Colour Stability of Composite Resins: A General Overview

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ABSTRACT
Composite resins have been shown to be susceptible to discolouration on exposure to oral environment over a period of time. Discolouration of composite resins can be broadly classified as intrinsic or extrinsic. Intrinsic discolouration involves physico-chemical alteration within the material, while extrinsic stains are a result of surface discolouration by extrinsic compounds. Although the effects of various substances on the colour stability of composite resins have been extensively investigated, little has been published on the methods of removing the composite resins staining. The purpose of this paper is to provide a brief literature review on the colour stability of composite resins and clinical approaches in the stain removal.

Key Words: Not available


INTRODUCTION

The first plastic material, a self cured methacrylate resin was developed by German chemist during World War II to replace the only dental aesthetic material previously available; silicate cements. Despite their initial success, chemically cured acrylic resins were plagued with poor colour stability and associated with inferior mechanical properties. In an attempt to minimize the drawbacks of acrylic resin, many researchers added filler particles to the acrylic resin. One of these researchers, Dr Rafael Bowen, explored the possibility of adding methyl methacrylate groups to the end groups of the epoxy resin resulting in the discovery of the famous Bis-GMA (bisphenol-A-glycidyl methacrylate) in 1959. Together with acid etching of dental enamel, proposed by Buonocore in 1955, the breakthrough has led to the introduction of composite resins into the mainstream of restorative dentistry.

Since then, composite resins have become the popular choice of material, owing to their inherent property to emulate the natural colour of teeth and the increasing demand amongst patients for aesthetics. The last few decades saw significant development of the material resulting in evolution of a multitude of contemporary composite resins. Notwithstanding the remarkable improvement in the clinical performance of the material, colour stability of composite resins remains problematic. Clinical studies of composite resin revealed median survival rates of 4.9-8 years. While the materials showed acceptable clinical performance, some of the main reasons for failure include secondary caries, wear, bulk fracture, and discolorations. Kiremitchi et al 2009 found that 4 out of 47 restorations displayed staining and marginal discoloration after six years. A 12 year clinical evaluation by Wilder et al (2009) using the modified U.S. Public Health Service criteria showed that 12% of the restorations received ‘bravo’ scores for staining. In another study, colour change with surface staining was noted at 18 months. A retrospective study by Redman et al 2001 found that most discolouration of composite resins was detected in the first year. The failure peaks again at the fifth year. This is further substantiated by reports from several short term studies. Majority of the failures of composite resins that occurred within 1-2 years service were due to discolouration.

“Colour stability” or the ability of the material to retain the matched shade over a long period of time is crucial for a lasting impression of the esthetic outcome. Mjor et al (2000) pointed out that patient’s dissatisfaction with the
The colour change due to alteration in the chemical structure of the composite resins under physical and chemical conditions, while extrinsic factors are mainly due to surface staining from absorption or adsorption of exogenous substances.

Intrinsic Discolouration

In restorative dentistry, dental composite resins consist of three main components: (1) organic resin (matrix phase), (2) inorganic filler particles (dispersed phase), and (3) the coupling agent that chemically bonds the inorganic filler to the resin matrix (surface interfacial phase).26 Any alteration or changes to any of these components within the material may result in a permanent discolouration at the subsurface and internal layers of composite resins.25

Traditionally, it is believed that changes in amine compound (N,Ndimethyl-p-toluidine) in the initiator system of chemically cured resin produce intrinsic colour change in composite resins.27 This is thought to be related to the tendency of isomeric dimethacrylates to form yellow-tinted charge-transfer complexes with the tertiary aromatic amines.28 Studies have also found that the photoinitiator (camphoroquinone) in light polymerized based cement may oxidize into a yellowish-brownish coloured compound thus leading to the discoulouration of the composite resins.29,30

