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Remineralizing Potential of Chicken Egg Shell Powder in Demineralized Dental Tissue

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Abstract

With the increasing emphasis on preventive and minimally invasive dentistry, there is a growing demand forsustainable and biocompatible materials that support enamel remineralization. Chicken eggshell powder (CESP), a naturalbyproduct rich in calcium and other bioactive compounds, has emerged as a promising eco-friendly alternative for dentalapplications. This review explores the potential of CESP in remineralizing demineralized dental substrates, examining itsphysicochemical properties, biocompatibility, and mechanism of action in restoring enamel integrity. Studies havedemonstrated that CESP can effectively promote mineral deposition, enhance surface hardness, and potentially reverseearly-stage carious lesions, making it a viable candidate in non-invasive treatment protocols. This article consolidatescurrent research on CESP's dental applications, highlighting its benefits,

limitations, and future prospects in clinicalpractice. The findings support further exploration of CESP as a cost-effective and environmentally responsible approach topreventive oral care. The aim of this review article is to critically evaluate the potential of chicken eggshell powder(CESP) as a sustainable, biocompatible, and effective agent for the remineralization of demineralized dental tissues.

Keywords: Calcium Phosphate, Eggshell Powder, Enamel, Hydroxyapatite, Noninvasive Dentistry, Remineralization.

Introduction

Deficiency of calcium in the diet is a common problem. Calcium intake from dairy products is an appropriate way to fulfill calcium requirements. However, people do not usually consume them in the amounts established by clinical guidelines. Supplementation with tablets is costly and sometimes involves difficulties of adherence to treatment. Chicken eggshell powder is a source of calcium, which is available at home and can be used for calcium supplementation.

Utilization of eggshell is an inexpensive approach to reduce the chances of calcium deficiency and other problems associated with it[1].

The poultry sector is growing across the globe owing to urbanization, population increase and rise in purchasing power. From the year 1961 to 2017, the global production of eggs has increased from 15 to 87 million tonnes to fulfil surge in demand. In developing countries, around 80% rural households raise poultry. A global output of more than 60% makes Asia the highest eggproducing region. With 42% of production, China is the largest egg producer worldwide, with 7% production United States stands second and India with 6% production is third in the position.

In 2018, the global egg production was 76.7 million tonnes with China producing 26.90 million tonnes in 2018 followed by United States of America with a gross annual production of 6.46 million tones and India at a third position with annual produce of 5.23 million metric tones. In India according to the department of animal husbandry, Andhra Pradesh, Tamil Nadu, Telangana, West Bengal and Haryana are the top egg producing states with a contribution of nearly 65% to the total egg production of the country. Andhra Pradesh is the major egg producer in the country with a contribution of over 19% in the total production . As per Indian Council of Medical Research (ICMR), the recommended consumption of eggs per person per year is 180. The actual consumption is however very less as compared to the recommendations. In cities, the consumption is 90-105 eggs per person per year and in rural areas it is 50-70 only[21].

In the recent years, several attempts have been made to utilize eggshell waste. Around 750-800mg of calcium can be obtained from a teaspoon of eggshell powder, which is a good amount of calcium to prepare food products fortified with calcium. The calcium from eggshell is a good natural source of calcium and is better than calcium obtained from sources like limestone and coral. The absorption of calcium derived from eggshell is around 90%[2].

Interestingly, CESP has been identified as a promising biomimetic substance, Owing to its well-documented efficacy in promoting enamel remineralization together with its wide range of application in several medical and dental fields.[1]

For instance, the unique role of CESP in enhancing remineralization process has been demonstrated. This was confirmed through previous studies showing that CESP-driven nanohydroxyapatite can effectively seal

dentinal tubules and their lateral extensions in treated root canals when combined with sodium fluoride.3 Furthermore, the combined application of CESP and nanohydroxyapatite crystals on bleached enamel specimens has resulted in the highest microhardness and the lowest surface roughness compared to untreated samples[4].

Onwubu, Mhlungu & Mdluli (2019) synthesized eggshell-derived EnHAp via wet chemical precipitation. EnHAp- treated dentin showed ~97 % tubular occlusion, outperforming eggshell powder, calcined powder, calcium phosphate, and Colgate Sensitive treatment[13].

Onwubu et al. (2020) studied nanohydroxyapatite synthesized from eggshell waste via mechanochemistry.

