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Efficacy of Eggshell Powder and Nano-Hydroxyapatite as a Remineralizing Agent: A Literature Review

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Abstract

Dental bleaching, while effective for tooth whitening, often leads to enamel demineralization, manifesting as increased surface roughness and reduced microhardness. This literature review systematically evaluates the efficacy of eggshell powder (ESP) and nano hydroxyapatite (nHA) as remineralizing agents for bleached enamel, comparing their performance with established commercial products such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and fluoride-based agents. A literature review was conducted, including peer-reviewed in-vitro studies published in English that quantitatively assessed the remineralization effects of eggshell powder or nanohydroxyapatite on bleached enamel. Studies were selected based on the use of standardized microhardness or surface roughness measurements and the presence of control groups, with no restrictions on publication date. Data extraction focused on study design and key findings related to enamel remineralization. Findings indicate that both ESP and nHA significantly restore enamel microhardness and reduce surface roughness, with results comparable to or, in some cases, approaching those of CPP-ACP. ESP, derived from calcined chicken eggshells, offers a sustainable and cost-effective remineralization strategy, while nHA's biomimetic properties facilitate deep mineral penetration and adhesion.

Keywords: Bleached enamel, Demineralized enamel, Eggshell powder, Nano hydroxyapatite, Remineralization, Enamel microhardness, Surface roughness, Casein phosphopeptide amorphous calcium phosphate, Fluoride, Dental bleaching, Biomimetic agents.

Introduction

The application of biomaterials such as eggshell powder and nano-hydroxyapatite has garnered significant attention in the field of dental research due to their promising remineralizing properties and potential for clinical use. Recent studies have explored the effectiveness of these materials in restoring the microhardness and surface integrity of enamel, particularly after bleaching procedures, which are known to increase enamel roughness and susceptibility to demineralization [1]. Eggshell powder, recognized as a rich source of calcium and phosphate, has been evaluated for its capacity to remineralize demineralized enamel surfaces, especially following orthodontic treatments where enamel is often compromised [2], [3]. Investigations have also compared the remineralizing effects of eggshell powder with other agents such as novamine and fluoride, demonstrating comparable or superior outcomes in the management of initial caries-like lesions in young permanent teeth [4].

In addition to eggshell, other biogenic materials such as cuttlefish bone have been studied for their remineralizing potential, offering alternative natural sources for enamel repair [5]. Eggshell-based formulations, including toothpaste, have shown promise as cost-effective interventions for conditions like dentin hypersensitivity, providing both remineralization and symptomatic relief [6].

The resistance of enamel treated with eggshell powder to further acidic challenges has been quantitatively assessed, with findings indicating enhanced durability and mineral content following treatment [7]. Furthermore, the impact of eggshell powder on the microhardness of cementum and its efficacy in preventing artificially induced cemental erosion have been explored, broadening the scope of its dental applications [8].

Studies have also examined the abrasive and remineralizing efficacy of eggshell from various avian sources, such as coturnix quail, highlighting its versatility as a dental biomaterial [9]. Comparative assessments between nano-hydroxyapatite derived from eggshells and other sources, like fish scales, have provided insights into the optimal materials for remineralization strategies [10].

Systematic reviews have synthesized the available evidence on the role of eggshell in mitigating dental erosion, reinforcing its potential as a preventive and restorative agent [6]. Comparative investigations between undemineralized dentin powder and chicken eggshell powder have further elucidated their respective remineralization potentials on enamel carious lesions [7].

Physicochemical characterization studies have detailed the properties of dental eggshell powder as an abrasive material, supporting its safe and effective use in oral care products [11]. The development of nano-hydroxyapatite crystals from chicken eggshell has been shown to improve the microhardness of bleached enamel, underscoring the significance of particle size and formulation in enhancing remineralization outcomes [12].

Research comparing the remineralization potential of chicken eggshell powder solution with amorphous calcium phosphate has provided valuable data on the relative effectiveness of these agents in managing initial enamel lesions [13].

2. Methodology

To ensure a comprehensive and unbiased review, a systematic approach was adopted for selecting relevant studies. The inclusion criteria focused on in-vitro studies examining the remineralization effects of ESP (eggshell powder). No date restrictions were applied, allowing inclusion of studies published both before and after 2015 to capture the full scope of available evidence. Studies were required to report quantitative outcomes, such as microhardness or surface roughness. Only English-language articles were considered to maintain consistency in data interpretation.

On the other hand, excluding studies that do not investigate the specific intervention of interest, or that combine interventions in a way that confounds results. Also, studies not published in English nor studies with insufficient methodological quality were involved; to ensure that the literature review remains focused, reproducible, and relevant to the research objectives.

