
Polymers in everyday things – dentistry

(Background information)

Polymers are a part of everyday life and examples can be found almost anywhere. Many people think of polymers simply as plastics used for packaging, in household objects and for making fibres, but this is just the tip of the iceberg.

Polymers are used in all sorts of applications you might not have thought much about before. Polymers and composites (materials made by combining two or more materials) are vital to modern dentistry, for example.

Teeth

Bones and teeth, the hard tissues in the human body, are made partly of organic and partly of inorganic material. The inorganic component mainly consists of a substance called hydroxyapatite. The simplest formula of hydroxyapatite is $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$.

The outer layer of your teeth is the hardest material in your body and is called enamel. Enamel consists of approximately 92% hydroxyapatite. Enamel is a ceramic material.

Beneath the enamel, the bulk of a tooth is made of dentin. This is a composite material and contains a mixture of hydroxyapatite, collagen, water, and salts. Collagen is an organic substance.

Teeth function in one of the most inhospitable environments in the human body. They are subject to larger temperature variations than most other body parts and can cope with exposure to ice at 0 °C and to hot tea and coffee. Teeth also encounter pH changes in the range 0.5 to 8, as well as large mechanical stresses during chewing.

Tooth decay, called caries, occurs when teeth are frequently exposed to foods containing carbohydrates (starches and sugars). These foods include milk, some soft drinks, ice cream, cakes and even some fruits, vegetables and juices. Bacteria that live in the mouth form plaque. Plaque is a film on the teeth where bacteria reproduce. The plaque interacts with deposits left on your teeth from sugary and starchy foods to produce acids. Over time, these acids damage tooth enamel because they dissolve the hydroxyapatite present in your teeth. The acids formed by plaque can be partly counteracted by saliva in your mouth.

The acids in plaque can eventually dissolve the enamel surface of the tooth and create holes (cavities) in the tooth. Cavities are usually painless until they grow very large and destroy the nerve and blood vessels inside the tooth. It is important that any holes that form in our teeth are filled as soon as possible.

Fillings

Amalgam fillings

When we visit the dentist for a filling, he or she may use a material that looks like a silvery metal to fill up the tooth cavity. This filling material is often called 'amalgam'. Dental amalgam is an alloy of mercury (50%), silver (30%), tin, copper and zinc. It is made by dissolving the solid metals in the liquid mercury. Amalgam has been used to fill teeth for about 160 years.

The table shows some of the advantages and disadvantages of amalgam fillings.

Advantages	Disadvantages
Reasonably priced and cost effective	Silver colour is no longer considered aesthetically acceptable (it is thought to look unpleasant)
Strong, resistant to wear and durable	Does not stick to the tooth, which means the dentist has to make a large undercut cavity to keep the filling in place
Dependable	Conducts heat too well, which results in some people with amalgam fillings experiencing pain when they eat hot or cold foods
Least time consuming kind of filling for a dentist to perform	Contains mercury (mercury compounds are poisonous)
Average lifetime of amalgam fillings is about 15 years	Getting rid of millions of potentially environmentally hazardous old fillings is a substantial disposal problem
Used for more than a century with good results	

Dental amalgam and the 'mercury issue'

In 1995 a news programme ran a story about dental amalgam. A researcher claimed that amalgam is poisonous because of its mercury content and is responsible for most of the diseases that have not yet been cured by medical science. Many people who watched this programme were appalled and contacted their dentists immediately to have their amalgam fillings removed, or even to have their teeth extracted!

When other scientists looked at the evidence they discovered that the research was poorly done. The results were misinterpreted and often contradictory.

Scientists have evidence that the mercury metal used in amalgam fillings is very inactive. The American Food and Drug Administration has concluded that amalgam causes no demonstrated clinical harm to patients if it is properly placed and that removing existing amalgam fillings will not prevent ill health or reverse the effects of existing diseases. The use of amalgam is still strongly supported by the American Dental Association.

