becomes sufficiently extensive to form a gel. The ongoing polymerization shrinkage and the development of elastic modulus create stresses within materials, at the interfaces of restorations and teeth, as well as within the tooth structure.118 Post-gel point, polymerization shrinkage induces strain on the network and the bonding system interface. These stresses are likely to promote gap formation and compromise the duration of the restoration.119 The stress of polymerization shrinkage is influenced by various aspects, including the configuration factor, the composition of resin composites, material qualities, and clinical procedures.

Marginal Adaptation Evaluation Tests

- Dye penetration method

The dye penetration method is commonly employed to assess a marginal gap. At the junction of enamel and dentin/restoration, the extent of dye infiltration is observable.120–122 After soaking the teeth in dye, they are cut into sections and examined under a microscope to determine how much dye has penetrated. Theoretically, a restoration with an insignificant dye penetration should last longer, especially with less recurring caries and less marginal discoloration.123 Dye infiltrates dentin margin restorations more profoundly than enamel margin restorations.124 Nevertheless, the correlation between the existence of peripheral gaps and dye penetration is either entirely unestablished or just partially established, contingent upon the location and the dye utilized. Dye penetration measurements lack reliability due to the absence of clinical correlation.123

- Automatic marginal gap detection

An optical sensor is used to perform the automatic marginal gap detection.

An optical sensor is used to evaluate the margin of the epoxy resin filling reproduction after the polishing of the filling is finished. By making profiles and radially refocusing the light beam from the filling's center to the repair margin. When a gap is detected, its width and depth are automatically measured.124

- Microscopic marginal adaptation analysis

The scanning electron microscope (SEM) offers exceptional magnification and detail, rendering it an optimal instrument for a comprehensive examination of restoration margins.125,126 SEM generates various signals at the surface of solid specimens through the application of a concentrated beam of high-energy electrons. The signals generated from reactions between electrons and samples provide information about the sample, and data collecting occurs over a designated area of the sample's surface, resulting in a two-dimensional image that reveals the marginal interface. For high-resolution electron imaging Samples are coated with a thin coating of conductive substance, primarily gold, or various alloys or metals. The SEM is capable of analyzing chooser point locations on the sample. SEM examination is regarded as "non-destructive"; that is, the signals generated by electron interactions do not result in volume loss of the sample, allowing for repeated study of the same materials.127,128 SEM is a widely utilized instrument for examining adaption at interfaces. The following are many of its advantages.129 Facilitate the characterization of marginal gaps resulting from dental fractures or irregularities, with examination conducted at extremely high magnification and depth of focus (varying from 20X to nearly 30,000X), allowing for the detection of questionable areas at elevated magnification. SEM examination of light-cured resin adhesion to bleached enamel indicated that resin integrity alters upon exposure to hydrogen peroxide.130 The bleaching agent may include substances that accelerate adhesive interface breakdown, according to the literature. This could impact adaption and shorten the restoration's lifespan. 131

Abe et al.132 assessed the impact of 35% hydrogen peroxide-based bleaching treatments on the tooth-restoration interface by scanning electron microscopy. The SEM analysis indicated minor gaps between tooth enamel and adhesive following exposure to all bleaching chemicals; yet, the most pronounced gap at the tooth-restoration interface was noted soon after the application of the agents. Also, Silva et al.133 evaluated the effects of different bleaching techniques on the tooth-restoration interface of composite restorations. They conclude tooth bleaching techniques does not damage the tooth-restoration interface of composite restorations.

Piemjai et al.134 assessed the distance and/or thickness of dye infiltration at the enamel and edges of restorations prior to and following essential bleaching. Concluding a negative control or leakage-free restoration is crucial for elucidating the impacts of bleaching on marginal seal or microleakage. Teeth restored with self-etch bond exhibited leakage-free control specimens, while extra-coronal tooth whitening with 38% hydrogen peroxide, conducted either prior to or subsequent to restoration insertion, resulted in marginal leaking of the restorations. Storage in artificial saliva for seven days was inadequate to diminish the impact of bleaching on microleakage at the resin-tooth interface, regardless of whether self-etch or total-etch moist bonding adhesives were employed.

Iovan et al.135 examined the contact between composite restorations and dental tissues in teeth that have undergone dental bleaching. The shape of the interface between the composite resin and the cavity edges was not considerably affected by the adhesive application procedure. The study's results indicated that the marginal adaption and interface morphology were mostly unchanged following bleaching with the 40% hydrogen peroxide system tested. The bleaching process appeared to have minimal impact on the interface between composite resin and dental tissues, as the flaws were too subtle to be seen by scanning electron microscopy. The tested materials indicated that the bleaching method appeared safe concerning the preservation of marginal adaptation of composite restorations; however, further investigation is required to evaluate the long-term effects of dental bleaching on the restorations' capacity to safeguard adjacent dental tissues.

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