FESEM and XRD confirmed full dentin tubule occlusion and excellent acid resistance, with particle sizes ~9–21 nm and high crystallinity (~82%)[14].

EB-TiO_2 composite (eggshell modified with titanium dioxide) showed complete remineralization of dentin tubules and could resist acidic challenge in bovine dentin blocks, confirming a promising low-cost desensitizing agent[15].

Hussein et al (2021) conducted an in vitro study on The Effect of Eggshell and Seashell Nanoparticles Alone and Combined With Nd: YAG Laser on Occlusion and Remineralization Potential of Patent Dentinal Tubules. Nanoparticles of eggshell (and seashell) tested with and without Nd:YAG laser; both showed significant dentinal occlusion and Ca^{2+} uptake. Laser offered no extra benefit over particles alone[16].

Saravana Karthikeyan, B.; Mahalaxmi, S. (2024), in International Journal of Biological Macromolecules, authored "Biomimetic dentin remineralization using eggshell-derived nanohydroxyapatite with and without carboxymethyl chitosan." Their in vitro study on pre-demineralized human dentin revealed that the EnHA-CMC combination achieved full tubular occlusion, highest microhardness, and improved collagen stability without cytotoxicity[17].

Kunam et al in 2016, Compared effects of EnHAp alone versus EnHAp + 2 % NaF on extracted human dentin discs. Found that combining nHAp with 2 % fluoride resulted in complete tubule occlusion and greater penetration depth. Concluded that fluoride addition amplifies the occlusive effectiveness of eggshell-derived nHAp[18].

Baskar et al, in 2021 Prepared porous scaffolds combining EnHAp and CMC (optimized at 1:5 w/w). Tested with human dental pulp stem cells (hDPSCs), showing enhanced cell viability, DSPP and VEGF expression over 3 weeks. Suggested the composite scaffold supports dentin regeneration potential in tissue engineering contexts[19].

Rani at al,in 2023, Combined EnHAp with phytosphingosine, assessing mineral deposition using Micro-Raman & SEM Demonstrated improved mineral uptake and occlusion, with enhanced acid resistance. Suggested that phytosphingosine significantly boosts EnHAp performance in dentin remineralization[20].

Composition

Component	White eggshell powder
Moisture (%)	0.46
Protein (%)	3.92
Ash (%)	94.61
Fat (%)	0.35
Calcium (%)	34.12
Magnesium (%)	0.29
Phosphorus (%)	0.04
Potassium (%)	0.03
Sodium (%)	0.05
Copper (ppm)	<1 ppm
Iron (ppm)	22 ppm
Magnesium (ppm)	<1 ppm
Zinc (ppm)	<1 ppm

Discussion

In recent decades, modern dentistry has increasingly emphasized noninvasive approaches for managing initial carious lesions, aiming to halt their progression and enhance the esthetics, strength, and functionality of dental hard tissues.

Demineralization, encompassing both caries and erosion, presents a significant global oral health burden, driven by intricate interplay between causative and protective factors. Fortunately, these processes can be partially reversed through a combination of pH neutralization and remineralization, facilitated by the incorporation of calcium phosphate components into the hydroxyapatite crystals. A variety of agents chiefly based on fluoride, and newer ones such as hydroxyapatite-based, casein phosphopeptide–amorphous calcium phosphate fluoride, as well as nutritional/herbal components have been utilized for this purpose.

Calcium carbonate (CaCO3) from eggshells could provide substitute minerals used in paper treatment to improve its surface brightness, opacity, and strength. This chemical compound can also be used to enhance the texture and appearance of the paper among other functions such as abrasives on different textures.

Therefore, this research aimed to demonstrate the effectiveness of eggshell in the field of dentistry.

Jain, et al., in 2025 conducted a study on Biomimetic remineralization of enamel and dentin with chicken eggshell slurry, they concluded that the elevated pH of the chicken eggshell solution, coupled with the abundant bioavailable calcium content, holds the potential to favor remineralization. The findings suggest that the application of CESP slurry could contribute to the remineralization process[5].

Nano-hydroxyapatite (nHA) is a biocompatible and bioactive agent. It attracts large amounts of calcium and phosphorous ions from the remineralizing solutions to the enamel surface promoting enamel remineralization. The study conducted on Effect of Eggshell Powder and Nano-Hydroxyapatite on the Surface Roughness and Microhardness of Bleached Enamel by Hassan et al., in 2023, they reported that the application of the tested remineralizing agents following the bleaching procedure had improved the surface roughness and microhardness of the bleached enamel. ESP and nHA present promising and potent remineralizing agents[6].

