Enamel demineralization and regeneration

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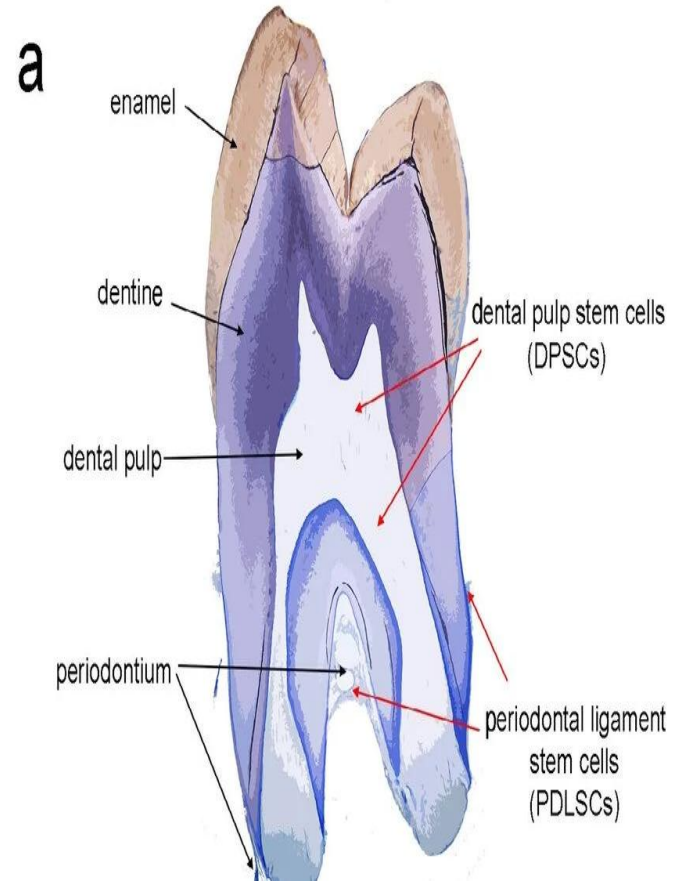
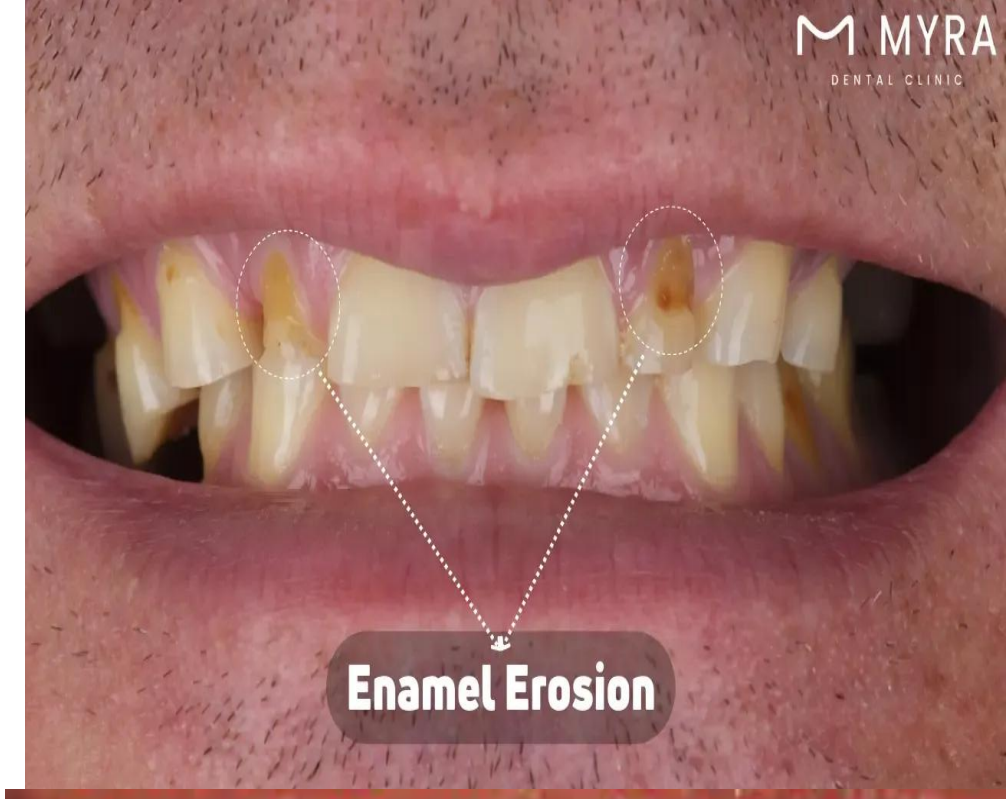
INTRODUCTION

