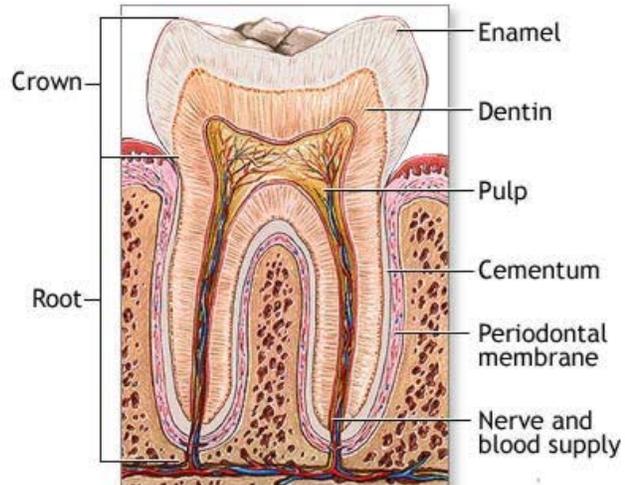


TOOTHPASTE

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INTRODUCTION

Toothpastes claim to clean, remove plaque, prevent cavities, and whiten teeth. Is there really a difference in toothpastes? Is one truly superior to another? Does a higher price mean a toothpaste is better?



Teeth are the calcified structures in our mouths that are used to break down food. Teeth are made of multiple tissues of varying density and hardness.

The two major parts of a tooth are the crown and the root. The roots of teeth are embedded in the maxilla (upper jaw) or the mandible (lower jaw) and are covered by our gums. The crown is the visible portion that extends above the gums.

The crown is covered by a glossy, white, hard coating called enamel. Enamel is composed primarily of the mineral hydroxylapatite, which is a crystalline calcium phosphate. The enamel is the hardest substance in the human body, but is brittle, subject to injury, and can also be worn down by abrasive action or acidic foods.

The layer located beneath the enamel is called the dentin. Dentin is a bone-like calcified connective tissue with an organic matrix of collagenous proteins. Dentin is not as hard as enamel and, although it is a protective layer, it is susceptible to decay. In a healthy mouth, however, there is only a shallow crevice between the enamel and the gums exposing little or no dentin.

Cementum is a specialized bone-like substance which covers the root of a tooth. It is approximately 45% hydroxyapatite, 33% collagen and 22% water. Cementum is excreted by cementoblasts within the root of the tooth and is thickest at the root apex. Its coloration is yellowish and it is softer than either dentin or enamel. Its principal role is to serve as a medium by which the periodontal ligaments can attach to the tooth for stability.

The dental pulp is the central part of the tooth filled with soft connective tissue. The pulp contains blood vessels and nerves that enter the tooth from a hole at the apex of the root. The pulp is commonly called "the nerve" of the tooth.

Almost immediately after a thorough cleaning, a thin, biofilm called the *pellicle* begins to coat the teeth, gums, and tongue. Pellicle is derived from proteins in saliva. Bacteria, along with stains from food and

drink, collect on the pellicle forming a gel-like material called *plaque*. The bacteria in the plaque ferment the sugars and starches in foods to produce lactic acid which dissolves the calcium and phosphorus in the tooth enamel. When enough demineralization occurs, bacteria can enter the dentin and cause decay. Tooth decay or cavities are known as *dental caries*.

Plaque can seep below the gumline and cause a mild gum disease called *gingivitis* resulting in gum inflammation.

Within 2 to 14 days of plaque formation, the plaque deposits will bond with minerals in the saliva to form a calcified deposit called *calculus*, more commonly known as *tartar*. The calcified tartar can only be removed by professional cleaning.

Oral hygiene is the practice of keeping the mouth clean and is a means of preventing dental caries, gingivitis, periodontal disease, bad breath, and other dental disorders. It consists of both professional and personal care. Healthcare professionals recommend regular tooth brushing at least twice a day (morning and evening) and after meals. A toothbrush is able to remove most plaque, except in areas between teeth and raises the pH of the tooth surface neutralizing acids. Flossing is also considered a necessity to maintain oral hygiene. When used correctly, dental floss removes plaque from between teeth and at the gum line, where periodontal disease often begins and could develop caries.

Regular cleanings, usually done by dentists and dental hygienists, remove tartar that may develop even with regular brushing and flossing. Professional cleaning may also include tooth scaling, which uses various instruments to remove deposits from teeth.

Toothpaste is a paste or gel dentifrice used, with a toothbrush, to clean and maintain the aesthetics and health of teeth. Toothpaste serves as an abrasive that aids in removing the dental plaque and food from the teeth, assists in suppressing halitosis, and delivers active ingredients such as fluoride or xylitol to help prevent tooth and gum disease. Most of the cleaning is achieved by the mechanical action of a toothbrush, and not by the toothpaste. Salt and sodium bicarbonate (baking soda) are among materials that can be substituted for commercial toothpaste.

