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Review article

An Overview of the Effect of Tooth Bleaching Agents on Ceramic Restorations

Lotfeia Khamas

Department of Prosthodontics, Faculty of Dentistry, Sabratha University, Libya.
***Email**: lot.1983@yahoo.com*

Abstract
Tooth bleaching is a widely used aesthetic dental procedure that commonly involves hydrogen peroxide and carbamide peroxide. Despite its effectiveness in improving tooth color, concerns remain regarding its effects on ceramic restorations. This review evaluates the influence of bleaching agents on the microhardness, surface roughness, and optical properties of ceramic materials. The literature indicates that bleaching agents may increase surface roughness and slightly affect optical properties, while their effect on microhardness remains controversial and depends largely on the ceramic type. Glass-based ceramics appear more susceptible to alterations compared to zirconia-based materials. Overall, bleaching agents may produce clinically relevant changes in ceramic restorations, highlighting the importance of careful treatment planning and patient awareness during aesthetic procedures.
Keywords. Tooth Bleaching, Hydrogen Peroxide, Carbamide Peroxide, Ceramic Restorations.

Introduction

In recent years, aesthetic dentistry has witnessed a significant increase in patient demand for brighter and more attractive smiles. Tooth whitening has become one of the most commonly requested cosmetic dental procedures due to its conservative nature, effectiveness, and relatively low cost compared to restorative treatments [1]. Dental bleaching agents are primarily based on hydrogen peroxide (HP) or carbamide peroxide (CP), which are widely used in both in-office and home bleaching techniques. These agents act through the release of free radicals that penetrate enamel and dentin, breaking down complex chromogenic molecules into smaller, less pigmented compounds, thereby improving tooth color [1,2].

Despite their effectiveness, concerns have been raised regarding the potential adverse effects of bleaching agents on dental hard tissues and restorative materials. Previous studies have reported that bleaching procedures may induce microstructural alterations, including increased surface roughness and changes in microhardness of enamel [2]. At the same time, ceramic restorations such as veneers, crowns, inlays, and CAD/CAM restorations are increasingly used due to their excellent esthetic properties, biocompatibility, and mechanical strength [3]. Lithium disilicate and zirconia-based ceramics have become especially popular due to their improved durability and superior optical behavior [4]. However, the interaction between whitening agents and ceramic materials remains a subject of growing concern in restorative dentistry. Recent studies have shown that bleaching agents can influence the surface characteristics of ceramic restorations. For instance, exposure to hydrogen peroxide has been associated with a significant increase in surface roughness of different ceramic materials, which may negatively affect their long-term clinical performance [3].

Increased surface roughness is clinically relevant as it promotes plaque accumulation, discoloration, and potential periodontal complications [5]. Moreover, bleaching agents may also affect the optical properties of ceramics. A recent study demonstrated that while bleaching can improve stain removal from ceramic surfaces, it may simultaneously increase surface roughness, indicating a trade-off between aesthetic improvement and surface integrity [6]. Importantly, the extent of these effects depends on several factors, including the type of ceramic material, concentration, and type of bleaching agent, pH, and duration of exposure [3]. This variability highlights the need for a comprehensive understanding of the interaction between whitening agents and ceramic restorations to ensure optimal clinical outcomes. Therefore, this study aims to evaluate the effect of tooth whitening agents on ceramic restorations, with particular focus on changes in microhardness, surface roughness, and optical properties of ceramic materials.

Relevant literature was identified through electronic searches in PubMed, Google Scholar, ScienceDirect, and Scopus databases using combinations of the previously mentioned keywords. Priority was given to English-language studies published between 2003 and 2025, including original studies and review articles related to ceramic restorative materials. Articles focusing solely on enamel without evaluation of restorative materials were excluded.

Mechanism of Action of Bleaching Agents

Tooth bleaching agents primarily act through oxidation reactions involving the release of reactive oxygen species. Hydrogen peroxide (HP), the main active component in most bleaching systems, penetrates enamel and dentin and decomposes to generate free radicals such as hydroxyl radicals (•OH) and perhydroxyl ions. These highly reactive species break down complex chromogenic molecules into smaller, less pigmented compounds, resulting in a whitening effect [1,7].

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Carbamide peroxide (CP), another commonly used bleaching agent, decomposes into hydrogen peroxide and urea, producing a similar oxidative effect but at a slower rate due to its gradual breakdown [1]. The overall effectiveness of bleaching depends on several factors, including peroxide concentration, application time, and diffusion ability within dental tissues [8].

