Toothbrush design—Is there a better bristle?

by Richard Moyer and Susan Everett

What kind of toothbrush do you use—manual or electric? What is the shape of the head and the handle? The firmness of the bristles? The layout and number of bristles? There are many types of toothbrushes; in fact, there are more than 3,000 toothbrush patents. Is one type better than others for cleaning your teeth? Manufacturers often claim that their particular design is better than the competitors, but is it?

This article describes a 5E learning-cycle lesson where students explore various manual toothbrush designs (for more information on learning-cycle lessons, see *Teaching Science as Investigations: Modeling Inquiry Through Learning Cycle Lessons* [Moyer, Hackett, and Everett 2007]). One of the International Technology Education Association (ITEA) standards urges students in grades 6 through 8 to learn that "there is no perfect design" (ITEA 2002, p. 95). As in the design of all products, engineers are faced with prioritizing costs and benefits. For example, a very simple toothbrush (see Figure 1) can be purchased for 50¢, while a more complex toothbrush that has variable bristles intended to clean between different tooth surfaces and a bent handle to allow easy access to the hard-to-reach back of the mouth may cost $3–$5. Engineers must consider the economic issues involved with selling the products they create, as well as their functionality: to produce the best possible toothbrush regardless of cost, or the toothbrush that will sell the most, or perhaps the toothbrush that costs the least to produce.

As with other lessons in this series, there is a connection to science content, as well. It is important for students to appreciate the value of proper dental hygiene. Regular effective brushing protects the body from dental caries and periodontal disease, which may be associated with other health concerns, including heart health. You can use this lesson when focusing on the following National Science Education Standard: "Disease is a breakdown in structures or functions of an organism" (NRC 1996, p. 157).

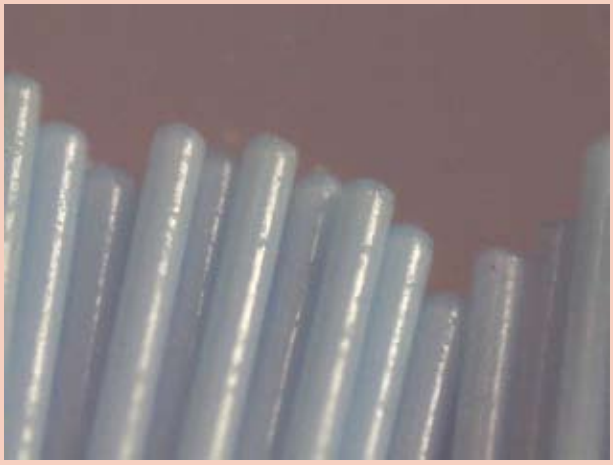
Historical information

Primitive toothbrushes have been found in tombs of ancient Egyptians—evidence that humans have been using devices to clean their teeth for at least 5,500 years. These first tooth "brushes" were usually made of twigs that had been frayed at one end to clean between teeth. In the 15th century, the Chinese used boar bristles stuck into a bone or a stick—sometimes made from aromatic trees—to brush their teeth, as well as to freshen the breath. Two hundred years later, Europeans were using rags soaked in salt solutions to clean their teeth. In 1780, William Addis made a toothbrush using hairs from a cow's tail attached to a handle carved from an ox's thighbone. The Addis family is still producing toothbrushes in England today. Toothbrush design did not change all that much until 1938, when nylon toothbrushes were introduced in the United States. Nylon proved to be beneficial because the bristles could be shaped on the ends to be gentler and to reach spaces between teeth and under the gum line (see Figure 2). It also proved to be more hygienic, because the bristles were more resistant to bacteria growth than animal-hair bristles. It was not until after soldiers came home from World War II in 1945, however, that the idea of brushing one's teeth became popular with most Americans (ADA 2007).

During this activity, students may logically inquire about the purpose of toothpaste.

FIGURE 1 Toothbrush designs

FIGURE 2 Bristles at 30X



You may want to have them research this on their own. Essentially, toothpaste serves a number of purposes. Most toothpastes contain a detergent to help clean the teeth and a flavor enhancer to mask the taste of the detergent and to freshen the breath. Most, but not all, contain a fluoride compound to help prevent tooth decay, and some contain whiteners that remove superficial stains. Children's toothpaste contains about a third less fluoride because they are more likely to swallow it. Toothpastes also usually contain some abrasive materials—a fine grit—to help scrub away plaque. Some people prefer natural toothpaste alternatives made of organic herbal material.