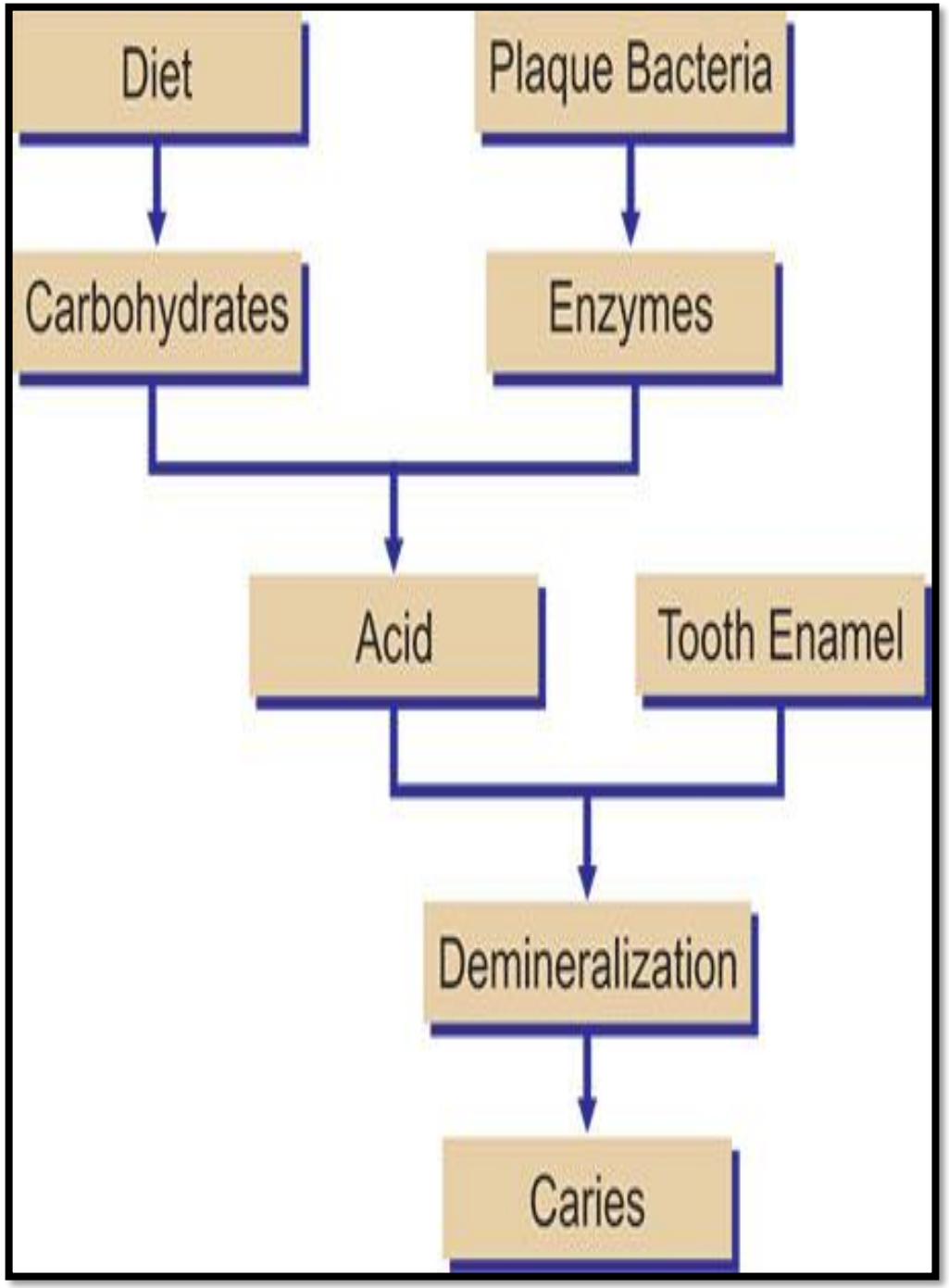
- **Tooth enamel, the hardest tissue in the human body, is a highly organized dental tissue that covers the outer layer of the tooth crown**
- **It possesses unique mechanical and structural properties due to its high hydroxyapatite (HAp) content. In its mature form, enamel consists of 96% HAp, 1% organic components, and 3% water.**



- **Enamel is subjected to various challenges, including abrasion, attrition, compressive stresses up to around 700 N and acidic attacks from food and plaque.**
- **The outermost portion of tooth enamel is in direct contact with saliva and plaque fluid, and the surfaces of the enamel HAp crystals maintain a dynamic equilibrium with these surrounding.**