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Data extraction involved recording study characteristics (authors, year, sample size, and remineralization protocols) as well as key results related to enamel remineralization.

3. Discussion

[13] conducted an in vitro study to compare the remineralization efficacy of chicken eggshell powder solution (CESP) versus amorphous calcium phosphate (ACP) on initial enamel carious lesions. Forty freshly extracted premolars with artificially induced early enamel lesions were divided into groups treated with either CESP, ACP, or control solutions. The specimens underwent pH cycling to simulate oral demineralization and remineralization conditions. Evaluation methods included microhardness testing and lesion depth analysis to assess mineral gain. The results demonstrated that both CESP and ACP significantly enhanced enamel remineralization compared to controls, with CESP showing comparable or superior effects in increasing surface microhardness and reducing lesion depth. The study concluded that chicken eggshell powder solution is an effective, natural, and economical remineralizing agent capable of promoting the repair of early enamel lesions, offering a promising alternative to conventional calcium phosphate-based treatments.

[14] evaluated the effect of nano-hydroxyapatite (nHA) crystals derived from chicken eggshell on the microhardness of bleached human enamel in comparison with a commercial casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) paste. The study synthesized nHA powder from chicken eggshell using a combustion method and prepared a slurry applied to bleached enamel surfaces. Forty maxillary anterior teeth were divided into four groups: unbleached control, bleached only, bleached plus CPP-ACP treatment, and bleached plus nHA treatment. After two weeks of storage in artificial saliva, Vickers microhardness testing showed that bleaching with 30% hydrogen peroxide significantly reduced enamel microhardness. Both CPP-ACP and eggshell-derived nHA significantly restored microhardness to levels comparable to the control, with no significant difference between the two treatments. The study concluded that nano-hydroxyapatite sourced from chicken eggshell is as effective as CPP-ACP in remineralizing and restoring the microhardness of bleached enamel, suggesting its potential as a natural and cost-effective alternative for enamel remineralization following bleaching procedures.

[3] evaluated the remineralizing effects of eggshell powder and novamine on initial caries-like lesions in young permanent teeth in an in vitro study. The study involved 96 permanent teeth, each sectioned into two halves to serve as treated and control specimens. Artificial carious lesions were created by immersing the specimens in a demineralizing solution. The teeth were then divided into three groups treated with eggshell powder solution, novamine toothpaste, or fluoride toothpaste. Microhardness testing and lesion depth measurements were used to assess remineralization. Results showed that both eggshell powder and novamine significantly increased enamel microhardness and reduced lesion depth compared to their controls, whereas fluoride showed no significant difference from its control. Furthermore, eggshell powder and novamine demonstrated superior remineralization effects compared to fluoride. The authors concluded that eggshell powder and novamine are effective, safe alternatives to fluoride for remineralizing early enamel carious lesions in young permanent teeth, although they noted limitations related to the in vitro design and the inability to fully replicate oral conditions.

As a natural byproduct, eggshell powder is biocompatible, widely available, and environmentally friendly, making it an attractive alternative to synthetic or fluoride-based agents, especially in populations where fluoride use is limited or contraindicated. The favorable physicochemical properties of eggshell powder, including its high calcium content and ability to be processed into nano-sized particles, support its incorporation into toothpastes, pastes, and other dental care products for both preventive and restorative

purposes.

[6] conducted an in vitro study to quantitatively evaluate the remineralization potential of chicken eggshell powder (CESP) solution on early demineralized enamel lesions and to assess the resistance of the treated enamel to further acidic challenges. The study used 36 sound human premolars with standardized enamel windows, which were artificially demineralized by immersion in a demineralizing solution. The specimens were divided into two groups based on treatment frequency: one group was immersed once daily and the other twice daily in CESP solution for 12 minutes over seven days, with storage in artificial saliva between treatments. Following treatment, the samples underwent a five-day pH cycling regimen simulating alternating demineralization and remineralization. Calcium and phosphorus content were analyzed using energy-dispersive X-ray analysis, while enamel surface morphology was examined by scanning electron microscopy. Results showed that twice-daily treatment significantly increased calcium content and the Ca/P ratio compared to once-daily treatment, indicating enhanced remineralization. Both groups demonstrated improved resistance to acid challenges after treatment. SEM images supported these findings, showing surface deposition consistent with remineralization. The study concluded that chicken eggshell powder solution effectively remineralizes early enamel lesions and enhances enamel resistance to subsequent acidic attacks, highlighting its potential as a natural and economical remineralizing agent.

