Prevention and treatment of dental caries with mercury-free products and minimal intervention

WHO oral health briefing note series

World Health Organization

Prevention and treatment of dental caries with mercury-free products and minimal intervention

WHO oral health briefing note series

World Health Organization

Prevention and treatment of dental caries with mercury-free products and minimal intervention: WHO oral health briefing note series

ISBN 978-92-4-004618-4 (electronic version)
ISBN 978-92-4-004619-1 (print version)

Suggested citation. Prevention and treatment of dental caries with mercury-free products and minimal intervention: WHO oral health briefing note series. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Sales, rights and licensing. To purchase WHO publications, see http://apps.who.int/bookorders. To submit requests for commercial use and queries on rights and licensing, see https://www.who.int/copyright.

Contents

Acknowledgements

The World Health Organization (WHO) is grateful to all those who contributed to this oral health briefing note series.

Benoit Varenne, Dental Officer, Oral Health Programme, WHO Noncommunicable Diseases Department, provided overall direction and supervision of preparation of the document in collaboration with Nicole Rendell, Technical Officer, Oral Health Programme, WHO Noncommunicable Diseases Department and with the technical support of Gampo Dorji and Ratnasabapathipillai Kesavan, (WHO Regional Office for South-East Asia), Huda Abdul Ghaffar (WHO Regional Office for the Eastern Mediterranean), Yuriko Harada (WHO Regional Office for the Western Pacific), Carolina Hommes (WHO Regional Office for the Americas) and Yuka Makino (WHO Regional Office for Africa). The lead writer was Mary Plummer, WHO consultant.

Thanks are also due to the following for their review of the content: Habib Benzian and Richard Niederman (WHO Collaborating Centre for Quality-Improvement & Evidence-Based Dentistry, New York University, United States of America), Jaime Aparecido Cury (University of Campinas, Brazil), Ritu Duggal (WHO Collaborating Centre for Oral Health Promotion, All India Institute of Medical Sciences, India), Carlos Alberto Feldens (Lutheran University of Brazil, Brazil), Jo Frencken (Radboud University, The Netherlands), Mairead Harding, (University College Cork, Ireland), Edward Lo and Duangthip Duangporn, (University of Hong Kong, China), Prathip Phantumvanit (Thammasat University, Thailand), Derek Richards (Centre for Evidence-based Dentistry, United Kingdom of Great Britain and Northern Ireland), Pisol Senawongse (WHO Collaborating Centre for Oral Health Education and Research, Mahidol University, Thailand).

Funding source: funds received from the WHO voluntary contributions from The Borrow Foundation, United Kingdom.

Background information

This WHO oral health briefing note series focuses on prevention and treatment of dental caries (tooth decay) with mercury-free products and minimal interventions. Dental caries is a major public health problem globally as the disease affects all age groups, with an onset in early childhood and continued increase over the life course. This first section explains why mercury-free materials and products and minimally invasive interventions are important. The following sections describe six essential strategies using mercury-free products and minimally invasive intervention approaches to prevent and treat dental caries: fluoride toothpaste, fluoride varnish, glass ionomer cement sealants, glass ionomer cement restorations, silver diamine fluoride and composite resin restorations.

1. What is dental caries?

- Dental caries (hereafter referred to as "caries") is tooth decay that results when free sugars contained in food or drink are converted by bacteria into acids that destroy a tooth over time. Free sugars are all sugars added to foods by the manufacturer, cook or consumer, plus sugars that are naturally present in honey, syrups and fruit juices. Tooth decay can lead to cavities, which are permanently damaged areas in the hard surface of the teeth that develop into openings or holes *(1, 2)*.
- Caries is mostly preventable, but nonetheless it is the most common noncommunicable disease globally. Caries is a disease across the life course and affects all age groups *(1)*. It is estimated that 2.3 billion people suffer from caries of permanent teeth and more than 530 million children suffer from caries of primary teeth *(3, 4)*.
- Caries remains largely untreated and has a very unequal distribution globally. Within and between countries, vulnerable and marginalized populations have low access to caries prevention and treatment services, especially in low- and middle-income countries *(4)*.
- Caries has negative impacts. Early stages of caries are often without symptoms, while advanced stages of caries may lead to pain, infections and abscesses, or even sepsis. Also, caries links with anxiety and reduced quality of life as well as absenteeism from school and workplaces. Caries is among the main reasons for hospitalization of children in some high-income countries *(1, 4–6)*.

