HAP E-Book

Discover the Power
of Hydroxyapatite (HAP)



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1 HAP: An unexpected Discovery

In the 1960s, at NASA's Electronics Research Centre in Cambridge, Massachusetts, a senior NASA scientist made an unexpected discovery that would bridge the gap between space research and oral health.

Bernard Rubin was growing crystals for use in semiconductors and found that using silica gel produced higher-quality crystals. This led to a groundbreaking realization: the crystal growth process in the gel closely resembled how calcium phosphate crystallizes during bone formation.

This insight sparked an idea. Hydroxyapatite (HAP), a form of calcium phosphate, is the primary mineral component of teeth and bones. Rubin and his colleagues recognized the potential to apply their findings to dental health. They filed a patent for a method to repair teeth by growing hydroxyapatite crystals directly on the tooth surface.

While NASA's original intent was to address bone and tooth density loss experienced by astronauts during zero-gravity missions, the implications of this research extended far beyond space travel. The patent caught the attention of Shuji Sakuma, who acquired it and invested several years of research into launching the world's first hydroxyapatite toothpaste in Japan in 1980.



The innovation behind hydroxyapatite and its use in dental care lies in its ability to remineralize teeth. It essentially repairs enamel by providing the same substance that naturally makes up tooth structure. Unlike fluoride, hydroxyapatite is biocompatible, making it entirely safe even if accidentally swallowed.

Over the past four decades, research has shown that hydroxyapatite not only helps prevent cavities but also reduces sensitivity and promotes a healthier oral microbiome.



2 What is Hydroxyapatite (HAP)?

Hydroxyapatite (HAP) is a naturally occurring form of calcium apatite.

This mineral, with its chemical formula $Ca_{10}(PO_4)_6(OH)_2$, comprises about 70% of human bone by weight, roughly 97% of dental enamel, and about 70% of the inner layer of the tooth (dentin). NASA researchers realized that if they could harness the power of HAP, they might be able to counteract the mineral loss experienced in space.

When used in oral care products, micro-sized particles of HAP can adhere to the tooth's surface and even penetrate the deeper layers of enamel. As HAP particles bind to the teeth, they fill in microscopic defects and pores in the enamel. Over time, this process can help remineralize teeth, potentially reversing early stages of decay and strengthening the overall tooth structure.

The benefits of HAP don't stop at remineralization. Research has shown that HAP can also:

1. Reduce tooth sensitivity by occluding dentinal tubules
2. Naturally whiten teeth
3. Help maintain a healthy oral microbiome
4. Stabilize mouth pH, creating an environment less conducive to tooth decay

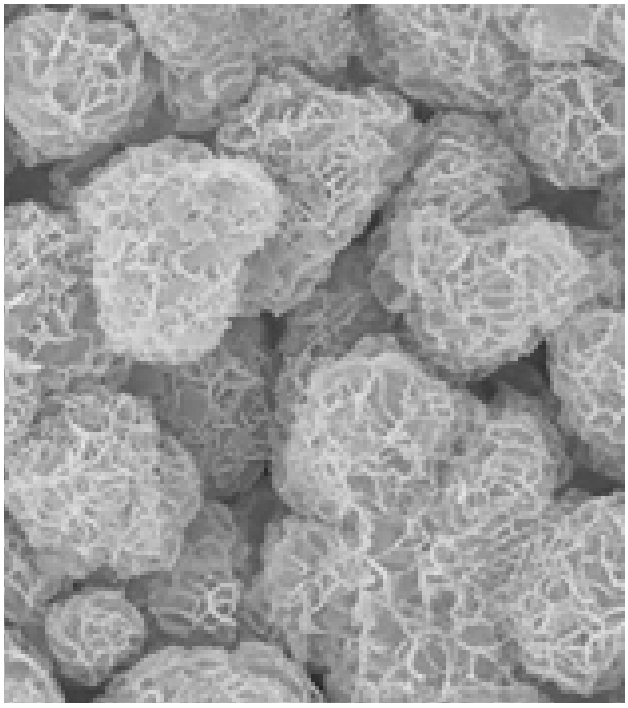


Fig. 1: Visualization of HAP Minerals

3 How HAP interacts with enamel

Our teeth face a constant onslaught from acids, bacteria, and everyday life's general wear and tear.