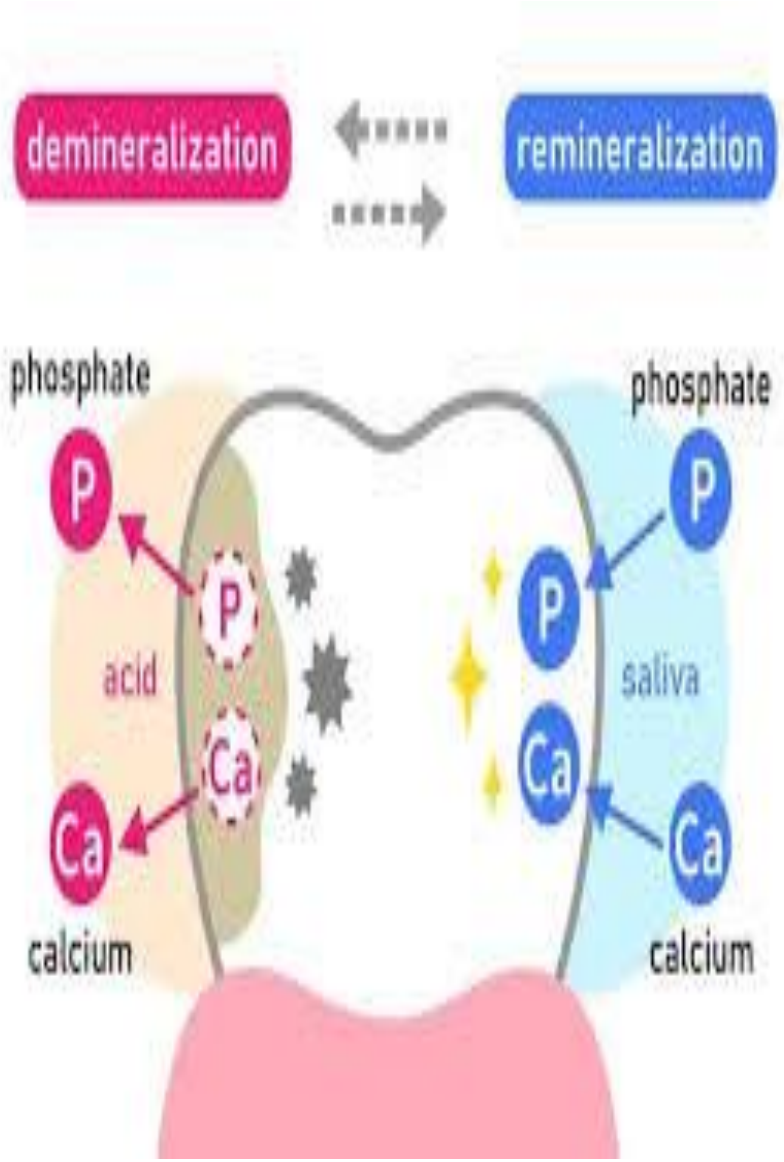
- **The pH and the concentration of calcium and phosphate ions in the surrounding solution directly affect enamel dissolution.**
- **This process contributes to oral health problems, such as dental caries and tooth erosion, which are linked to enamel demineralization.**



Enamel demineralization

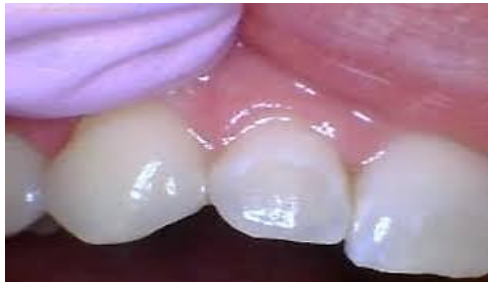
- **Demineralization**: refers to the process by which organic acids produced by plaque microorganisms destroy the mineral content (HA crystals).
- The most stable form of hydroxyapatite exists in an environment with a pH of 7.4.
- There is a constant chemical equilibrium between the hydroxyapatite in the enamel ($Ca_{10}(PO_4)_6(OH)_2$) and the dissolved hydroxyapatite in the plaque biofilm.