[8] developed and evaluated a novel experimental toothpaste formulated with Coturnix (quail) eggshell to assess its abrasive and remineralizing efficacy on dental enamel. The in vitro study compared the surface microhardness of bovine enamel and the surface roughness of polymethylmethacrylate (PMMA) blocks treated with the quail eggshell toothpaste against several commercial polishing pastes. Results showed that the quail eggshell toothpaste significantly enhanced enamel microhardness, achieving the highest remineralizing effect (272 ± 21.18 kg/mm^2) compared to the control and other commercial pastes. In terms of abrasive efficiency, it maintained a moderate surface microroughness (1.16 ± 0.40 µm), which was higher than some commercial pastes but still within acceptable limits for clinical use. The study concluded that the quail eggshell-based toothpaste is effective as a remineralizing agent while providing adequate polishing properties, highlighting its potential as a natural, sustainable, and cost-effective alternative for dental care products aimed at enamel remineralization and surface maintenance.

[10] conducted a systematic review to evaluate the microhardness and remineralizing effects of chicken eggshell powder (CESP) on dental erosion. The review followed PRISMA guidelines and included four in vitro studies that investigated the impact of eggshell powder on extracted human teeth subjected to erosive challenges. The analysis found consistent evidence across all studies that eggshell powder treatment significantly increased enamel microhardness and enhanced remineralization of erosive enamel surfaces, while also reducing surface roughness. The authors concluded that chicken eggshell powder is an effective natural agent for promoting enamel remineralization and mitigating dental erosion, highlighting its potential as a cost-effective and biocompatible alternative in preventive dental care.

[9] conducted a comparative in vitro study assessing the remineralization characteristics of nano-hydroxyapatite (nHAp) extracted from waste eggshells (EnHAp) and fish scales (FnHAp). The study detailed the extraction methods and analyzed the physicochemical properties of the nHAp samples, including Ca/P ratio, crystallinity, particle size, surface morphology, and buffering capacity. Results showed that EnHAp exhibited higher crystallinity, superior buffering effects against citric acid, and smaller particle size compared to FnHAp. These properties contributed to enhanced dentine tubule occlusion, as confirmed by field scanning electron microscopy, with EnHAp demonstrating a significantly greater percentage of occluded dentine tubules ($p < 0.001$). The smaller particle size of EnHAp allowed better

attachment to dentinal surfaces, facilitating effective remineralization. The study concluded that nano-hydroxyapatite derived from eggshells is a more favorable and sustainable bio-waste material for dental remineralization applications than that derived from fish scales, offering promising potential for the development of eco-friendly oral healthcare products.

[1] investigated the effects of eggshell powder (ESP) and nano-hydroxyapatite (nHA) on the surface roughness and microhardness of bleached enamel in their study. Using fifty bovine anterior teeth, the authors applied an in-office bleaching agent and subsequently treated the enamel with either 10% ESP solution, 10% nHA solution, or a commercial remineralizing agent (MI Paste Plus). Surface roughness and microhardness were measured to assess the impact of these treatments. The results demonstrated that bleaching significantly increased enamel surface roughness and decreased microhardness. However, application of ESP, nHA, and MI Paste Plus effectively reduced surface roughness and enhanced microhardness compared to bleached enamel without treatment. Notably, ESP showed the greatest improvement in microhardness, followed by nHA and MI Paste Plus. The study concluded that both eggshell powder and nano-hydroxyapatite serve as effective remineralizing agents capable of reversing the adverse effects of bleaching on enamel surface properties, suggesting their potential use in clinical dental practice to mitigate bleaching-induced enamel damage.

Eggshell-derived materials have been effective in reversing the adverse effects of bleaching, repairing post-orthodontic white spot lesions, and remineralizing early carious and erosive lesions. Their efficacy is supported by improvements in both surface and subsurface mineralization. Eggshell powder has emerged as a promising natural remineralizing agent due to its high calcium carbonate (94%) and trace mineral content. The calcination process, which involves heating eggshells to high temperatures, converts calcium carbonate into bioactive calcium oxide, enhancing its remineralization potential. Studies have demonstrated that ESP effectively replenishes lost minerals in bleached enamel. For instance, [1] found that a 10% ESP solution significantly increased enamel microhardness (345.11 VHN) compared to untreated bleached enamel (282.78 VHN). Similarly, [13] reported that ESP restored calcium and phosphate levels in demineralized enamel, performing comparably to synthetic amorphous calcium phosphate (ACP). The alkaline pH of ESP solutions (pH ~11.7) further promotes remineralization by maintaining a supersaturated environment conducive to mineral deposition.