Enamel, the hardest substance in the human body, is already made up of tightly packed HAP crystals. These crystals form long, thin structures called prisms that interlock to create the strong, protective outer layer of our teeth. However, enamel is not impenetrable. Daily acid attacks from foods, drinks, and bacteria can cause these crystals to dissolve, leading to demineralization and, eventually, cavities.

Most people believe that fluoride is the only ingredient that prevents cavities, but HAP can do the same and has additional benefits.

When HAP is applied to your teeth, the particles are small enough to penetrate the micropores created by acid erosion. Like microscopic building blocks, they fill in these gaps, patching the weakened enamel areas. But their job doesn't stop there.

The presence of these HAP particles triggers a process called remineralization. They act as nucleation sites, attracting calcium and phosphate ions from saliva and other sources. These ions begin to crystallize, gradually rebuilding the enamel structure.





The benefits of HAP extend beyond just fighting cavities. It can help reduce tooth sensitivity by plugging up exposed dentin tubules. Perhaps most importantly for those concerned about fluoride intake, HAP is entirely safe if accidentally swallowed, as it's the same substance your body uses to build bones and teeth.

Ultimately, the story of HAP is one of biomimicry – science imitating nature to solve problems. By harnessing the very substance our bodies use to build strong teeth, research has created a powerful tool for oral health.

With regular application, the HAP particles can help create a new protective layer on the tooth surface. This layer not only fills in existing damage but also makes the tooth more resistant to future acid attacks.

"The interaction between HAP and tooth enamel is a testament to the power of biomimetic technology – science imitating nature to solve problems."

4 Benefits of Hydroxyapatite

Remineralization

When we eat food, the bacteria break down the sugar into acid, which attacks the tooth. Over time, these attacks can create tiny breaches - the beginnings of cavities. Hydroxyapatite has the ability to repair these microscopic defects. The HAP particles can fill in the micro gaps, essentially rebuilding the enamel. Unlike fluoride, which primarily works on the surface, HAP can penetrate deeper into the enamel structure, providing a more comprehensive repair.



Fig. 2: Visualization of HAP filling a micro defect

Cavity Prevention

HAP also plays a crucial role in preventing new cavities from forming. By creating a protective layer on the tooth surface, HAP acts as a shield against acid attacks. Moreover, HAP has been shown to interfere with bacterial adhesion to tooth surfaces, making it harder for plaque to form and reducing the overall bacterial load in the mouth. This multi-pronged approach to cavity prevention makes HAP a powerful ally in maintaining oral health.



Fig. 3: Dental X-ray used for cavity detection

Sensitivity Reduction

For many, tooth sensitivity is a daily struggle that can turn simple pleasures like enjoying ice cream into a painful experience. HAP offers relief by filling in the microscopic tubules in dentin that are exposed when the enamel wears away. By blocking these pathways to the nerve endings, HAP reduces the transmission of temperature and pressure sensations, effectively desensitizing teeth. Unlike some sensitivity treatments that work by numbing nerve endings, HAP addresses the root cause by repairing the tooth structure itself. (Limeback, Enax, & Meyer, 2023)