It is certainly not disputed that mercury is a poison if it enters the body in large quantities. Although the mercury in amalgam fillings is bound to the other metals in the amalgam, it can be freed during chewing or when the teeth are brushed. When this happens, the mercury is released from the filling as a vapour. Mercury vapour is also present when amalgam fillings are placed into and removed from teeth. To remove a filling, the dentist has to drill into it. The friction between the drill and the amalgam can vaporise some of the mercury in the filling. It is thought that the amount of mercury vapour that enters the body by inhalation during this process is small enough to be safe.

New research is being carried out to investigate the relationship between amalgam fillings and some diseases, such as multiple sclerosis and Alzheimer's disease. No link has yet been proven. The UK Department of Health and the US and Canadian authorities generally favour the continued use of amalgam fillings on the basis of current scientific advice.

The Department of Health advises that pregnant women avoid having amalgam fillings put in or removed as a precautionary measure. This is because mercury has been shown to cross the placenta from mother to unborn baby.

White fillings

White fillings are routinely used on front teeth and are increasingly being used on back teeth. There are two main types of white filling materials currently used by dentists: composite fillings and glass ionomer cements.

Composite fillings

Composites used for filling teeth are generally made of silica or glass particles bound with a polymer resin.

The polymers that are used as the resin in composites for fillings are based on a monomer called methacrylic acid.

The polymer resin is usually filled with between 35 to 85% glass filler.

The procedure used to place a composite filling in a tooth involves several steps. First, the tooth must be prepared. It is etched with acid to remove debris and an adhesive is applied. The solvent in the adhesive is then evaporated.

Next, the cavity is filled with a layer of composite. This layer is hardened by shining a light on it – a process called photocuring. The light causes the monomer molecules to react with one another and link together to form a solid resin.

The resin shrinks a little during polymerisation so several successive composite layers are added and photocured. Photocuring is useful because it allows the dentist time to work with the material, building and shaping it correctly before it is exposed to light. When the dentist is ready, the filling can be hardened immediately by shining light on it. Finally, the filling is polished.

Composite fillings have advantages and disadvantages. The table below summarises these.

Advantages	Disadvantages
<p>Colour and texture can be matched to the patient's teeth by the addition of different fillers</p> <p>May be used to change tooth colour, shape and size to improve the smile.</p> <p>Does not contain mercury</p> <p>Very useful for front teeth and small holes in the back teeth where the biting load is not too great and appearance is crucial</p> <p>Less tooth has to be removed to provide a key for the filling than is necessary with amalgam fillings</p>	<p>Less durable than amalgam and not strong enough to withstand the chewing forces in the back of the mouth</p> <p>Subject to shrinkage and loosening when the material sets, which leads to formation of a small gap between the tooth and filling</p> <p>Cannot be used for large fillings</p> <p>Wears out faster than amalgam</p> <p>If the coating is too thick, the polymer may separate from the tooth surface during the setting process, which weakens the bond between the filling and the tooth</p> <p>The acid-etching technique removes minerals from the dentin in the tooth and can weaken it</p> <p>Dental caries and composite fillings have poor X-ray contrast with their surroundings, which makes it hard for the dentist to identify new areas of decay</p> <p>Filling a tooth using composites is a more precise procedure and takes longer to perform than inserting an amalgam filling; composite fillings may therefore cost more</p>

Glass ionomer fillings

Glass ionomer fillings are similar to composite fillings because they also use a polymer resin. However, the filling material contains strontium, phosphate and fluoride ions. The big advantage of this filling material is that it interacts with the enamel and dentin in the tooth and forms an excellent seal between the filling and the tooth. A true biological and chemical link is formed with the tooth and this reduces the sensitivity of the filled tooth.

Another advantage of glass ionomers is that the fluoride ions from the filling material are continually released by reaction with saliva. These fluoride ions are next to the teeth and can react with the enamel. This helps strengthen the teeth and prevent further decay.

The disadvantages of glass ionomer materials are that they are not as aesthetic as composites and they are weak under normal chewing forces.

Polymers in everyday things – dentistry

1. Write down the names of the elements in hydroxyapatite.

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2. How many atoms in total make up the simplest formula of hydroxyapatite?