While this mechanism is effective in natural teeth, its impact on ceramic restorations differs significantly. Ceramic materials lack organic chromophores; therefore, their intrinsic color cannot be altered through oxidation [7,9]. Instead, bleaching agents mainly interact with the ceramic surface, particularly the glaze layer. This interaction may lead to superficial chemical changes, including degradation of the glaze layer and increased surface roughness. As a result, light reflection and scattering patterns may be altered, which can affect optical properties such as gloss and translucency without modifying the internal structure of the material [2,3,6]. This mechanism can be further illustrated by the following diagram (Figure 1)

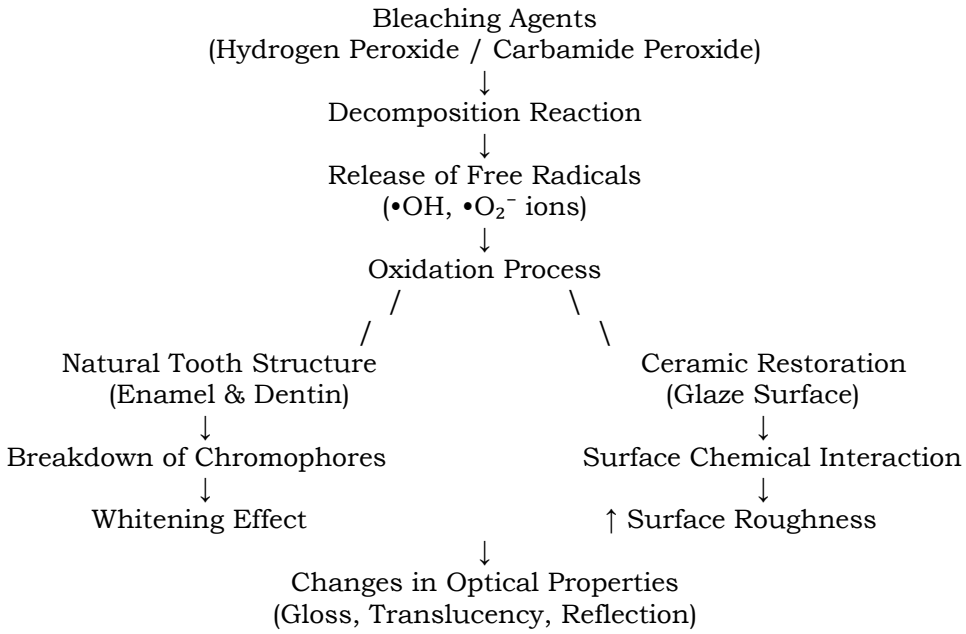

Figure 1. The mechanism of action of bleaching agents and their different effects on natural teeth and ceramic restorations [1,7].

Effect on Microhardness

Microhardness is a fundamental mechanical property that reflects the resistance of ceramic materials to localized surface deformation and plays a crucial role in their long-term clinical performance.

A considerable number of studies investigated the influence of bleaching agents on the microhardness of ceramic materials; however, the findings remain inconsistent. Early research by Türker and Biskin [10] demonstrated that bleaching agents may negatively affect restorative materials through chemical surface degradation. Similarly, Moraes et al. [11] found that peroxide-based agents could penetrate surface defects, potentially weakening the structural integrity of the material. Subsequent studies provided a more conservative interpretation. Attin et al. [9] reported that although changes in microhardness may occur, they are often minor and not clinically significant. This view was further supported by Alqahtani [1], who emphasized that the effect is highly dependent on the concentration and duration of exposure.

More recent investigations have produced mixed results. AlJasser et al. [2] reported a reduction in microhardness in silica-based ceramics following bleaching, whereas Türkmen et al. [5] found no significant changes in zirconia-based materials, attributing this to their dense crystalline structure and chemical stability. Furthermore, Karan et al. [3] confirmed that susceptibility to microhardness reduction is material-dependent, with feldspathic ceramics being more affected than lithium disilicate and zirconia. Supporting this observation, Li et al. [12] reported slight but statistically significant reductions in the hardness of lithium disilicate ceramics after exposure to high-concentration bleaching agents.

Taken together, these findings suggest that the effect of bleaching agents on microhardness is not uniform but rather influenced by material composition and treatment conditions.

Effect on Surface Roughness

Surface roughness is a critical factor influencing both the biological and aesthetic performance of ceramic restorations. It directly affects plaque accumulation, bacterial adhesion, and light reflection.

Unlike microhardness, there is strong agreement in the literature regarding the effect of bleaching agents on surface roughness. Early work by Türker and Biskin [10] revealed that bleaching agents can cause

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surface alterations in restorative materials. This was further supported by Attin et al. [9], who acknowledged that such changes, although present, may remain within clinically acceptable limits.

More recent studies have provided stronger evidence. Alqahtani [1] reported that peroxide-based agents can disrupt the ceramic surface, leading to increased roughness. Türkmen et al. [5] emphasized the clinical implications of this effect, highlighting its role in plaque retention and periodontal complications. In agreement, Karan et al. [3] found a significant increase in surface roughness across different ceramic materials, particularly feldspathic ceramics. Similarly, Kaheel et al. [6] demonstrated that bleaching improves stain removal but simultaneously increases surface roughness, indicating a trade-off between aesthetic enhancement and surface integrity. However, some variability still exists. Studies on zirconia-based ceramics [5] showed minimal changes, indicating that material composition plays a protective role. Nevertheless, the overall consensus remains that bleaching agents tend to increase surface roughness to varying degrees.