The colour change due to alteration in the organic resin matrix may be directly related to monomers hydrophobicity28 and their water absorption properties.31-33 Water absorption produces deleterious effects including hydroscopic swelling, plasticization, softening and hydrolysis of the resin matrix that leads to penetration of staining pigments.34,35 Composite resins with lower water sorption rates arising from the use of hydrophobic (less affinity to water) resin monomers are less prone to discolouration.32 It has been shown that the hydrophobic urethane dimethacrylate (UDMA) exhibits less staining compared to Bisphenol A-glycidyl methacrylate (Bis-GMA), which is the common resin monomers used31. Conversely, composite resins with hydrophilic monomers e.g. tri-ethylene glycol dimethacrylate (TEDGMA) exhibit higher water absorption,29 and therefore permits penetration of any hydrophilic colourant into the resin matrix. However, Bis-GMA monomer has been a predominant constituent in most of the commercial composite resins6, and the above findings are largely in vitro observations. Therefore, the clinical significance of these findings remains to be seen.

The influence of fillers on the staining potential of composite resins is related to its surface structure.36,37 Fillers appear to affect how well a composite finishes38. During the polishing procedure, fillers may dislodge from the matrix leaving voids on the restorative surface. In general, larger filler particles leave bigger defects, thus producing a rougher surface.39 The rougher the surface, the more susceptible the material is to staining.40

The effect of daylight41 or ultraviolet irradiation,42 thermal changes and water43-47 on colour properties of composite resins have been widely documented. The colour change of composite resins upon exposure to various aging conditions is time and dose dependent, and may be attributed to changes in the surface microstructure and chemical composition within the matrix of the composite resins and also at the interface between organic matrix and filler particles.46 On this note, Schulze et al.46 postulate that a weakening of the chemical bonds in the organic polymer create pores within the resin matrix as well as exposure of filler particles, thereby contributing to the colour changes in composite resins. Surface deterioration induced by the physico-chemical changes creates microcracks within the material that facilitate the
penetration of stains. A slow intermittent temperature fluctuation in a humid or moist environment such as in the oral environment has been shown to produce darker and less translucent materials.48,49

Results from laboratory studies revealed that the degree of polymerisation also plays a role in the colour stability of composite resins.50 Suboptimal polymerisation leaves unreacted initiators or accelerators in the composite resins that in turn result in a yellowing of the composite resins.27 Furthermore, incomplete conversion of monomers as a result of insufficient polymerisation is related to increased water absorption of the composite resins which subsequently could potentiate the risk of discolouration.51

Extrinsic Discolouration
Unlike intrinsic staining, extrinsic discolouration of composite resins may occur as a result of staining by the pigments from exogenous contaminants. Extrinsic discolouration involves surface or subsurface adsorption or absorption of chromogenic substances and can be removed mechanically or chemically.52

Colour alteration of composite resins after immersion in various liquid beverages has been a subject of great interest in many studies. Research has found that beverages including coffee,52-59 tea,52,57-59 alcohol beverages,52,57-59,60 carbonated drinks,52,55-60,62 and fruit juices50-62 caused significant colour changes in composite resins. Composite resins are also susceptible to staining by artificial food dyes (erythrosine and sunset yellow).39 Significant colour change was observed by Stober et al (2001)59 when composite resins were exposed to 0.1% turmeric solution.

There has been a lot of speculation about the discolouration of composite resins by coffee and tea. According to Um and Ruyter (1991),54 discolouration caused by coffee and tea is due to yellow colourants in the beverages. The investigators believe that yellow colourants in tea have higher polarity compared with coffee. Therefore, tea caused adsorption of colourant on surface of composite resins and can be mechanically removed. While coffee stains composite resins by adsorption and absorption of colourant into the organic matrix of material as a result of the compatibility of yellow colourant in coffee with the organic matrix of composite resins. Another group of researchers found that addition of sugar in coffee accentuates the staining by coffee.63 This is thought to be caused by the sticky effect produced by sugar.63

Presence of alcohol and low pH (such as in red wine) resulted in surface degradation of the composite resins, thereby contributing to the colour change.64 SEM analysis of a composite resin after pH cycling revealed that there was disintegration of the polymer matrix and degradation of silane bonding between filler and organic matrix leading particle loss.65 Consequently, surface roughness was noted. Similarly, alcohol affects the colour of composite resins through softening of the surface material,66 facilitating the absorption of external pigments.67 In addition, Satou et al33 believe that the discolouration of composite resins is the result of binding between hydrophilic un-reacted component in the initiators in the composite resins and the hydrophilic pigments in the exogenous agents e.g. red wine.