Toothpastes are complex mixtures of abrasives and surfactants; anticaries agents, such as fluoride; tartar control ingredients, such as tetrasodium pyrophosphate and methyl vinyl ether/maleic anhydride copolymer; pH buffers; humectants (to prevent dry-out and increase the pleasant mouth feel); and binders, to provide consistency and shape. (See Table 1). Binders keep the solid phase properly suspended in the liquid phase to prevent separation of the liquid phase out of the toothpaste. They also provide body to the dentifrice, especially after extrusion from the tube onto the toothbrush.

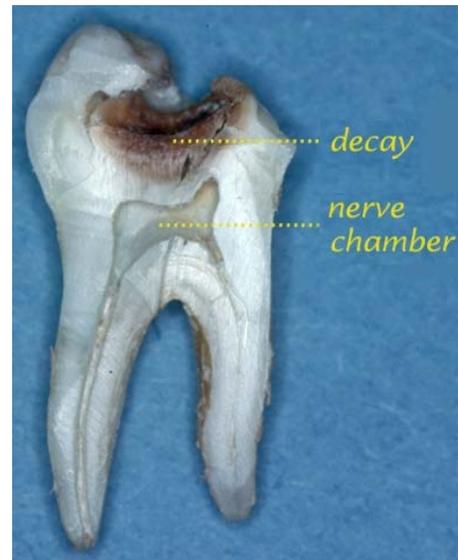


Table 1. Components of toothpaste

Ingredients	% by weight
Humectants	40-70
Water	0-50
Buffers/salts/tartar control	0.5-10
Organic thickeners (gums)	0.4-2
Inorganic thickeners	0-12
Abrasives	10-50
Actives/Antibacterial agent (e.g., triclosan)	0.2-1.5
Surfactants	0.5-2
Flavor and sweetener	0.8-1.5

Fluoride sources provide 1000-15000 ppm fluorine.

Table 2 lists typical ingredients used in formulations; the final combination will depend on factors such as ingredient compatibility and cost, local customs, and desired benefits and quality to be delivered in the product.

Table 2. Typical toothpaste ingredients

Gums	Inorganic Thickeners	Abrasives	Surfactants	Humectants	Tartar Control Ingredient
Sodium carboxymethyl cellulose	Silica thickeners	Hydrated silica	Sodium lauryl sulfate	Glycerin	Tetrasodium pyrophosphate
Cellulose ethers	Sodium aluminum silicates	Dicalcium phosphate dihydrate	Sodium N-lauryl sarcosinate	Sorbitol	Gantrez S-70
Xanthan Gum	Clays	Calcium carbonate	Pluronics	Propylene glycol	Sodium tri-polyphosphate
Carrageenans		Sodium bicarbonate		Xylitol	
Sodium alginate		Calcium pyrophosphate	Sodium lauryl sulfoacetate	Polyethylene glycol	
Carbopols		Alumina			

Table 3 lists the hardness of dental material and typical abrasives used in toothpastes. Hardness is measured using the Moh's Hardness Scale. The Moh's hardness scale ranges from 1 for talc ($Mg_3(Si_2O_3)_2(OH)_2$), to 10 for diamond.

Table 3 Moh's hardness of Dental Abrasives

Compound (Formula)	Moh's Hardness
Dentin	3.0-4.0
Tooth enamel	5.0
Baking soda, NaHCO ₃	2.5
Dicalcium phosphate dihydrate, CaHPO ₄ ·2H ₂ O	2.5
Calcium carbonate, CaCO ₃	3.0
Anhydrous dicalcium phosphate, CaHPO ₄	3.5
Hydrated silica dioxide, SiO ₂	2.5-5.0
Calcium pyrophosphate, Ca ₂ P ₂ O ₇	5.0
Alumina, Al ₂ O ₃	9.25

Some active toothpaste ingredients are:

Tartar control additives, such as tetrasodium pyrophosphate, do not remove tartar already formed on your teeth, they react with the minerals in your saliva to prevent them from forming tartar.

Toothpaste for sensitive teeth contain potassium nitrate. The potassium nitrate blocks nerves connected to your teeth for people with receded gums. It is not effective for sensitivity from cavities.

Baking soda, sodium bicarbonate, is a mild abrasive and reduces stains on the teeth. It neutralizes acids in the saliva and provides a foaming action in the mouth.

Triclosan (2,4,4'-trichloro-2'-hydroxydiphenyl ether) is a chlorinated aromatic compound with functional groups that include both phenols and ethers. It is an antibacterial additive that clings to your teeth after brushing and continues to kill bacteria

Fluoride is effective in strengthening tooth enamel. If the toothpaste is approved by the American Dental Association, then the fluoride is effective. Differences in the amount of fluoride has little effect.