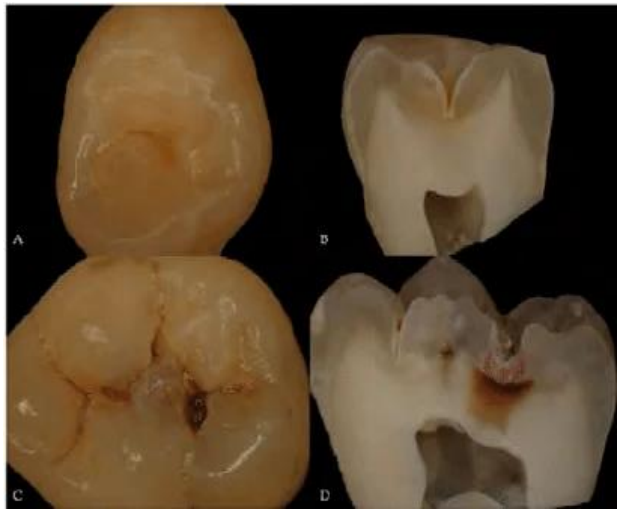
- **Mineral crystal dissolution takes place when the pH level of the plaque falls below 5.5.**
- **When the minerals are dissolved, the intercrystalline space expands, and the surface of the enamel becomes softer and more porous, leading to the formation of caries.**
- **Demineralization compromises the structure and strength of enamel, making the teeth more susceptible to sensitivity, damage, and decay.**



Stages of demineralization

1. White spot lesions are considered the initial stage of enamel demineralization, which produced by bacterial plaque activity that is retained over enamel surfaces for a prolonged period.
2. White spot lesions are characterized by mineral loss from the enamel surface, which turns the enamel surface into a rough, opaque area that becomes apparent when dried by air. the surface consistency become softer.
3. Subsurface Lesion (Enamel Breakdown): The decay advances beneath the surface forming subsurface cavity. This stage marks the beginning of irreversible tooth damage.
4. Enamel Decay/Cavitation: The weakening leads to a physical hole (cavity) in the tooth enamel.

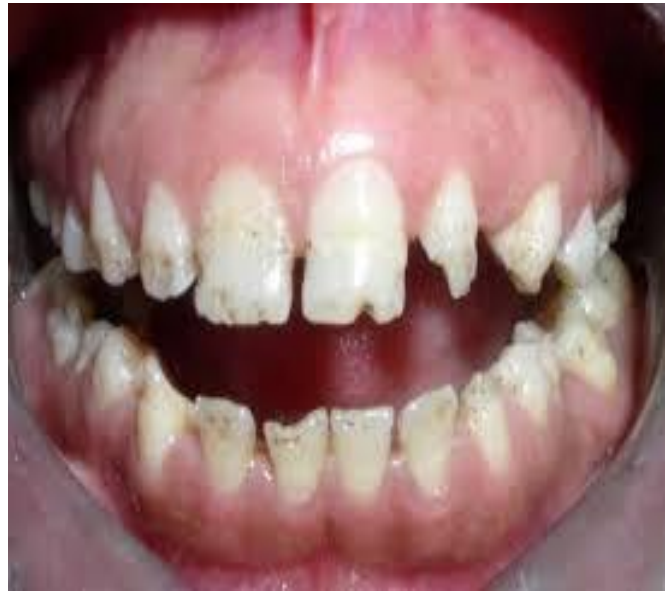




- **Early detection and prevention of demineralization and remineralization, are critical process to maintain enamel integrity before cavitation and using restorative materials.**
- **Unlike bone, which has regenerative capabilities due to its cellular and vascular tissue, enamel has limited regenerative potential because it lacks regenerative cells (ameloblasts) before tooth eruption**

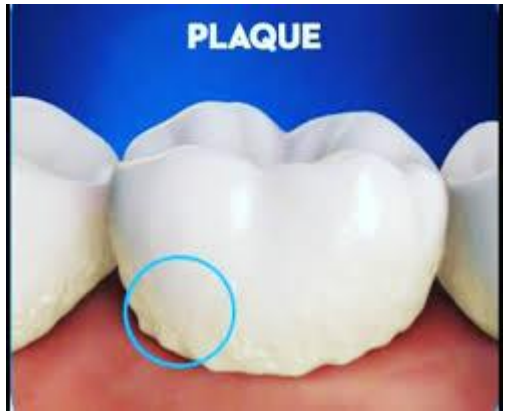
Signs of enamel demineralization is:

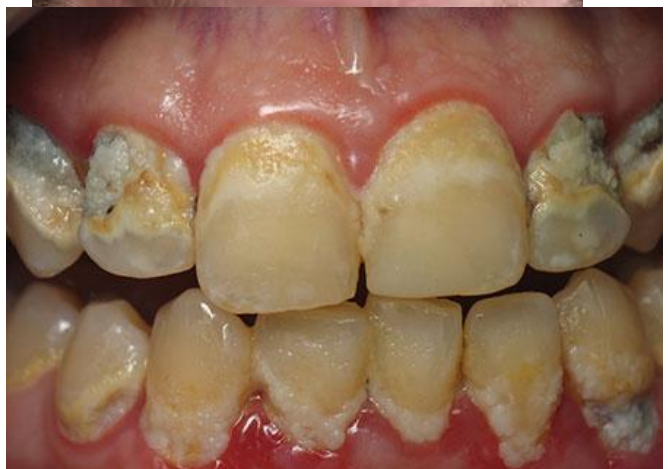
1. **White Spots on Enamel:** This is often the first and most common sign. dull, chalky white especially near the gingiva line or interproximal area.
2. **Some people experience discomfort or sharp pain while brushing or eating, especially with hot, cold, sweet, or acidic foods.**
3. **Cracks and enamel chipping may occur.**
4. **Rough or Pitted Tooth Surface on areas of demineralization.**
5. **Sensitivity becomes more intense, and in severe cases, biting or brushing can trigger acute discomfort.**



Causes of Demineralization

1. **Acid Attacks from Sugary Foods and Drinks: (like candies, sodas, fruit juices, and even some processed foods)**
2. **Poor Oral Hygiene: sticky film is called plaque act as home for those acid-making bacteria. The longer plaque stays on teeth, the more acid it produces, and the more demineralization occurs.**
3. **Dry Mouth (Xerostomia): Saliva has washing action, antibacterial action, neutralizes acids, and even contains minerals that help repair enamel. Dry mouth can be caused by certain medicines, medical conditions, or even just not drinking enough water.**





4. **Acidic Foods and Drinks (Even Healthy Ones):** Things like citrus fruits (oranges, lemons), tomatoes, and sparkling water can be acidic. While these are part of a healthy diet, having them very often or letting them sit on teeth for a long time can contribute to demineralization.

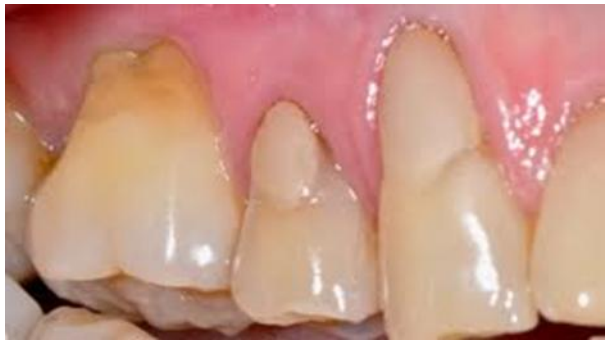
5. **Acid Reflux (GERD):** For some people, stomach acid can come back into their mouth, causing acid reflux or GERD. Stomach acid is very strong, and repeated exposure to it can severely demineralize tooth enamel.

Areas Most Affected

1. **Near the Gum Line**
2. **Around Orthodontic Brackets (Braces): white spots around the brackets when removed. Braces create lots of tiny nooks where food and plaque can get trapped, making it very difficult to clean.**
3. **In Between Teeth: without regular interdental flossing, interproximal areas become prime spots for acid attacks and demineralization.**

4. **On the occlusal Surfaces of premolars and molars: it contain tiny grooves and pits. These can trap food particles and bacteria. This is why dental sealants are often recommended for children – they fill in these grooves to protect them.**

5. **Exposed Root :the root covered by cementum which less mineralized than enamel, making it much more vulnerable to demineralization and decay.**



HOW TO TREAT ENAMEL DEMINERAIZATION

- Terms such as regeneration, remineralization, restoration, and repair are often used interchangeably
- Regeneration is the complete restoration of lost or damaged tissue to its original structure and function, through cellular or biomaterial-based methods.
- Remineralization is the replacement of lost minerals, such as calcium and phosphate, within demineralized enamel, is the replacement of lost minerals, such as calcium and phosphate.
- Restoration replaces lost tissue with synthetic materials without restoring biological function of the tissue.
- Repair refers to restore some degree of function but not necessarily the original structure.

Cellular enamel regeneration

- Since enamel-forming cells (ameloblasts) are lost after tooth development, alternative cellular sources are required to achieve cellular-based enamel regeneration.

- Non dental epithelium-derived human cells, including gingival epithelial cells or human keratinocyte stem cells (hKSCs) were suggested to differentiate into enamel-forming ameloblasts when combined with mouse or human embryonic dental mesenchyme.
- When dental epithelium and mouse embryonic dental mesenchyme were transplanted into renal capsules for 30 days, tooth-like structures with enamel and dentin formed.
- Similarly, human keratinocyte stem cells combined with embryonic mouse dental mesenchyme, enamel deposition in renal capsules was observed.