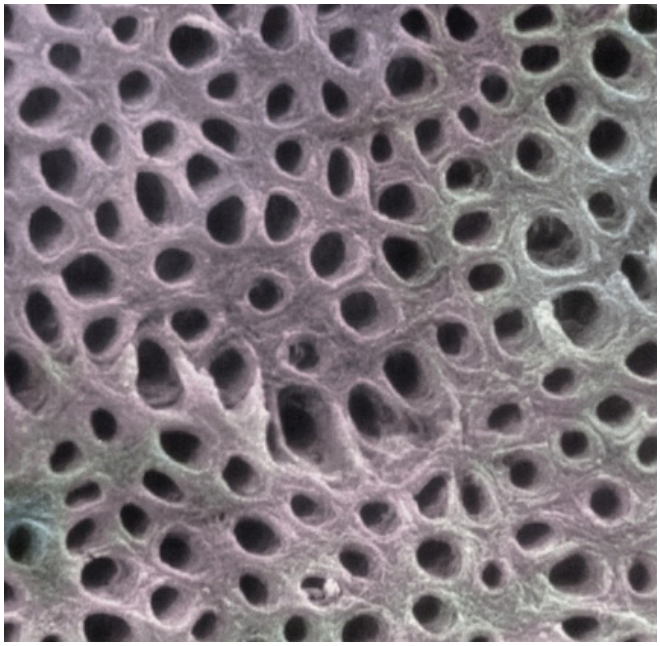


Fig 4: 2000x magnification of dentin tubules

Whitening Effect

It has been shown that HAP can have a natural whitening effect (Limeback, Meyer, & Enax, 2023). HAP creates a smoother, more reflective surface, as it fills in surface irregularities and micro-cracks in the enamel. This natural effect can lead to a noticeable brightening of teeth over time. Additionally, HAP's ability to repel stain-causing molecules helps maintain that brightness, offering a sustainable approach to tooth whitening, even though the effects are not as pronounced as traditional bleaching agents, such as hydrogen peroxide.

In conclusion, hydroxyapatite represents a paradigm shift in oral care. By working in harmony with the natural composition of our teeth, HAP offers a holistic approach to dental health. As research continues to unveil its benefits, HAP is poised to become a cornerstone of modern oral care routines, promising stronger, healthier, and brighter smiles.

5 Scientific Summary

Hydroxyapatite (HAP) has emerged as a promising alternative to fluoride in oral care products. This chapter explores the scientific principles behind HAP's effectiveness and presents evidence from various studies supporting its use in dental care.

1.Chemical Composition and Biomimetic Properties

With its chemical formula $Ca_{10}(PO_4)_6(OH)_2$, HAP is the primary mineral component of tooth enamel and dentin. Its biomimetic nature allows it to integrate seamlessly with natural tooth structure, making it an ideal candidate for remineralization and caries prevention. In contrast to fluorides, hydroxyapatites can be used without dosage limitations (no regulatory restrictions) and are safe for all age groups. (Pawinska, et al., 2023)

2. Remineralization Efficacy

Multiple studies and scientifc reviews have demonstrated HAP's ability to remineralize early caries lesions:

- Limeback et al. (2021) concluded that HAP reverses and remineralizes carious lesions and provides additional calcium and phosphate for improved remineralization.

- Amaechi et al. (2019) conducted a study comparing 10% HAP toothpaste to 500 ppm fluoride toothpaste. The results showed that HAP was equally effective in remineralizing early caries lesions in children's teeth.

3. Caries Prevention

Clinical trials have provided strong evidence for HAP's caries-preventing properties:

- Paszynska et al. (2023) conducted an 18-month double-blinded randomized clinical trial comparing a fluoride-free HAP toothpaste to a 1450 ppm fluoride toothpaste in adults. The study found that the HAP toothpaste was as effective as the fluoride toothpaste in preventing caries.

- Schlagenhauf et al. (2018) demonstrated the non-inferiority of a HAP toothpaste to a 1400 ppm fluoride toothpaste in preventing caries in orthodontic patients.

- Amaechi et al. (2020) showed that 15% HAP gel was as effective as 12,500 ppm fluoride gel in an in vitro pH-cycling study. While this study was done in the lab, it gives a promising indication for the caries prevention capabilities of HAP, as such highly concentrated fluoride gels have use restrictions, whereas HAP doesn't.

- A systematic review by Epple et al. (2022) concluded that HAP-based oral care products are at least as effective as fluoride in preventing caries and remineralizing initial lesions.

These studies suggest that HAP is a genuine alternative to fluoride when it comes to caries prevention and remineralization. Due to its high safety profile for the body, the environment, and the benefits of sensitivity reduction and natural whitening, HAP is a versatile and very powerful oral care agent.

6 Literature

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frsh wants you to smile your best – that's why frsh creates oral care products with Hydroxyapatite and other innovative and science-backed ingredients so that you can take optimal care of your most valuable asset: your smile.

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