



Effect of Aging on Color Stability and Bond Strength of Different Resin Cements with and without Color cleanup Indicator: A Narrative Review

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Abstract

Resin cements are an important factor that affects the mechanical and esthetic success of indirect dental restorations. Their performance can be negatively affected by aging processes that compromise the shear bond strength and color stability over time. The aim of this narrative review is to discuss the effects of different aging methods on the shear bond strength and color stability of resin cements, particularly the types with a color cleanup indicator. Various aging methods, such as thermocycling, water storage, and ultraviolet exposure, have been used to simulate clinical conditions. Most studies reported a decrease in shear bond due to hydrolytic degradation. Similarly, in color stability, discoloration occurs over time due to changes in the material's intrinsic composition and external factors. Color cleanup indicators have been added to help remove excess cement, but their impact on long-term mechanical and optical properties remains debated; more studies are needed to study their actual effect. A standardized aging protocol and longer-term clinical studies will help to assess their effect in resin cements.

Keywords: Color cleanup, Indicator, Resin cement, Aging

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1. Introduction

The longevity of an indirect restoration is affected by many factors [1-2]. One of the main factors is the luting material. Choosing the proper luting material is a must to give the restoration the strength and appearance [3]. Cement forms a link between the restoration and the tooth, helping to keep both parts united under chewing forces and sealing the margins to prevent recurrence of caries. Of all the materials used to cement indirect restorations, resin-based cements are often favored. The physical and chemical properties of these materials make them suitable when retention is compromised, and tooth preparation is minimal [4]. The mechanical properties of cements in saliva undergo a long-term aging process that can cause a significant reduction [5]. This process typically involves leaching unreacted components and degrading the network of polymers [5-6]. Composite resin color stability is affected by both internal material reactions and external factors like diet [7-8]. The color of resin-based materials can undergo changes with aging and has been examined in laboratory settings using techniques such as UV radiation/condensation exposure, thermocycling, and water storage [9-11]. More recent types of resin cements with a color cleanup indicator are supplied by the manufacturer. They are used to make the removal of excess

cement more convenient and faster. Their initial pink color gradually reaches the final shade as the setting reaction goes on. Once the pink color fades, it's the proper time to remove the excess. However, the impact of these color cleanup indicators on long-term mechanical and esthetic properties of resin cements is still unclear.

2. Development of Resin Cements

Resin cement was first developed in the 1950s and has since been improved through various reformulations. Because of the increased demand for more attractive all-ceramic restorations, resin cement has become common in modern dentistry [12]. In the 2000s, self-adhesive resin cement was introduced to simplify clinical procedures compared with traditional resin cements [13].

3. Classification of Resin Cements

3.1 Based on adhesive characteristics

3.1.1 Total Etch Resin Cements

Require the application of phosphoric acid etchant, followed by the application of the adhesive system. With this type of the resin cement, complete removal of the smear layer and the dentine demineralization exposes the collagen fibers (Table 1) [14-15].

3.1.2 Self-Etch Resin Cements

In this type of adhesive system, the phosphoric acid-etching step is eliminated because the adhesive's acidic component performs it. Self-etch resin cements involve applying a self-etching primer to the tooth surface, followed by mixing the cement and applying it over the primer. They function differently from etch-and-rinse adhesives. Unlike the latter, they do not require rinsing and drying, thereby retaining the smear layer, which becomes infused with the acidic monomers. This process exposes intertubular collagen, allowing resin monomers to fill the voids left by removed minerals, thereby creating a micromechanical interlocking effect within the collagen spaces [16].

3.1.3 Self-adhesive Resin Cements

This type of resin cement bonds to teeth without the need for an extra etchant or an adhesive. Their main ingredient is an acid-functional monomer. They form a chemical bond with the tooth through an acid-base reaction, although these cements cannot completely dissolve or remove the smear layer for mechanical retention. Overall, self-adhesive cements have performed well compared to other multistep resin cements [17].

3.2 Based on the mode of polymerization

3.2.1 Self-cure Resin Cements

They polymerize when a chemical reaction starts with peroxide as the initiator. Because of their composition, self-curing resin cements do not hold their color as well, so they are not the first choice for bonding translucent or thin ceramic restorations. In these situations, light-cure resin cements work better. Materials that harden through chemical polymerization set slowly, which helps reduce shrinkage stress [18-19].