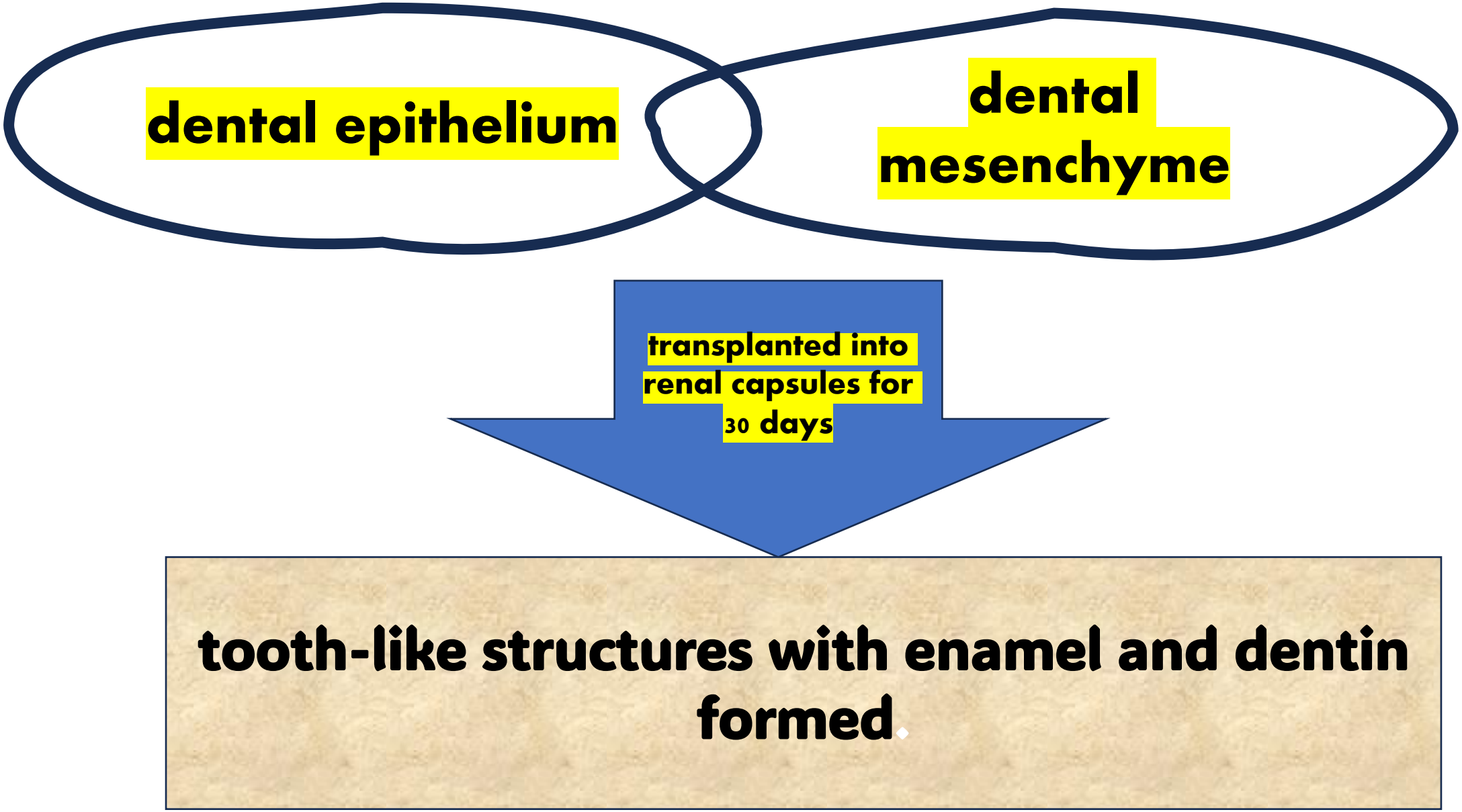
- gingival epithelial cells
- human keratinocyte stem cells (hKSCs)