2. Why use mercury-free products to prevent and treat caries?

- WHO considers mercury to be one of the top 10 chemicals or groups of chemicals of major public health and environmental concern. People are mainly exposed to methylmercury, an organic compound, when they eat fish and shellfish that contain it and through worker inhalation of elemental mercury vapors during industrial processes *(7)*.
- Dental amalgam, which contains 50% mercury, has been commonly used as a restorative material to fill cavities caused by caries. Mercury pollution from dental amalgam is often the largest source of mercury in municipal wastewater. Mercury enters the soil via wastewater sludge, land disposal and the burial of deceased persons with dental amalgam fillings. It enters the air from incineration of deceased persons with amalgam fillings in crematoria *(8)*.
- The Minamata Convention on Mercury is a global treaty that aims to protect human health and the environment from emissions and releases of mercury and mercury compounds *(9, 10)*.
- Annex A Part II of the Minamata Convention on Mercury outlines the provision that, to phase down the use of dental amalgam, a country that is Party to the Convention shall implement two or more of nine measures. This should take into account the Party's domestic circumstances and relevant international guidance.
- As part of such measures, the Minamata Convention recommends the use of cost-effective and clinically effective mercury-free products for dental restoration *(9)*. Some of these materials have an added benefit of caries prevention through the slow release of fluoride *(11)*.

3. Why use minimally invasive intervention approaches to prevent and treat caries?

- Minimal intervention restorations preserve as much of the natural tooth as possible, making this method potentially beneficial to the lifelong health of all patients. Minimal intervention approaches include atraumatic restorative treatment (ART), which involves removing tooth decay using hand instruments alone and filling the cavity with an adhesive dental material, such as glass ionomer cement. ART causes minimal tissue loss because the shape of the carious lesion defines the cavity *(11–15)*. However, ART can only be used to treat cavities that are accessible.
- Minimally invasive intervention approaches avoid unnecessary pain, infection and permanent damage to teeth while preventing and treating caries *(11, 12, 14–16)*. Minimally invasive interventions also generate few or no aerosols, which is particularly beneficial when there is concern about possible airborne transmission of illness, such as during the COVID-19 pandemic *(17)*.
- Minimally invasive intervention approaches emphasize the importance of upstream primary prevention of caries. Upstream measures can include taxation of products containing free sugars, policies limiting sugar advertising and implementation of clear nutrition labelling as well as family education to reduce consumption of free sugars *(1)*.
- Minimally invasive interventions may also include secondary prevention, such as application of fluoride varnish, glass ionomer cement sealant or silver diamine fluoride application *(18)*.
- Conventional dental restorations involve an electric drill to clear away decayed areas of a tooth. Typically, a conventional restoration also removes healthy tooth tissue to make filling placement easier *(12, 14–16)*. The resulting cavity is filled with a dental material like dental amalgam or composite resin.
- Minimally invasive intervention techniques generally are faster and require fewer resources and training than conventional methods. Minimally invasive intervention techniques cannot entirely replace conventional approaches, but in high-, middle- and low-resource oral health care settings and settings other than health facilities, such as preschools, day-care facilities, schools, ambulatory care, and retirement residencies, care is simplified, thereby reducing care time, increasing access and reducing costs *(14, 15, 19, 20)*.

Briefing note 1. Fluoride toothpaste to prevent caries

1. Key facts about fluoride toothpaste

- Fluoride toothpaste is a paste, cream or gel that prevents caries and slows progression of existing caries. Twice-daily toothbrushing with a 1000–1500 ppm fluoride toothpaste is a form of self-care recommended by the World Health Organization (WHO) for all age groups throughout the life course *(13)*.
- Fluoride toothpaste is safe, simple to use and cost-effective, making it suitable for self-care in all settings and populations, including remote, rural and otherwise vulnerable populations.
- There is a need to improve the quality, accessibility and affordability of fluoride toothpaste globally, especially for people in low- and middle-income countries.