The earliest references to toothpastes date to 5000 BC in Egypt, where a paste was described for cleaning teeth. Over the years, toothpaste has evolved and has included various abrasives—some actually harmful to the enamel of the teeth. Before about 1850, tooth cleaners were actually powders and not pastes. The first toothpaste tube was introduced in 1890, and tube containers are still used today—another example of everyday engineering (Colgate World of Care 2006).

Investigating toothbrushes (teacher background information)

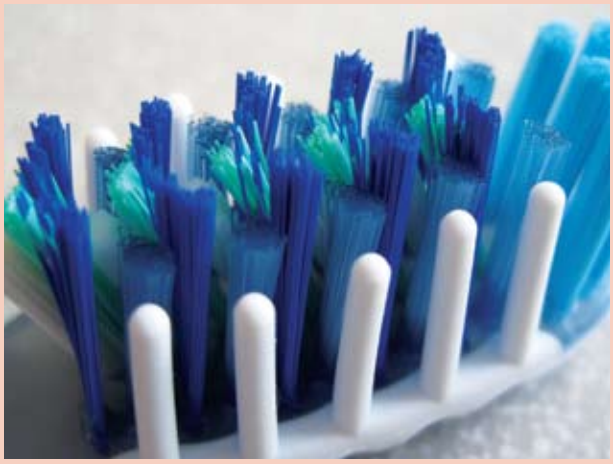
Engage

You will need to gather an assortment of toothbrushes of different designs. You might consider contacting local dentists for donations or purchasing some at your local dollar store. A less desirable option is to collect an assortment of used toothbrushes and then sterilize them by boiling or bleaching. For the Explore phase, each group of three to four students will need two different toothbrushes and two additional, more complex toothbrushes for the Extend phase. After rinsing, the toothbrushes can be reused for later classes. In addition, each group will need two plastic combs, two disposable cups, a cup of water to rinse brushes, a plastic knife, about 60 cm of electrical tape, and about 15 mL (1 tbsp.) of marshmallow cream (some groups may request additional cream for part 2 of the Exploration). (**Safety note:** Remind students that marshmallow cream may not be eaten in the lab.) Also, students will need a few general supplies: some kind of tape (duct tape or electrical tape) to hold the materials to the lab table, scissors, and newspaper to protect the floor. Because students are planning their own experiments, they may request additional materials.

Even though we all use our toothbrushes (hopefully) at least twice a day, it is likely that most of us have never really studied this simple example of everyday engineering. Therefore, before distributing the toothbrushes, ask students what they know about toothbrushes and dental hygiene in general. You may wish to have students investigate some of the history of toothbrushes. Next, have students consider what

FIGURE 3 Exploration setup

FIGURE 4 More complex toothbrush



their own toothbrushes look like and ask them to make a sketch. It is likely that students will have difficulty recalling specific details: whether the bristles are all the same height, the number of tufts in a row, the direction the tufts point, or the number of rows of tufts. After students share their drawings, distribute two different brushes to each group and ask students to compare them to each other. Help students realize that toothbrushes have a range of features. In the second part of the exploration, students will test to discover if any of these differences result in a more effective toothbrush.

Explore

In this activity, students will set up two models of a mouth and teeth using a disposable cup and a plastic comb as shown in Figure 3. Students should place a piece of electrical tape around the base of the comb's teeth to represent the gum line and then evenly smear marshmallow cream on the teeth to simulate plaque and food particles. Each group of students should plan a fair test to determine whether or not one of their toothbrushes is more effective at cleaning the marshmallow cream off of the teeth of the combs.

One possible procedure might be to brush five strokes in one direction on each side of the comb, rinsing in between sides. To operationalize the dependent variable of effectiveness, students can visually compare the amount of marshmallow cream remaining on each comb. Students can also compare the amount remaining underneath the gum line.

FIGURE 5 Toothbrush design features

Design feature	Purpose
Bent handle	Clean hard-to-reach teeth in back of mouth
Thumb grip	Properly position brush in hand to reach all parts of mouth
Flexible handle	Reduce pressure on gums
Soft rubber bristles along edge	Clean and massage along gum line
Bristles pointing in different directions	Clean spaces between teeth
Bristles of different lengths	Clean spaces between teeth
Rough area on back of brush	Scrub the tongue and cheeks

FIGURE 6 Sample scoring rubric for toothbrush-design activity

	3	2	1
Design	Creative design that clearly meets some specific purpose	Purpose and design are not well matched	Purpose or design is not clearly stated
Toothbrush information	Accurate information about toothbrush characteristics and functions is provided	Some information about the toothbrush design is provided	Inaccurate information about toothbrush characteristics and functions is provided
Communication	Creatively and clearly communicates the selling points of the toothbrush	Clear but not creative communication of the selling points is provided	Communication of selling points is lacking or ineffective

In the second part of the exploration, students will determine how to get the model teeth as clean as possible. Here, the driving question is whether it is possible to clean the teeth regardless of which brush is used. Students will need to reapply the marshmallow cream and try out different brushing techniques. Students should make note of the techniques used.