Staining by alcohol based mouthwashes,47,53,59 fluoride varnishes68 and bleaching agents64 has been described. Khokhar et al31 and Omata et al57 found that the addition of chlorhexidine and saliva increased the staining effect of coffee and tea. Leard et al63 explains that this phenomenon may be attributed to the binding of the cationic (positive charged) in the anti-septic mouthwash surface anionic (negative charged) surfaces of chromogenic agents in beverages.

The staining potential of composite resins is related to its surface structure. The rougher the surface, the more susceptible the material is to extrinsic staining.41 The surface characteristic of composite resins depends on types of fillers and finishing or polishing technique.48,69 For this reason, a wide variety of burs, diamonds, abrasives, strips and pastes have been introduced by manufacturers for finishing and polishing composite resins.70 Many studies have been conducted to establish a finishing and polishing procedure that will produce a smooth-surfaced restoration. However, there is no consensus in the literature about the effectiveness of different finishing and polishing procedures in relation to the staining susceptibility of composite resins.
METHODS OF STAIN REMOVAL

At this point the question might be raised as to whether the discolouration of composite resins could be removed. This is the most relevant aspect in clinical practice as premature replacement of functional composite resin has both financial and biological implications. Several emerging researches have sought to evaluate the possibility of removal of the composite resins staining.

A recent study by Anfe et al 201171 measured the colour changes in some of the contemporary composite resins after immersion in red wine and coffee. Following the staining process, the composites were subjected to abrasive wear of 20, 40, 60 µm. They found that staining by red wine and coffee occurs superficially (~20 µm) and can be removed through re-polishing.

This result is consistent with a report by Mundim et al (2011).72 They concluded that re-polishing decreased the degree of coffee staining to a clinically acceptable level. Similar findings have also been published on the effect of re-polishing and nicotine staining.73 However, the method may not return the original colour of the material and could lead to surface alteration of the composite resins.

The effectiveness of bleaching in eliminating both extrinsic and intrinsic staining of teeth has been well established.74,75 One might wonder if similar result could be achieved with composite resins. Research has shown changes in the physical characteristics of composite resins after bleaching. Alteration of surface microhardness and roughness, staining susceptibility, tensile strength and marginal integrity following bleaching has been reported.76 Torres et al (2012)77 found significant changes in the colour and fluorescence of composite resins after exposure to 20-35% of hydrogen peroxide bleaching gels. Considerable alteration in colour,76,78,79 gloss79 and refractive index80 of composite resins have been reported. It is believed that the colour change in composite resins may be attributed to the alteration of the resin matrix in the restorative material.76 The inadvertent changes in colour of the composite resins produced by the bleaching procedure may be beneficial in removing the stained composite resins.

An in vitro study by Villata et al (2006)64 demonstrated complete removal of wine stains from composite resins with at-home bleaching system (Crest Night Effects, Colgate Simply White Night, or Opalescence Quick). Earlier study by Turkun et al (2004)81 showed composite resins stained by coffee and tea responded positively to both bleaching and polishing. The colour of composite resins tested returned to almost baseline colour. In removal of deeply penetrated stains, bleaching with 15% hydrogen peroxide was shown to be more effective than repolishing.

Recently, the use of whitening tooth paste and ozonated gel have also been found to be helpful.82,83 Composite resins seem to display diverse degree of whitening depending on the types of composite resins and the concentration bleaching agents used.84 Hafez et al (2008)82 examined the effects of Beyond (Beyond Technology Corp), LumaWhite-Plus (LumaLite, Inc.)