2. What is fluoride toothpaste?

- Fluoride toothpaste is a paste, cream or gel that contains between 1000 ppm and 1500 ppm fluoride. Fluoride is a mineral that prevents caries and slows progression of existing caries. Fluoride toothpaste is designed for oral hygiene self-care as part of a twice-daily toothbrushing routine for all age groups throughout the life course, starting as soon as teeth erupt *(13, 19, 21–24)*.
- Fluoride toothpaste is included in the 2021 WHO Model List of Essential Medicines and the Model List of Essential Medicines for Children because of its important role in preventing and arresting caries. These lists specify the most efficacious, safe and cost-effective medicines for priority conditions to meet the minimum medicine needs of a basic health care system *(25, 26)*.
- Low-fluoride toothpastes containing less than 1000 ppm fluoride are not effective in preventing caries *(24)*.
- High-fluoride toothpastes, such as those containing 2800 ppm or 5000 ppm fluoride, may be medically prescribed in special circumstances, such as for individuals at high risk of caries, for root dentine caries control or in supervised community settings, such as schools *(27)*.
- Fluoride toothpaste is widely available, although not universally accessible and affordable for all populations. In most countries, fluoride toothpaste containing up to 1500 ppm fluoride is regulated as a cosmetic product and should comply with the stipulations of ISO 11609. High-fluoride toothpastes are often regulated as medicines or medical products and require a prescription *(4, 19, 20, 27–30)*.

3. Why is fluoride toothpaste used to prevent caries?

- Fluoride prevents caries and inhibits carious lesions in tooth enamel by several different actions. The most important action of fluoride is topical when it is present in the saliva in the appropriate concentration. It also inhibits the bacterial growth that causes caries and interferes with the process by which bacteria metabolize sugars to produce acid that can dissolve enamel structure. Fluoride delays the demineralization and hastens the remineralization of tooth enamel lesions *(13)*.
- Fluoride toothpaste can prevent new carious lesions, slow the progression of existing caries and reduce the severity of cavities. Using fluoride toothpaste does not depend on a diagnosis of caries *(19)*.
- Brushing teeth with a fluoride toothpaste twice daily is a preventive and protective lifelong hygiene behaviour for everyone in all age groups, starting as soon as teeth erupt. This is universally recommended by WHO, the FDI World Dental Federation and the International Association of Dental Research as well as other national and international public health organizations *(13, 31)*.
- Using fluoride toothpaste is more effective in preventing caries and slowing progression of existing caries than using toothpaste without fluoride. It also enhances the effectiveness of using fluoride mouth rinses, gels or varnish *(32)*.

4. Is fluoride toothpaste simple to use to prevent caries?

- Yes. Twice-daily use of fluoride toothpaste for toothbrushing is simple and effective in preventing caries and slowing progression of existing caries among infants, children, adults and seniors (19).
- For children up to 6 years of age: Caregivers should begin brushing children's teeth as soon as they erupt. For children under 3 years old, a smear or rice-sized amount of toothpaste should be used over the width of the brush, while for children aged 3–6 years old, a pea-sized amount should be used. Supervision is required to ensure that toothpaste is not swallowed but is spat out without subsequent rinsing. Toothbrushing programmes with toothpaste containing 1000–1500 ppm fluoride should be promoted for everyone, particularly for mothers and children in primary health facilities conducted by nurses and in preschools and primary schools conducted by teachers *(19, 28, 29, 33)*.
- For all people older than 6 years of age: Individuals should brush teeth twice daily with a pea-sized amount of fluoride toothpaste on the toothbrush. They should spit out the toothpaste afterward. To maximize the effectiveness of the toothpaste, they should not rinse their mouths with water *(19)*.
- Fluoride toothpaste is widely available in high-income countries, but it is not universally accessible and affordable to populations in middle- and low-income countries. There is a need to improve the quality, accessibility and affordability of fluoride toothpaste globally, especially in low-income communities *(4, 19, 20, 27–30)*.