Effect on Optical Properties

The optical properties of ceramic restorations, including color, translucency, and surface gloss, are essential for achieving optimal aesthetic outcomes. The literature consistently indicates that bleaching agents do not significantly alter the intrinsic color of ceramic materials. Joiner [7] explained that bleaching primarily affects organic chromophores, which are absent in ceramics. This finding was supported by Attin et al. [9], who confirmed that ceramic restorations do not respond to bleaching in the same way as natural teeth. However, bleaching agents may influence surface-dependent optical properties. Alqahtani [1] highlighted that surface alterations may affect light reflection, potentially impacting the overall appearance of restorations. Karan et al. [3] further demonstrated that increased surface roughness can modify light scattering and reduce translucency. Some studies showed slight reductions in translucency and gloss following bleaching procedures, particularly in highly polished ceramic surfaces [13]. In addition, systematic reviews suggested that translucency and gloss of monolithic zirconia may be influenced by surface treatments and chemical exposure [14].

Yilmaz et al. [15] further reported that bleaching agents may induce subtle optical alterations in zirconia restorations, particularly in translucency and light reflection. In this context, Shahmiri et al. [16] found that zirconia ceramics exhibit relatively high optical stability compared with glass-based ceramics, although surface alterations may still affect light transmission and aesthetic appearance. More recently, Kaheel et al. [6] reported that while bleaching improves stain removal, it may also lead to subtle changes in gloss and optical appearance. In addition, AlJasser et al. [2] emphasized the clinical challenge of color mismatch between bleached teeth and existing restorations.

Overall, while the intrinsic color of ceramic materials generally remains unchanged, the indirect effects of bleaching on surface properties may compromise aesthetic harmony. The main studies investigating the effects of bleaching agents on ceramic restorations are summarized in Table 1.

Table 1: Summary of Studies Investigating the Effect of Bleaching Agents on Ceramic Restorations

Study	Study Focus	Testing Method	Key Findings
Türker & Biskin (2003) [10]	Bleaching effect on restorative materials	Surface analysis, hardness testing	Surface alterations and hardness reduction
Moraes et al. (2006) [11]	Structural changes after bleaching	Bond strength test	Potential weakening of restorative materials
Li et al. (2009) [8]	Bleaching mechanisms	Spectrophotometric analysis	Oxidative reactions responsible for whitening
Li et al. (2019) [12]	Lithium disilicate ceramics	Microhardness testing	Slight reduction in hardness
Türkmen et al. (2020) [5]	Zirconia ceramics	Roughness and hardness testing	Minimal changes in zirconia
Sulaiman et al. (2020) [4]	CAD/CAM ceramics	Optical analysis	Superior translucency and stability
Çelik et al. (2021) [17]	Feldspathic ceramics	Vickers hardness test	Reduced hardness after bleaching
AlJasser et al. (2022) [2]	Restorative materials and bleaching	Spectrophotometry, hardness testing	Material-dependent alterations
Karan et al. (2022) [3]	Multiple ceramic materials	SEM, roughness, hardness tests	Increased roughness and variable hardness reduction

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Alrabeah et al. (2023) [19]	Home bleaching and ceramic roughness	Roughness and optical analysis	Increased roughness after home bleaching
Ahmed et al. (2023) [13]	Optical changes in ceramics	Translucency analysis	Slight reduction in translucency
Hassan et al. (2023) [18]	Surface topography after bleaching	SEM analysis	Microscopic surface irregularities detected
Silva et al. (2024) [20]	CAD/CAM ceramics and bleaching	Roughness analysis	Increased roughness after repeated bleaching
Yilmaz et al. (2024) [15]	Optical behavior of zirconia	Spectrophotometric analysis	Optical changes affected by surface finish
Kaheel et al. (2025) [6]	Surface and optical properties	Color and roughness analysis	Improved stain removal with increased roughness

Conclusion

Within the limitations of the reviewed literature, it can be concluded that tooth bleaching agents have measurable effects on ceramic restorations, although the extent of these effects varies depending on several factors. Bleaching agents tend to increase surface roughness, which may compromise aesthetic appearance and promote plaque accumulation. Their effect on microhardness remains controversial, with evidence suggesting that glass-based ceramics are more susceptible to softening than zirconia-based materials. In terms of optical properties, bleaching does not significantly alter the intrinsic color of ceramics but may affect surface gloss and translucency, leading to potential color mismatch with natural teeth. From a clinical perspective, these findings emphasize the importance of careful case selection and treatment planning. Dentists should inform patients that existing ceramic restorations will not whiten like natural teeth and may require replacement after bleaching procedures. Additionally, polishing of restorations following bleaching may help restore surface smoothness and minimize the adverse effect.

Conflict of interest: The author declares no conflict of interest.

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