Whitening ingredients do little in your toothpaste other than remove some stains. (All toothpastes remove stains.) No toothpaste can whiten your teeth permanently.

Gels vs. pastes is more of a personal preference. Gels use silica as an abrasive to polish teeth while pastes usually use calcium carbonate.

Non-active ingredients include:

Sodium lauryl sulfate and ammonium lauryl sulfate are surfactants that promote foaming action. The foaming action is equated with cleaning.

Alginate or Xanthan gum are binding agents to maintain the consistency of toothpaste for mouth feel properties.

Sodium benzoate or ethylparaben are preservatives to prevent growth of micro-organisms.

Humectants, such as water, sorbitol or glycerin, hold moisture so the toothpaste does not dry up.

Flavoring is added to impart a pleasant taste.

Sodium saccharine is added to give the toothpaste a sweet taste.

Titanium dioxide is considered to be a coloring agent. It makes the toothpaste opaque and gives it a white color.

Artificial dyes are added to make colored toothpastes such as blue, green or red.

In this experiment, we will make 3 simple toothpaste formulations and evaluate them, along with some commercial toothpastes for its properties and cleaning effectiveness.

SAFETY PRECAUTIONS

Wear goggles or safety glasses at all times in the laboratory.

There are no hazards associated with any of the substances used in this experiment.

Do not taste or use any of the toothpastes provided or prepared in this experiment.

DISPOSAL

All substance used in this experiment can be disposed of in the trash.

EXPERIMENTAL PROCEDURE

Materials Needed

Baking soda, sodium bicarbonate, NaHCO_3
Salt, sodium chloride, NaCl
Calcium carbonate, CaCO_3
Glycerin, $\text{C}_3\text{H}_5(\text{OH})_3$
Sodium lauryl sulfate
Vinegar
Hard cooked eggs
Toothpaste samples
Permanent marker
Toothbrushes
Food color
Plastic microscope slides
Parafilm
Waxed paper
Cotton swabs
Glass squares, 10 x 10 cm (4 x 4 in)
Stirring rod
Ruler
Weight, 1 kg
Hot plate
pH meter
Dissecting Microscope
Optional: Coffee, tea, artificially colored drink

Procedure

Part 1: Making colored eggs

Eggshells have a high calcium content and most approximate tooth enamel for testing cleaning effectiveness of toothpaste. You will need one egg for each two toothpastes you are testing.

Measure 120 mL of water into a 250-mL beaker. Heat to boiling on a hot plate.

Remove the beaker of water from the hot plate. Add 15 mL of vinegar and 20 drops of food coloring (red or blue recommended).

Immerse a hard-boiled egg in the food coloring solution for 5 minutes, until it is stained with color.

Remove the egg from the food coloring solution and place it on a paper towel to dry.

If not being used immediately, store the stained egg in a refrigerator overnight or until the next class.

Other coloring materials that can be used are coffee, tea, and artificially colored drinks.

Part 2. Make toothpaste

Recipe 1. Baking soda and salt:

Measure 10 g (2 tsp) baking soda, and 1.5 g (1/4 tsp) of sodium chloride into a plastic cup. Stir.

Add 4 mL of glycerin to the baking soda/salt mixture. Stir it as thoroughly as possible. The mixture will be thick.

Add distilled water with a dropper while stirring until the mixture has about the same consistency as commercial toothpaste.

Recipe 2. Baking soda, salt and calcium carbonate:

Measure 5 g (1 tsp) baking soda, 1.5 g (1/4 tsp) of sodium chloride, and 1.5 g (1 tsp) calcium carbonate into a plastic cup. Stir.

Add 4 mL of glycerin to the baking soda/salt/calcium carbonate mixture. Stir it as thoroughly as possible. The mixture will be thick.

Add distilled water with a dropper while stirring until the mixture has about the same consistency as commercial toothpaste.

Recipe 3. Baking soda, salt, calcium carbonate, and detergent (sodium lauryl sulfate):

Measure 5 g (1 tsp) baking soda, 1.5 g (1/4 tsp) of sodium chloride, 1.5 g (1 tsp) calcium carbonate and 0.5 g sodium lauryl sulfate into a plastic cup. Stir.

Add 4 mL of glycerin to the baking soda/salt/calcium carbonate/sodium lauryl sulfate mixture. Stir it as thoroughly as possible. The mixture will be thick.
Add distilled water with a dropper while stirring until the mixture has about the same consistency as commercial toothpaste.

Note: No flavor has been added to these home-made toothpastes. If you make your own toothpaste at home, you can add flavors such as peppermint, wintergreen, citrus, cinnamon, or others that you can find in the flavoring areas of the spices in your local market.