5. What are the benefits of using fluoride toothpaste?

- **Effectiveness against caries**: More than 60 years of research provide strong evidence of the effectiveness of fluoride toothpaste in preventing caries and slowing progression of existing caries in children and adults. Fluoride toothpaste efficacy is estimated at 25%. This means that, under ideal circumstances, people who use fluoride toothpaste are about 25% less likely to develop caries *(20)*. Fluoride toothpaste's ability to prevent caries increases with higher levels of initial disease, higher fluoride concentration in the toothpaste, higher frequency of use and, for children, when used under supervision *(19, 24)*.
- **Improved health and quality of life**: By protecting teeth, preventing caries and slowing the progression of existing caries, fluoride toothpaste reduces infection, pain, tooth damage and the need to fill cavities. This in turn decreases the financial burden on individuals and health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life *(19, 28, 29)*.
- **Self-care**: Using fluoride toothpaste is one of only two self-care interventions that enable people to reduce caries and its severity independently. The other self-care intervention is avoiding risks to oral health, by reducing intake of sugars, for example *(34)*.
- **Cost-effectiveness**: Fluoride toothpaste is highly cost-effective when compared with other fluoride interventions. Prices of fluoride toothpaste vary significantly among available brands, fluoride compounds and package sizes as well as among countries. In some countries, taxes and import duties markedly increase consumer costs *(20, 35)*.
- **Safety**: Extensive clinical trials over the last 60 years have shown that fluoride toothpaste delivers fluoride safely. Moreover, when using the concentration of 1000–1500 ppm fluoride and the recommended pea-sized amount of fluoride toothpaste, no association with dental fluorosis is found. Dental fluorosis, hypomineralization of tooth enamel that may result in white or yellowish spots on the tooth surface enamel, occurs when excessive levels of fluoride are ingested during tooth formation, such as in areas with high naturally occurring concentrations of fluoride in groundwater *(13, 36)*.
- **Suitable for all**: Fluoride toothpaste is suitable for use by all people, including rural, remote and otherwise vulnerable populations, because it is simple to use and does not require special training. Twice-daily home use of fluoride toothpaste can be promoted through preschools, schools, communities and primary care facilities *(19, 28, 29)*.

Briefing note 2. Fluoride varnish to prevent and arrest caries

1. Key facts about fluoride varnish

- Fluoride varnish is a medical product that prevents caries and can arrest carious lesions. It is applied topically and stays on teeth for several hours. This prolonged contact time between tooth enamel and a high concentration of fluoride improves the effect of the fluoride. Fluoride varnish can be reapplied two to four times per year.
- Fluoride varnish is safe, simple to use and cost-effective. It is applied without complex or specialized equipment, making it suitable for an oral health care service, a primary care facility or a community setting such as a school, including use for people with special needs.

2. What is fluoride varnish?

- Fluoride varnish is a clear liquid typically containing 1–5% fluoride that can be applied to teeth to arrest and prevent caries lesions. Regular applications every three to six months are required to maintain effectiveness *(19)*.
- Fluoride varnish is a topical formulation of fluoride that is an appropriate complement to other oral hygiene measures, such as twice-daily toothbrushing with fluoride toothpaste *(27)*.
- Appropriate topical formulations of fluoride are included in the 2021 WHO Model List of Essential Medicines and Model List of Essential Medicines for Children because of fluoride's important role in preventing caries and arresting carious lesions. These lists specify the most efficacious, safe and cost-effective medicines for priority conditions to meet the minimum medicine needs of a basic health care system *(25, 26)*.

3. Why is fluoride varnish used to arrest carious lesions and prevent caries?

- Fluoride prevents and arrests carious lesions by several different actions. It delays the demineralization and increases the remineralization of tooth enamel lesions. It also inhibits bacterial growth and interferes with the process by which they metabolize sugars to produce acid, which dissolves the enamel and causes lesions and cavities *(19, 27, 37)*.
- Regular application of fluoride varnish can prevent the development of new carious lesions. Applications every three to six months are required to maintain effectiveness *(19, 37)*.
- Fluoride varnish is well accepted by children. It may be most useful with children with special needs and/or children at high risk of caries *(18, 38)*.
- Fluoride varnish application has also been found to be effective in decreasing radiation caries and sensitivity for irradiated head and neck cancer patients *(39)*.

