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RETRO-FUTURISM OF TEETH CLEANING

In the modern routine, most people begin their day by applying a dollop of toothpaste onto a toothbrush and brushing for about two minutes. This cleaning act aims to remove dental plaque — a microbial biofilm that accumulates on teeth due to the activity of oral bacteria. These microorganisms thrive on residual food particles from daily consumption and metabolise sugars to produce lactic acid. The oral cavity provides a favourable environment for this complex matrix of bacteria, salivary proteins, food debris, and extracellular polysaccharides to accumulate, proliferate, and mature. Our current staple and processed foods — often low in essential nutrients and high in sugar — further encourage the growth of cariogenic bacteria. The resulting plaque is highly acidic and, when left unremoved, gradually demineralises enamel, the hardest substance in the human body, composed primarily of hydroxyapatite.

To counter this damage, humans adopted the practice of oral hygiene. Historically, this involved natural abrasives like chewing sticks, crushed eggshells, and sand. In the present, it revolves around the toothbrush and toothpaste. Observing current trends, the future of oral care appears to be moving toward biomimetic dentifrices and AI-driven toothbrushes that adapt to individual oral microbiomes for personalised dental health. Despite regular brushing habits today, the prevalence of restorative dental treatments and tooth loss continues to rise. For a minute, let us take the route of temporal fluidity and try to arrive at a solution for preventing dental caries and other oral diseases; because in theory it is 100% preventable.

Teeth evolved as functional tools to aid in the mechanical breakdown of food, enhancing digestion and survival. Their origin traces back to dermal armor in early fish, eventually specialising for tearing, grinding, or cutting based on diet. This event took place in the palaeolithic era— a pre-agricultural phase in human history when diets were diverse, seasonal, and rich in protein, fibre, and micronutrients. These diets were naturally low in sugar and high in fibrous, abrasive foods, which passively helped maintain oral cleanliness and minimised cavities. As a result, tooth loss was less prevalent.

On the contrary, the agricultural times and societies i.e., the neolithic era introduced a reliance on a narrow range of starchy crops such as wheat and rice. While farming enabled food stability, population growth, and civilisation, it simultaneously decreased dietary diversity and introduced refined carbohydrates. These shifts worsened systemic and oral health, significantly increasing plaque formation and dental decay.

Progressing through the industrial and information ages, human diets have grown increasingly problematic — with ultra-processed foods, high sugar content, artificial additives, and diminished fibre. Toothbrushes and fluoridated toothpastes became the gold standard for oral hygiene, majorly due to commercial and consumer convenience. However, there is mounting evidence that the benefits of modern toothpaste are often outweighed by their biotoxic costs. Let us decipher further.

Before toothpaste dominated the market, tooth powder — a dry dentifrice — was the mainstream choice. It was simple, effective, and typically more biocompatible. However, as consumer preferences shifted (or were shaped), tooth powder was sidelined due to perceptions of inconvenience and challenges in mass production. The toothpaste format was developed for easier usage, palatability, and commercial scalability. But its formulation, dependent on non-inert excipients for maintaining its paste form, introduced a host of biocompatibility concerns.

Pharmaceutically speaking, pastes are derived from powders — a paste is simply powder mixed with a liquid base and stabilisers. The excipients required to stabilise a paste are often non-inert and can trigger biological responses over time. Hence, products that are not biocompatible may cause pathological effects — either immediately or cumulatively. From a present-day standpoint, earlier methods and materials for oral care — though less convenient — were more aligned with human biology: non-toxic, sustainable, and fundamentally biocompatible.

The future of teeth cleaning can continue down the path of non-biocompatible formulations or to pivot toward biocompatible, restorative solutions. The latter is not only righteous, but rational and increasingly necessary.

One of the solutions that treads this righteous path is rice husk, a byproduct of one of the most plaque-contributing staples in the world — rice. Agriculture gave us rice and wheat, both indispensable yet plaque-promoting. The innovation of using rice husk ash (RHA) as a dentifrice offers a profound form of poetic justice — transforming waste from a problem-causing staple into a preventive oral care solution.

The main functions of a dentifrice are:

1. To remove plaque
2. To remineralise enamel

Modern toothpaste achieves this primarily through fluoride (F^-), while RHA-based tooth powders achieve it through silica (SiO_2). The mechanism of action, however, are fundamentally different:

1. Fluoride-Based Remineralisation

Reaction (substitution of OH^- in hydroxyapatite):

$$Ca_{10}(PO_4)_6(OH)_2 + 2F^- \rightarrow Ca_{10}(PO_4)_6F_2 + 2OH^-$$

Explanation:

- Fluoride ions (F^-) replace hydroxyl groups (OH^-) in hydroxyapatite (HA).
- Resulting compound is fluorapatite, which is more resistant to acid but not structurally identical to native HA.

2. Silica-Based Remineralisation (Biomimetic Pathway)

Step-by-step Process:

a. Initial Binding and Scaffold Formation

$$SiO_2 + nH_2O \rightarrow SiOH$$

(silanol groups form on the silica surface)

- Nano-silica surfaces form silanol groups (Si–OH), which attract calcium (Ca^{2+}) and phosphate (PO_4^{3-}) ions from saliva.

<u>b. Nucleation (under physiological pH)</u>

$$Ca^{2+} + PO_4^{3-} \rightarrow Ca_{10}(PO_4)_6(OH)_2 \downarrow$$

- These ions begin to nucleate into new hydroxyapatite crystals directly on the silica scaffold.

<u>c. Crystal Growth and Integration</u>

New HA → Integration with native enamel lattice

- Reaction takes place under continued ionic supply
- This leads to layer-by-layer growth of hydroxyapatite, remineralising the enamel without altering its structure.

The following table and content further strengthens the case for silica as ideal remineralising candidate, over fluoride:

ASPECT	FLUORIDE-BASED TOOTH PASTE	SILICA-BASED TOOTH POWDER
SYSTEMIC RISK	High (fluorosis, glands' calcification, diminishing IQ)	Low
TISSUE COMPATABILITY	Moderate	High
BIOACCUMULATION	Yes	No
LONG-TERM USE	Risk of overdose	Safe for continuous use
INERT	No	Yes

In summary, the fluoride helps in remineralisation via substitution reaction by altering the original enamel lattice. While the silica helps in remineralisation via biomimetic reaction by preserving the original enamel lattice.

Thus, RHA based dentifrice represents a retro-futuristic approach to oral care—a model for the future of dentifrice formulations.