3.2.2 Light-cure Resin Cements

Light-cure cements harden when photoinitiators are activated. One main drawback is that their polymerization time is more controlled than that of the self-curing materials [18-19].

3.2.3 Dual-cure Resin Cements

Dual-cure cements have both amine initiators, which are chemical, and photoinitiators, which respond to light. These components let the polymerization process begin when exposed to a light source. The light-curing step triggers a chemical reaction that continues over time. The catalyst in dual-cure cements helps the material fully harden in places where light cannot reach, after the initial fast light polymerization [20-21].

4. Resin cements with color cleanup indicator

4.1 Mode of action

These cements include a color-cleanup indicator to help identify the best time to remove excess cement. The manufacturer recommends removing any excess material once the indicator's color has faded, as this indicates it is safe to do so. Then, light curing is done to achieve optimal bond strength between restoration and the tooth material [22]. They form a strong, durable bond and are compatible with a variety of dental substrates. They are also compatible with all indirect restorations, including PFM, anterior or posterior ceramics, CAD/CAM materials, and metal restorations (Table 2).

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4.2 Types of cements with color cleanup indicator

Like Maxcem Elite chroma and Nexus universal chroma, these are distinctive features that provide a clue to the optimal time to remove excess cement. The cement starts pink and gradually fades to its final color as curing process takes place, or within the first few minutes if the cement is left to autopolymerize. After the pink color disappears, any excess material can be removed. The final bond strength of the material is achieved through light curing. Manufacturers also state that tack curing for 1-2 seconds can speed up the removal of excess cement (Figure 1).

4.3 Causes behind using these cements

The timely and accurate removal of excess cement is essential, and determining the optimal timing is crucial. Investigations have examined the problems of interrupting the light-curing process at an unsuitable time to remove cement from unwanted areas. Resin cements, in particular, may adhere to the oral surfaces of restorations, complicating cleanup and prolonging cementation [23]. Any excess cement can lead to inflammation and peri-implantitis due to bacterial growth around it [24-25].

5. Effect of aging on the bond strength of resin cements

Reducing bond strength artificially over time gives a more accurate picture of how cement behaves in reality, so it is important for in vitro studies. Still, there is no single best method for accelerated aging that fully matches conditions in the mouth. Several approaches have been described by researchers, including thermocycling, thermomechanical aging, dynamic loading, and water storage [26-31]. A previous study examined how thermocycling affects the bond strength between CAD/CAM ceramics and resin cement. They found that this aging process significantly reduced bond strength. Other studies have also shown that bond strengths tend to decrease after aging and prolonged exposure to water. This can be explained by the small molecular size and highwater concentration, which can compromise polymer's thermal stability. As a result, this can lead to plasticization and, eventually, the breakdown of the resin cement through hydrolysis (Figure 2) [32-34].

6. Effect of aging on the bond strength of resin cements with color cleanup indicator

According to previous thermocycling-based investigations comparing a conventional cement without a color cleanup indicator (Maxcem Elite) and a cement with a color cleanup indicator (Maxcem Elite chroma), there were no statistically significant differences between them. This observation could be attributed to the cement filler content; the manufacturers reported the following: Maxcem EliteTM = 69% wt. and Maxcem EliteTM Chroma = 67%wt. This is consistent with the findings of Yang et al. (2022) [35], indicating that an increase in filler content leads to higher bond strength, and with the results of Malysa et al. (2022),[36] suggesting that thermocycling notably reduces the bond strength of dental cements.

7. Effect of aging on color stability of resin cements

Water aging has been used to mimic material degradation caused by hydrolytic effects in resin matrices. When water adsorbs into the cement, it leads to expansion and swelling of the matrix.