4. Is fluoride varnish simple to use to arrest carious lesions and prevent caries?

- Yes. Application of fluoride varnish is quick, easy and painless. Fluoride varnish is relatively thick and sets rapidly, which contributes to its ease of application, helps it adhere to tooth structures and reduces the amount of fluoride that may be accidentally ingested *(40)*.
- To apply fluoride varnish, a small amount is painted on each tooth. This takes just a few minutes. The fluoride varnish is sticky but hardens once it comes in contact with saliva. People may feel the hardened varnish with their tongues but will not be able to lick the varnish off. They should only eat soft foods and cold or warm (not hot) foods or liquids for 4 to 12 hours. No monitoring system is required after application *(41)*.
- Fluoride varnish can be applied without complex or specialized equipment in an oral health care service, primary care facility or community setting such as a preschool or school *(19, 29)*. Limited training for trained non-dental-health personnel (such as a community health worker) can suffice to apply fluoride varnish topically *(20)*.
- Regular application of fluoride varnish every three to six months is required to maintain effectiveness *(19)*.

5. What are the benefits of using fluoride varnish?

- **Effectiveness against caries**: Regular application of 5% sodium fluoride varnish every three to six months can prevent the development of new caries and help remineralization of early enamel lesions to a large extent *(19, 27, 37)*.
  - Treatment with fluoride varnish has been found to result in a 37% reduction in decayed, missing and filled tooth surfaces in primary teeth or baby teeth and a 43% reduction in decayed, missing and filled tooth surfaces in permanent teeth *(42)*.
  - Fluoride varnish's overall efficacy is estimated at 40%. This means that, under ideal circumstances, teeth treated with fluoride varnish are about 40% less likely to develop caries *(20)*.
- **Improved health and quality of life**: By protecting teeth and preventing and arresting carious lesions, fluoride varnish reduces infection, pain, tooth damage and the need to fill cavities. This in turn reduces financial burdens on individuals and health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life.
- **Safety and cost-effectiveness**: Fluoride varnish is cost-effective and has negligible risks or adverse effects, based on intensive study over 30 years of use around the world *(19, 20)*.
- **Suitable for all**: Application of fluoride varnish is suitable for use with urban, rural, remote and otherwise vulnerable populations (including people with special needs) because it is simple to use, well accepted, effective and does not require extensive dental training *(20, 38)*.

Briefing note 3. Glass ionomer cement as a sealant to prevent and arrest caries

1. Key facts about glass ionomer cement as a sealant

- Glass ionomer cement sealants can prevent and arrest carious lesions both structurally and chemically. To create a sealant, glass ionomer cement is applied to all pits and fissures of teeth. Structurally, sealants prevent caries development by creating a hard shield that keeps food and bacteria from getting into tiny grooves in teeth. Chemically, it bonds to the tooth enamel and dentine, providing a tight seal. It also releases fluoride ions that strengthen the enamel, remineralize early enamel lesions and prevent growth of bacteria and caries.
- Glass ionomer cement as a sealant is safe, simple to apply and cost-effective. Glass ionomer application is suitable in oral health care services, primary care facilities and field settings, including use for people with special needs.

2. What is glass ionomer cement?

- Glass ionomer cement is a medical product used as a powder containing fluoride, aluminum oxide and silicate that, when combined with a mild acidic liquid, can be used as a tooth-coloured dental material *(25, 26)*.
- Low- and high-viscosity glass ionomer cements differ according to their powder-to-liquid ratios as well as their ion compositions. High-viscosity glass ionomer cement is preferred as it is more durable (has higher survival rates) than the low-viscosity alternative *(43)*.
- High-viscosity glass ionomer cement is included in the 2021 WHO Model Lists of Essential Medicines—both the general list and the list specific to children. These lists specify the most efficacious, safe and cost-effective medicines for priority conditions to meet the minimum medicine needs of a basic health care system *(25, 26)*.
- Oral health care providers can apply single-use or multiuse forms of glass ionomer cement. In single-use capsules, one dose of powder is isolated from one dose of liquid, while multiuse bottles have larger quantities of both *(25, 26)*. Capsules offer a consistent and fast mix due to a precise powder-to-liquid ratio, but they require a spring-loaded or electric mixer and are more expensive. The multiuse bottles are mixed by hand and are less expensive, but the final product can be affected by mix precision and humidity (19).