+

- embryonic dental mesenchyme

mouse or human

enamel-forming ameloblasts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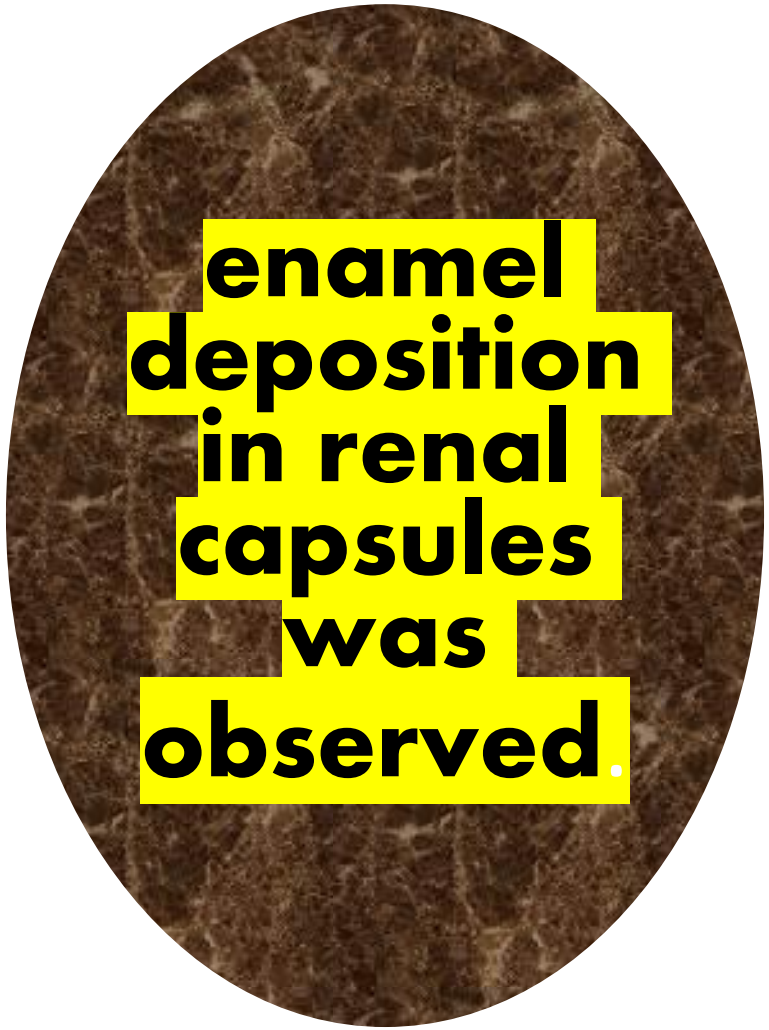


Limitation of enamel regeneration

- **Enamel regeneration is facing several challenges.**

1. **the arrangement of enamel prisms in regenerated tissue is somewhat asymmetrical.**
2. **The engineering of enamel tissue is further complicated by protein processing which required for crystal formation and the unique way in which ameloblasts shape hydroxyapatite (HAp) crystals into enamel rods.**
3. **the regenerated enamel-dentin complexes, which place enamel inside dentin in round or linear formations, do not replicate the morphogenetic characteristics of natural dental crowns.**

- **further research is essential to understand how to regenerate enamel tissue while precisely controlling both its shape and size.**