Feroz et al., in 2017 studied the Protective Effect of Chicken Egg Shell Powder Solution (CESP) on Artificially Induced Dental Erosion and concluded that CESP reduces the surface roughness of all treated teeth samples giving the protective effect of CESP againts erosive enamel loss[7].

Availability of calcium and phosphate ions is essential for remineralization to occur and increased pH of the solution along with rich bioavailability of phosphate and calcium ions is mainly involved for the process of remineralization. Thus by maintaining the state of supersaturation of these Calcium and phosphate ions promotes remineralization and depresses the process of erosion on tooth surfaces. CESP application results in the remineralization due to rich bioavailability of calcium as well as phosphate ions along with increased pH.

Allam et al., in 2018 conducted a study on the Mechanical Properties, and Calcium and Fluoride Release of Glass- Ionomer Cement Modified with Chicken Eggshell Powder and they concluded that The mechanical properties of conventional GIC were enhanced by the addition of CESP8. GIC unique property of fluoride release is not compromised by adding CESP to its powder component. Calcium release was potentiated at 5% CESP concentration, which can enhance the remineralizing ability of GIC.

In 2024, Eliwa et al., conducted a study on Enamel remineralisation prospect of Moringa Oleifera hydrogel, eggshell hydrogel versus sodium fluoride varnish on artificially demineralised primary teeth they reported that Moringa Oleifera hydrogel and Eggshell hydrogel have the ability to increase surface microhardness of demineralised enamel even higher than fluoride varnish[9]. Eggshell hydrogel has a promising future in treating initial enamel surfaces lesion due to its natural source of minerals and easy bioavailability. It may be used in the impending future for the remineralisation of early enamel caries.

Malaghan et al., in 2024 conducted a study on Remineralizing Potential of Chicken Eggshell Paste and Casein Phosphopeptide-Amorphous Calcium Phosphate on Surface Hardness of Bleached Enamel Surface and concluded that Chicken eggshell paste can be used as an alternate to commercially available remineralizing agents[10].

Despite the cariostatic effect of fluoride, the continuous use of fluoridated toothpastes increases the risk of dental fluorosis. Therefore, new safe alternative technologies of teeth remineralization must be introduced to arrest dental caries and remineralize the early enamel carious lesions. Mohamed et al., in 2020 conducted a study on Remineralization effect of egg shell powder and novamine on initial caries-like lesions in young permanent teeth they concluded that both egg shell powder and novamine can be used as remineralizing agents. Both egg shell powder and novamine appear to have a greater effect on remineralization of initial caries-like lesions when compared to fluoride in young permanent teeth[11].

Hussein et al., in 2022 conducted a study on the effect of eggshell and seashell nanoparticles alone and combined with nd: yag laser on occlusion and remineralization potential of patent dentinal tubules concluded that both eggshell and seashell nanoparticles are effective in the occlusion and remineralization of dentinal tubules. The combined treatments with Nd: YAG laser had no benefits when compared to the effect of treatments alone[12].

Conclusion

Eggshell-derived compounds have demonstrated significant potential in promoting dental remineralization. Their high calcium and phosphate content, along with elevated pH, facilitates enamel and dentin recovery. Studies confirm that eggshell powder, slurry, paste, and hydrogel enhance surface micro hardness and reduce erosion. Eggshell-based agents perform comparably or superiorly to conventional fluoride treatments in some cases. Nano-hydroxyapatite and eggshell combinations show synergistic effects in restoring bleached enamel.

Incorporation of eggshell powder into glass-ionomer cements enhances mechanical properties and ion release. Eggshell hydrogel may outperform fluoride varnish in remineralizing primary teeth. Natural, bioavailable, and safe, eggshell compounds offer promising alternatives to fluoride. Their application helps avoid risks like dental fluorosis associated with prolonged fluoride use. Eggshell-based remineralizing agents hold a promising future in minimally invasive, biomimetic dentistry.

Abbreviations

CESP-chicken egg shell powder, nHaP-nanohydroxyapatite, ENHAP – Eggshell-Derived Nano-Hydroxyapatite, SEM-scanning electro microscopy.

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