[2] conducted an in-vitro study to evaluate the remineralizing effect of chicken eggshell paste on enamel surfaces following the removal of fixed orthodontic appliances. The research involved preparing enamel samples from extracted human premolars, which were subjected to demineralization during orthodontic treatment simulation. After debonding the orthodontic brackets, the samples were divided into groups, with one group treated with chicken eggshell paste and others serving as controls or receiving alternative treatments. The methodology included application of the remineralizing agents, followed by assessment of enamel surface microhardness and morphological changes using Vickers microhardness testing and scanning electron microscopy. The key findings revealed that the application of chicken eggshell paste significantly increased the microhardness of demineralized enamel compared to the control group, indicating effective remineralization. The study concluded that chicken eggshell paste is a promising, natural, and cost-effective agent for enhancing enamel remineralization after orthodontic treatment, potentially reducing the risk of post-orthodontic enamel demineralization.

[4] conducted an in vitro study to assess the remineralizing potential of cuttlefish bone powder (CBP) and eggshell powder (ESP) on demineralized human enamel. The study used 40 extracted premolars divided into four groups: untreated control, demineralized only, demineralized treated with CBP solution, and

demineralized treated with ESP solution. Demineralization was induced using a demineralizing solution to simulate early enamel lesions. The treated samples were analyzed using scanning electron microscopy (SEM), energy-dispersive X-ray analysis (EDAX), and microhardness testing. The findings showed that both CBP and ESP solutions significantly improved enamel surface morphology, increased calcium and phosphorus content, and enhanced microhardness compared to the demineralized group. These results indicate that CBP and ESP have effective remineralizing properties and could serve as promising, natural, and cost-effective agents for repairing early enamel lesions and preserving tooth structure.

[11] conducted an in vitro study comparing the remineralization potential of undemineralized dentin powder (UDD) versus chicken eggshell powder (CESP) on artificially induced initial enamel carious lesions. The study used 100 sound maxillary premolars divided into four groups: baseline (no treatment), negative control (demineralized enamel), CESP-treated, and UDD-treated. After creating artificial carious lesions, the treated groups were immersed in their respective remineralizing solutions. The evaluation involved Vickers microhardness testing, scanning electron microscopy (SEM), and energy dispersive X-ray analysis (EDX) to assess enamel surface changes and mineral content. Results showed that both CESP and UDD treatments significantly increased enamel microhardness compared to the negative control, with UDD-treated samples exhibiting microhardness values closer to baseline. SEM revealed more complete enamel remineralization and prismatic enamel coverage in the UDD group, whereas the CESP group showed partial remineralization. Additionally, the Ca/P ratio increased significantly in both treated groups, with a higher increase observed in the UDD group. The study concluded that both biomimetic UDD and CESP powders are effective for treating early enamel carious lesions, with UDD demonstrating superior remineralization potential.

[7] investigated the effect of chicken eggshell powder (CESP) solution on the microhardness of artificially induced cemental erosion in an in vitro study. The study aimed to assess the remineralizing potential of CESP, which is rich in calcium and phosphorus, on cemental surfaces subjected to erosive challenges. Artificial cemental erosion was created on extracted human teeth, and the samples were treated with CESP solution at different application intervals. Microhardness testing was performed to evaluate the recovery of the eroded cementum. The results demonstrated that treatment with CESP significantly increased the microhardness of eroded cementum compared to untreated controls, indicating effective remineralization. The study concluded that chicken eggshell powder solution is a promising, natural, and cost-effective agent for enhancing microhardness and potentially protecting against cemental erosion, supporting its potential use in preventive and restorative dental care.

Most evidence to date is derived from laboratory studies. While these provide strong mechanistic and comparative data, clinical trials are needed to confirm efficacy, safety, and optimal application protocols in real-world oral environments. Also, variability in ESP preparation methods (e.g., calcination temperature, particle size) complicates direct comparisons between studies. Further research should focus on standardizing ESP formulations, concentrations, and application regimens to maximize remineralization outcomes and ensure reproducibility across studies.

4. Conclusion

In conclusion, eggshell powder and its derivatives, including nano-hydroxyapatite synthesized from eggshells, offer significant promise as natural, cost-effective, and sustainable agents for dental remineralization. Across a range of in-vitro studies, eggshell-based materials have consistently shown the ability to restore microhardness, reduce surface roughness, and enhance the mineral content of demineralized enamel. These effects are observed in various clinical scenarios, including post-bleaching,

post-orthodontic treatment, early carious lesions, and erosive challenges.

Recommendation
Further clinical studies are needed to validate their long-term effectiveness, evaluating their effects in combination with other remineralizing agents and optimize application protocols. Integrating these natural remineralizing agents into post-bleaching care protocols could enhance enamel recovery while minimizing adverse effects.

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