the enamel remineralization

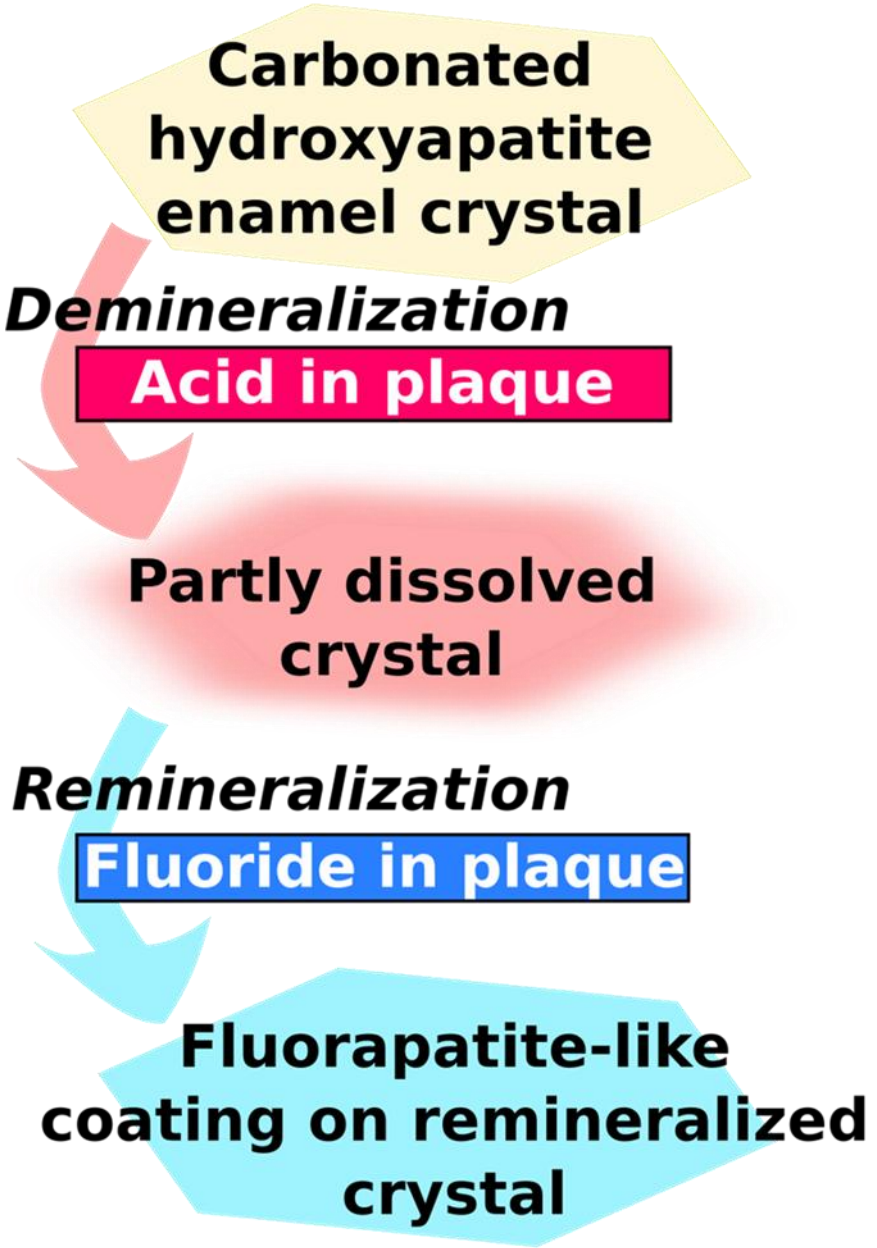
1-Fluoride therapy

- **Fluoride therapy promotes enamel remineralization by converting hydroxyapatite into less acid-soluble fluorapatite and calcium fluoride, strengthening the surface and reversing early caries.**
- **It acts as a gold-standard agent, with high-concentration varnishes and topical gels being highly effective at reducing white spot lesions and improving surface hardness**

Fluoride therapy

- **Mechanism:**

1. **Fluoride ions in saliva enhance mineral precipitation on demineralized enamel, forming acid-resistant fluoroapatite.**
2. **It also aids in reducing caries by impacting the metabolism of bacteria.**



CLINICALLY APPLIED TOPICAL FLUORIDE

- **These are applied by dental clinicians in dental clinics. Generally, 2-4 times a year.**

❖**Topical Applications:**

- **Fluoride Varnish (5% NaF): Applied with a brush to enamel and dentin, this sets upon contact with saliva, providing long-term contact. It is often preferred for young children or high-risk patients.**
- **Fluoride Gels (1.23% APF (Acidulated Phosphate Fluoride) Applied using trays that are inserted into the mouth for 4 minutes.**

➢the acid can etch and dull the surface of esthetic restorations.

- **Fluoride Foams: Applied similarly to gels using trays, often used to minimize the risk of ingestion in small children.**

- **Silver Diamine Fluoride (SDF): Used to arrest initial dentin caries and prevent further decay**.

➢It may cause permanent black staining of the decayed tooth or treated area (sound enamel does not stain).

- **Amine Fluoride: Amine fluoride often shows superior remineralization in comparison to other fluoride types**

- It spreads more evenly across tooth surfaces and can penetrate dental plaque more effectively than inorganic fluorides.

- Fluoride-Releasing Materials: Restorative materials like glass ionomer cements (GICs) and resin-modified glass ionomer cements (RMGICs) continuously release fluoride.

SELF APPLIED TOPICAL FLUORIDE

- **Fluoride Toothpaste (1000–1500+ ppm): The most common form of fluoride delivery, recommended for daily use.**
- **Fluoride Mouthrinses (0.05% NaF): Used as a daily or weekly rinse, beneficial for patients with high caries risk or ortho appliances.**
- **Fluoride Gels (0.5% APF or 1.1% NaF): Can be brushed on or used in custom trays at home.**

- **Fluoride has been shown to have caries preventive effects mainly through local topical application (post-eruptive effect).**
- **however, systemic fluoride administration may have pre-eruptive effects as well as cause dental fluorosis if fluoride is applied excessively during the tooth-development stage.**

the enamel remineralization

2-Laser aiding mineralization

- Lasers have been widely applied in dentistry for soft tissue cutting as well as bleaching of the teeth.
- Because of their photothermal properties, they can assist in crystal growth by warming the surrounding area and changing the reaction conditions.
- lasers can assist in preventing dental calculus from formation
- It can accelerate the mineralization of dental enamel and controlling the formation of HAp crystals in the affected areas.
- However, the primary drawback of this method is that the overheating effect of the diode laser may damage the dentinal and pulpal layers' nerve cells.