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3. Write down the name of the metal element in hydroxyapatite.

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4. What element must be present in collagen if it is 'organic'?

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5. How does the information above show that teeth are more likely to encounter strong acids than strong alkalis?

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6. Dentists often recommend chewing sugarless gum. Suggest why.

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7. Suggest two other ways to help prevent caries.

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8. Which of the metals in amalgam are called 'transition metals'?

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9. Nowadays amalgam is only used on teeth at the back the mouth. Suggest why.

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10. The European Economic Union has passed legislation to phase out the use of amalgam for fillings. Suggest why.

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11. It is important that all scientific research is checked carefully by scientists outside the group who did the research before any results are published. Explain why.

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12. Suggest why dentists may be more prone to the effects of mercury than their patients.

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13. It is suggested dentists wear gloves to avoid skin contact with mercury. Suggest one other precaution they could take.

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14. Explain why scientific research is important. Use the 'mercury issue' as an example.

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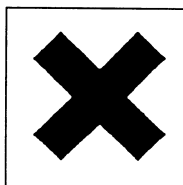
15. The use of white fillings for front teeth is very popular. Why?

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16. What is the advantage of using a composite material rather than any one of the substances from which it is made?

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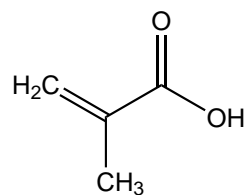
17. This symbol appears on bottles of methacrylic acid:



What precautions should be taken when using this substance?

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18. The structure of methacrylic acid is shown below.



Write down the simplest formula for methacrylic acid.

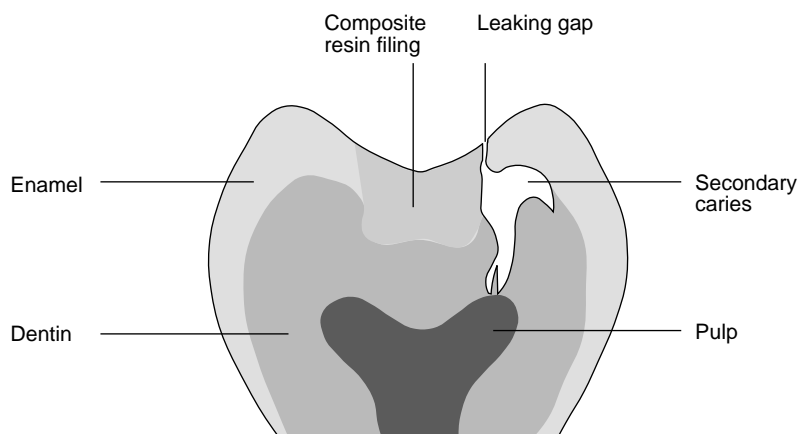
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19. Draw the repeat unit of PMAA poly(methacrylic acid).

20. It is important that the resin is not too sensitive to light. Suggest why.

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21. Look at the diagram below. Explain what has happened to the tooth.



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22. You have to advise someone about the best type of filling for a small cavity on a canine tooth. This is the third tooth along from the centre of the teeth. What advice would you give? Explain your choice.

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23. You have to advise someone about the best type of filling for a large cavity on a molar tooth. This is a large tooth at the back of the mouth. What advice would you give? Explain your choice.

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24. Find the formula for tooth enamel. Which of the ions in glass ionomers is also in tooth enamel? (The presence of this ion is what helps the glass ionomer bond so well to the tooth.)

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25. What is meant by the term 'aesthetic'?

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26. Dentists often use glass ionomer fillings in the 'milk teeth' of young children. Suggest two reasons why.

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27. Some dentists put a layer of glass ionomer in fillings and then place composite material on top of it. Suggest why.

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28. Complete the table below to summarise the advantages and disadvantages of glass ionomer fillings compared to composite fillings.

Advantages of glass ionomer fillings compared to composite fillings	Disadvantages of glass ionomer fillings compared to composite fillings