Gel-Point Indicator Color Change Mechanism

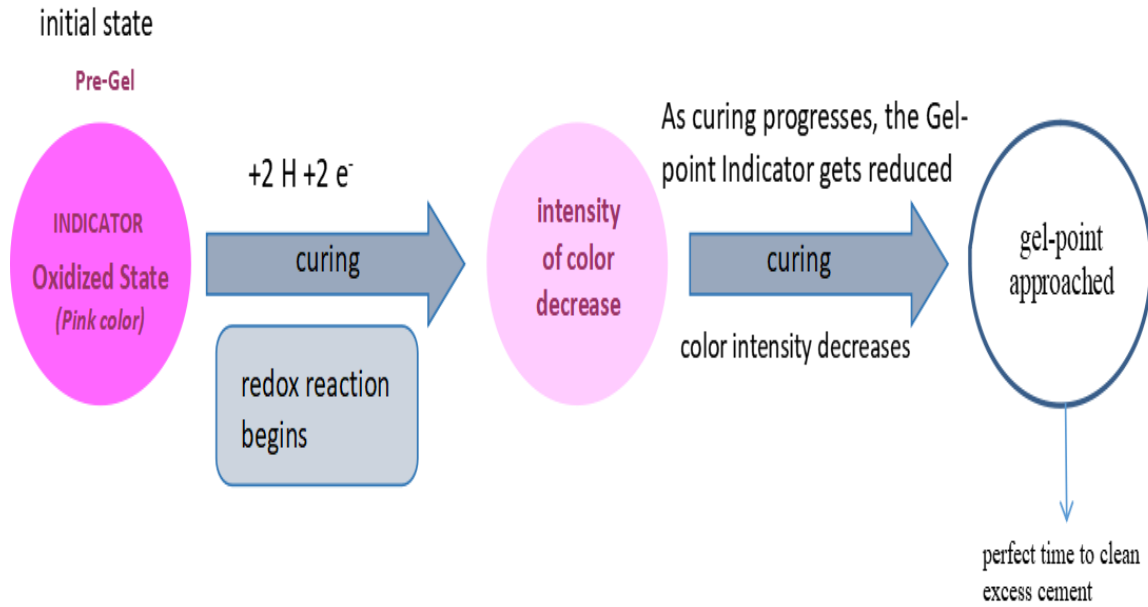


Figure 2: Color cleanup mechanism of action

effect of aging on:

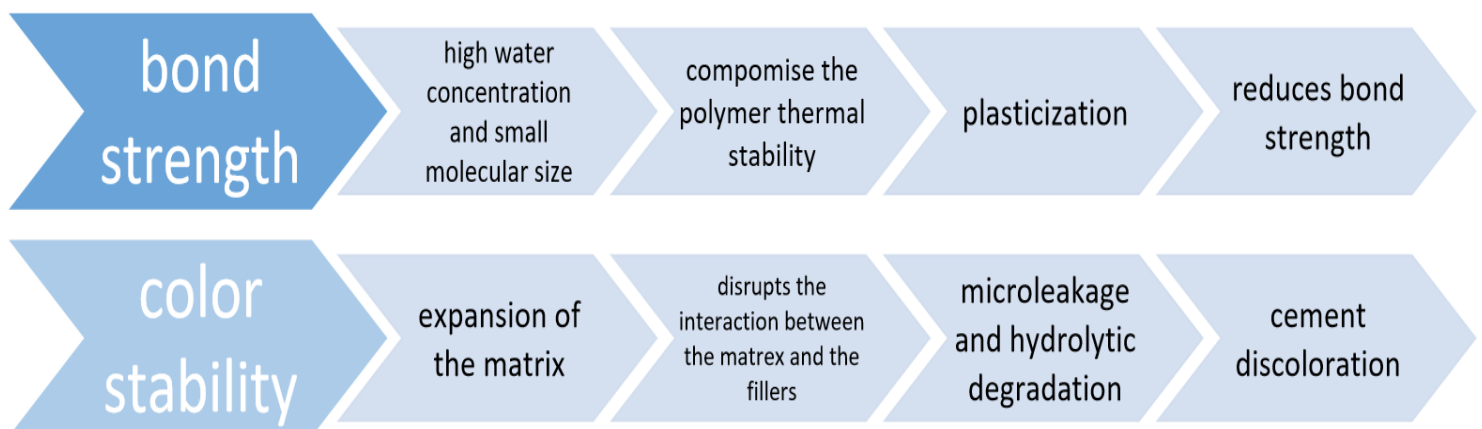


Figure 3: Showing the effect of aging on bond strength and color stability

Table 2: Classification of resin cements

According to			
1-Adhesive characteristics	Total etch resin cement	Self-etch resin cement	Self-adhesive resin cement
	<ol style="list-style-type: none"> 1. Require the application of phosphoric acid etchant, followed by the adhesive system 2. Complete removal of the smear layer 	<ol style="list-style-type: none"> 1. Involves applying a self-etching primer followed by cement 2. Retains the smear layer, which becomes infused with the acidic monomers, exposing intertubular collagen, allowing micromechanical interlocking 	<ol style="list-style-type: none"> 1. No need for an extra etchant or an adhesive 2. cannot completely dissolve or remove the smear layer 3. form a chemical bond with the tooth through an acid-base reaction,
2-Mode of polymerization	Self-cured resin cement	Light-cured resin cement	Dual-cured resin cement
	<ol style="list-style-type: none"> 1. Polymerizes when a chemical reaction starts with peroxide as the initiator 2. Slow reaction reduces shrinkage stresses 3. Do not hold their color 	<ol style="list-style-type: none"> 1. Harden when photoinitiators are activated. 2. Polymerization time is more controlled 3. More color stability 	<ol style="list-style-type: none"> 1. Have both amine initiators and photoinitiators 2. The light-curing step triggers a chemical reaction that continues over time. 3. The catalyst in dual-cure cements helps the material fully harden in places where light cannot reach

Table 3: Classification of resin cements according to color cleanup indicator

	With a color cleanup indicator	Without a color cleanup indicator
<i>Mode of action</i>	<ol style="list-style-type: none"> 1. Cement starts pink in color. Upon curing, the pink color gradually fades to the final shade (gel state), indicating the proper time for excess cement. 2. If cement is left to autopolymerize, this change of color occurs within a few minutes as polymerization takes place 	<ol style="list-style-type: none"> 1. Cement maintains a uniform color from mixing until setting with no indication of the gel state 2. The optimal timing for excess cement removal depends on manufacturer instructions and the clinician's experience
<i>example</i>	Maxcem chroma	Maxcem elite
<i>Clinical implication</i>	<ol style="list-style-type: none"> 1. Adherence of excess resin cement in unwated areas, complicating and prolonging the cleanup process 2. Incomplete removal of excess cement leads to gingivitis, periodontitis, and inflammation around cement-retained restorations. 	<ol style="list-style-type: none"> 1. Difficulty in identifying the optimal timing to remove the excess cement requires more experience 2. Higher risk of leaving unnoticed cement due to lack of visibility

This water absorption can disrupt the interaction between the resin matrix and the inorganic fillers, potentially leading to microcracks that may cause discoloration of the cement [21,37,38]. Artificial accelerated aging induces water sorption, which modifies the refractive index of resins and affects color parameters [39]. As a result, the observed color change may be partly due to hydrolytic degradation from sample aging [40]. Furthermore, the high concentrations of benzoyl peroxide in self-adhesive cements may oxidize, contributing to their color change. Moreover, during

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accelerated aging, the samples absorb UV light, resulting in a yellow color [41].

8. Effect of aging on color stability of resin cements with color cleanup indicator

A previous study by Abo Baker et al (2025) [42] measured how aging affects the color stability of resin cement using a color cleanup indicator, comparing Maxcem Elite and Maxcem Elite chroma. There was no significant change in chroma after thermocycling for Maxcem Elite chroma. As

reported by Yang. et al (2022) [35]. This finding can be explained by the resin matrix having a smaller particle size, which provides greater color stability. In contrast to previous studies, Alghazzawi et al. reported in 2024 that resin formulations with more hydrophilic monomers, such as TEGDMA, released higher levels of residual monomers into water and became more yellow over time. This shows that monomer chemistry and hydrophilicity are essential for long-term color stability [43].

9. Conclusion

Various aging processes, such as water storage, thermocycling, and ultraviolet exposure, have been shown to negatively affect the color stability and shear bond strength of resin cements. This is caused mainly by hydrolytic degradation, breakdown at the interface, and the material's own composition. Although resin cements usually provide reliable bonding, their long-term esthetic stability remains a point of questioning, especially in demanding clinical cases. Color-cleanup indicators facilitate the removal of excess cement, but there is scarce and somewhat conflicting evidence regarding their effects on mechanical and optical properties. Further investigations are needed, using standardized aging protocols, to better understand their long-term effects and what this means for clinical use.

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