Part 3. Properties of Toothpastes

You will be testing the 3 toothpastes you made, above, along with 2 or 3 commercial toothpastes.

A. Preparation of toothpaste solutions for testing

Weigh 2.0 g of toothpaste into a 250-mL beaker.

Add 80 mL of water to the beaker. Stir to form a suspension. **NOTE:** The mixture of toothpaste and water may have to sit for up to 30 minutes in order to get a uniform suspension.

Repeat this procedure for each sample of toothpaste you are testing.

Save these solutions for use in **Parts E and F**, in the procedure below.

B. Determination of hard and sharp edged abrasive particles

Squeeze a piece of toothpaste (homemade or commercial) approximately 3 cm long onto a piece of waxed paper.

Using your finger, press it along its length to test for the presence of hard and sharp edged abrasive particles.

Repeat this test for each sample of toothpaste you are using.

C. Abrasiveness

Place a pea-sized amount of toothpaste (homemade or commercial) on a clean plastic microscope slide.

Add 1 or two drops of distilled water to the toothpaste sample.

Using a clean cotton swab, rub the toothpaste sample in a back and forth motion 25 times using short 1 cm strokes.

Carefully rinse off the microscope slide and dry it with a soft tissue or paper towel.

Examine the slide under a dissecting microscope, illuminated from above, and determine the amount of scratches on the surface of the slide. Rate the scratches on a scale from 0 (no scratches) to 5 (a high degree of scratches).

Repeat this test for each sample of toothpaste you are using.

D. Determination of spreadability

Measure 1 g of toothpaste sample (homemade or commercial).

Place the sample at the center of a glass plate (10 x 10 cm). Place a second glass plate over the sample.

Place a 1 kg weight on top of the glass plate. Be careful to avoid sliding of the plate.

After 10 minutes, remove the weight and measure the diameter of the paste in centimeters.

Repeat this test for each sample of toothpaste you are using.

E. Determination of pH

Pour about 40 mL of the toothpaste solutions prepared in step A, above, into clean 100 mL beakers.

Measure the pH of each solution using a pH meter.

F. Determination of foaming ability

Pour 30 mL of one of the toothpaste solutions prepared in step A, above, into a 100 mL graduated cylinder.

Cover the top of the cylinder with a piece of Parafilm. Place your hand over the Parafilm and shake the graduated cylinder 25 times.

Place the graduated cylinder on the lab bench and measure the height of the foam above the water in cm. The foaming ability is the height of the foam.

G. Cleaning ability

Note: In the procedure below, you will test the cleaning ability of several toothpastes on the shells of the eggs you colored earlier. It is recommended that you use 5 to 10 brush strokes for each toothpaste. Your group may decide to use more brush strokes, if necessary, to obtain results. This is a comparison of cleaning ability, do not use excessive brushing. For comparison of results, repeat the brushing procedure as exact as possible for each toothpaste tested.

Using a permanent marker, draw a line along the length of an eggshell dividing it in half.

Moisten a toothbrush with water and shake off any excess water.

Brush one side of an egg with the damp toothbrush for 5 to 10 strokes. (Each stroke is a complete back and forth motion).

Inspect the egg to see if any color is removed.

Rinse the toothbrush with water, shake of the excess water, and place a pea-sized amount of toothpaste on the brush.

Brush one side of an egg with the toothpaste for 5 to 10 strokes. (The same number of strokes you used previously.)

Rinse the egg and the toothbrush and record your results.

Repeat the cleaning ability test with each different toothpaste on a fresh egg surface.

H. Cost

Determine the cost of a tube of each commercial toothpaste you tested. (Check the price online at a local pharmacy.) Calculate the cost per ounce.

Report Sheet

TOOTHPASTE

Name _____ Partner (If applicable) _____ Date _____

Toothpaste	Homemade 1	Homemade 2	Homemade 3	Names of commercial toothpastes		
Describe Appearance						
Abrasiveness By Touch						
Abrasiveness On microscope slide						
Spreadability						
pH						
Foaming ability						
Cleaning ability						
Cost of tube						
Cost Size (oz)						
Cost per oz						

Questions

1. Which toothpaste or toothpastes had the most pleasing appearance? Explain.
2. Which toothpaste felt the most abrasive? Which was the least abrasive?
3. Which toothpaste was the most abrasive making scratches on the microscope slide? Which was the least abrasive? Tell the abrasives present in each of the toothpastes.
4. Which toothpaste had the most spreadability? Why is this important?

9. Which toothpaste exhibited the greatest cleaning ability? Which toothpaste exhibited the least cleaning ability? Can you attribute cleaning ability to any specific ingredients in the toothpaste?

10. Based on the properties you observed and the price of the toothpastes, which toothpaste do you consider is the greatest value?