Figure 1. Discolouration of distal palatal 11 (left) and buccal (right). History indicated no particular exogenous substance that could contribute to the discolouration. Courtesy of Dr Ahmad Fauzi Muhairiri.

Figure 2. Labial discolouration of 22,23,24. Daily chlorhexidine mouthwash usage was identified in the history.
and Opalescence-Boost (Ultradent Products, Inc.)
in-office bleaching systems in lightening the coffee
stained microfilled and hybrid composite resins. Only the microfilled composite resins showed
significant reduction of stain after bleaching with Beyond and Luma White-Plus.

**Clinical Implications**
The composite resins were introduced in the 1950s
to overcome some of the problems associated with
previous tooth-coloured materials. Nevertheless, the performance of this material seems to be
obscured by its historical innuendo; poor colour
stability. From the above discussion, it is apparent
that extensive research has been carried out in
search of mechanism of discolouration of composite resins. Most of the factors involved in the
intrinsic discolouration are beyond the control of clinicians. It is also likely that various physico-
chemical conditions that exist naturally in the oral
environment may alter the chemical structure
within composite resins leading to inevitable colour
change in restorations. Various substances
especially dietary agents have potential deleterious
effect on the colour of composite resins. Therefore, patients should be educated on the possible colour changes in the restorative material on exposure to
these substances.

![Figure 3](image3.png) Possible coffee discolourations of anterior proximal restorations 12 (mesial), 11 (mesial & distal), 21 (mesial).

![Figure 4](image4.png) Marginal and bulk staining of anterior composite resins. History taking revealed regular tea and red wine consumption.

Although the susceptibility of composite resins to discolouration has been widely investigated, studies that specifically address the clinical management of composite resins discolouration have been limited. In clinical practice, it may be difficult to ascertain the mechanism of staining by clinical assessment alone. Figure 1-6 are some of the clinical examples illustrating composite discolouration cases. To determine the cause of staining, clinical evaluation of the restoration may need to be supplemented by thorough history taking and investigation. The determination of the mechanism of staining is crucial as the treatment options and outcome of the treatment largely depend on the diagnosis of the composite staining.

Dietary history, dental history e.g. oral hygiene practices or usage of mouthwashes and habits such as smoking are useful information in establishing the extrinsic nature of the discolouration. Clinical records of the types of composite resin used may be helpful in verifying the intrinsic cause. Intraoral examination of the restorations such as surface texture and quality of the polished surface may shed some light on the possible origins of the discolouration. As part of the diagnostic investigation, a clinician may try to

![Figure 5](image5.png) Labial staining on 12 and 13. Rough and irregular surface was detected in the clinical evaluation.
mechanically remove the stains. In general, most extrinsic stains are noted to be superficial, approximately 3-5 µm and could be reduced mechanically.

From aforementioned experiments, tooth brushing with whitening toothpaste, re-polishing and bleaching procedures have all showed promise in reducing the discolouration of composite resin. Nevertheless, research in this area is still in its infancy and there seems to be lack of consensus in the literature with regards to the most effective method of composite resins stain removal. The heterogeneity of the results in the literature may be related to the variations in the types of composite resins, the choice and concentration of polishing or bleaching agent tested. It appears that the selection of method to be employed for composite stain removal is very much material-dependent and is related to the mechanism of the discolouration.

CONCLUSION

The susceptibility of composite resins to intrinsic staining varies according to the chemical composition of resin matrix, types and amount of filler and initiator and accelerator system. A multitude of common dietary agents have been shown to have potential to stain composite resins. Instead of premature replacement of the restorations, routine use of whitening toothpaste, re-polishing techniques and bleaching procedures are viable ways to remove superficial stains of composite resin. While the effects various extrinsic and intrinsic substances have been implicated in the discolouration of composite resins, studies on methods of stain removal have been limited. Most studies on this subject are in-vitro in nature and data ought to be interpreted with caution when extrapolated to clinical settings. Therefore, long term clinical studies are needed to elucidate the mechanism underlying the composite resins and to address the clinical efficacy of the stain removal methods.

REFERENCE


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