Explain

Have students share their findings and compare differences and similarities. It is likely that students will be unable to see significant differences between their two toothbrushes if the techniques are carefully controlled. Students may be surprised that their results show little or no difference between expensive and inexpensive toothbrushes. Most of the toothbrushes used in this activity (especially if they came from dentists or major retail outlets) were probably approved by the American Dental Association (ADA). The ADA evaluates toothbrushes and gives the ADA Seal of Acceptance to those that meet their requirements. Currently, the approved list includes 34 different toothbrushes (ADA 2010); therefore, all should clean the teeth effectively. In fact, any toothbrush is likely to clean the model teeth similarly.

With sufficient brushing, students should be able to fully clean the model teeth with both of their brushes. Studies have shown that "there is no convincing evidence to support the idea that one type [of toothbrush] is better than the other in terms of its efficacy in plaque removal" (Sasan et al. 2006, p. 168). Students should conclude that the key factor is to brush for a sufficient amount of time and to reach all surfaces, including in between the teeth and along the gum line. To help answer additional questions, you may wish to ask a local dentist or hygienist to visit your class.

Extend

Provide two additional toothbrushes with more complex features (see Figure 4) to each group. These toothbrushes might have a curved or flexible handle, a thumb grip to properly position the brush in the hand, different types of bristles, and so on. Students should study the features of their brushes and make inferences as to their purpose. See Figure 5 for sample observations and inferences.

Evaluate

Because there is no one perfect design, students should articulate some specific characteristics that a person may value in a toothbrush by creating an advertisement. For example, if a student values a very inexpensive toothbrush, the advertisement could indicate that people should take the time and effort to brush all tooth surfaces effectively. Students could either design a print advertisement or use a video camera to produce a video commercial. Students can make a drawing of their design rather than making

Activity Worksheet: Toothbrush design—Does it matter?

Engage

1. Make a drawing of what your toothbrush looks like. Try to remember how it is shaped and what the bristles look like.
2. Compare the two toothbrushes your teacher has provided. Note how they are similar and how they are different. **Caution:** Do not put toothbrushes or any of the lab materials in your mouth.
3. In this activity, you will design and conduct a test to determine if one of these brushes is more effective than the other.
4. Write your prediction as well as your reasoning and discuss with your group.
5. Can you find a brushing technique that will allow you to clean teeth effectively with either brush?

Explore

1. Discuss with your group a plan to conduct a fair test of the two toothbrushes using the model teeth and mouth your teacher has supplied.
2. In your plan be sure to include the following:
   a. A set procedure for brushing—number of strokes, pressure used, direction of brushing, rinsing of brush, and so on.
   b. How you will determine the effectiveness of the toothbrushes.
3. After your teacher has approved your plan, set up and conduct your test.
4. Record your findings.
5. Using the same materials, investigate what you have to do to get your model teeth as clean as possible. Compare different brushing techniques. Record your findings.

Explain

1. Share your group's findings with the rest of the class. How do your findings compare?
2. Was any one brush obviously more effective than others? What conclusion might you draw from this part of the investigation?
3. Discuss with the class the various methods used to get the model teeth as clean as possible. How well did each brush clean the model teeth?

Extend

1. Examine the different toothbrushes your teacher has provided.
2. Notice the variation in the design of each brush.
3. Thinking like an engineer, what do you think is the intended purpose for each design feature of each brush?

Toothbrush	Design feature	Purpose of feature
One		
Two		
Three		
Four		

4. Present your ideas to the rest of the class and discuss.

Evaluate

Review some advertisements for toothbrushes to see what different types exist. What are the advantages that the commercials stress as selling points? Create an advertisement for a new toothbrush noting the purpose and advantages of your design.

Safety note: Marshallow cream used to simulate plaque and food particles may not be eaten.

the actual toothbrush itself. See Figure 6 for a sample scoring rubric.

Conclusion

The toothbrush analysis is a good example of the ITEA standard that "there is no [one] perfect design" (2002, p. 95). There are many equally effective toothbrushes from which to choose. As the ADA states, "Choose a toothbrush that you like and find easy to use so that you'll use it twice a day to thoroughly clean all of your tooth surfaces" (2007, p. 1288). Students should appreciate that in some cases a less complex engineering solution may be effective

if properly used or applied. Toothbrush design is but one factor in effective oral hygiene that is also impacted by time spent brushing, brushing technique, and brushing frequency. ■

Acknowledgment

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