3. Why is glass ionomer cement used as a dental sealant?

- Glass ionomer cement adheres to tooth tissue. It bonds directly with tooth dentine and enamel.
- Glass ionomer cement slowly releases fluoride. The release of fluoride stimulates healing by remineralizing hard tooth tissue to regenerate dentin and enamel and protect the teeth. The continued fluoride release reduces the growth of bacteria associated with caries as well *(11, 13, 18, 19, 44)*.
- As a sealant, glass ionomer cement provides a very thin, protective covering that fills the pits and fissures on the biting surface of back teeth. It has structural and chemical properties that shield the teeth from food and bacteria, reducing the development of carious lesions *(43)*.
- As a sealant, glass ionomer cement is most effective in preventing and arresting carious lesions if it is applied early after eruption of primary and permanent molars. For example, it might be applied after eruption of the first molars (around 6 years of age) and the second molars (around 12 years of age) *(45)*.
- Glass ionomer cement has a similarly high durability (survival rate) to composite resin, the main other sealant material *(46)*. Unlike composite resin, however, glass ionomer cement can be used where moisture control is less than optimal, as may be the case with young children or individuals with high caries risk whose teeth are erupting *(14)*. Using composite resin requires more time, steps and resources than using glass ionomer cement, and the cost is higher. The increased resources typically include a rubber dam, acid etch, air/water syringe, bonding agent and curing light.
- Glass ionomer cement has several properties that are favourable for all patients, including its chemical bonding and release of fluoride, its biocompatibility, its capability for thermal expansion similar to tooth structure and its low moisture sensitivity *(11, 18)*.

4. Is glass ionomer cement simple to use as a sealant?

- Yes. Clinical application of glass ionomer cement is quick, easy and painless. It can be done without complex or specialized equipment in an oral health care service, primary care facility or community setting such as a school. Glass ionomer sealants can be readily applied by a dental therapist, dental nurse, dental hygienist or dentist. Non-dental health care workers also have been trained successfully to apply dental sealants *(19)*.
- Applying glass ionomer cement as a sealant is simple. The tooth can be cleaned with a toothbrush, followed by an application of 10–20% polyacrylic acid conditioner. The tooth is then dabbed dry before a small amount of high-viscosity glass ionomer cement is placed on the chewing surface, held under the pressure of an index finger for about 30 seconds and contoured, with excess material removed using a hand instrument. The sealant is then covered with a thin layer of hydrophobic material, such as petroleum jelly or cocoa butter. Long-term retention of the sealant is not required for preventive effect, so monitoring is not essential *(19, 43)*.

5. What are the benefits of using glass ionomer cement as a sealant?

- **Effectiveness against caries**: The efficacy of glass ionomer cement sealants is estimated at 80%. This means that, under ideal circumstances, teeth treated with glass ionomer cement sealants are about 80% less likely to develop caries.
  - High-viscosity glass ionomer cement sealants prevent carious lesions in approximately 71% of treated surfaces, regardless of the presence of initial carious lesions *(45, 47–49)*.
  - Immediate outcomes for treated surfaces are similar to those for composite resin sealants, but high-viscosity glass ionomer cement has better long-term results *(45–49)*.
  - Glass ionomer cement is unique in its slow release of fluoride. This makes it one of several important public health tools providing appropriate levels of fluoride to protect the dental health of the population and address early childhood caries *(13, 18, 19, 44)*.
- **Improved health and quality of life**: By protecting teeth and preventing and arresting carious lesions, glass ionomer cement sealants prevent infection, pain, tooth damage and the need to fill cavities. This reduces financial burdens on individuals as well as health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life.
- **Aesthetics**: Glass ionomer cement is tooth-coloured, so sealants are not easily visible in the mouth *(11)*.
- **Safety and cost-effectiveness**: Glass ionomer cement is cost-effective and widely available, and it has negligible risks or adverse effects, based on intensive study over 40 years of use around the world *(11, 12, 18, 20, 30, 45, 50–52)*. The application of high-viscosity glass ionomer sealants also does not generate aerosols, which is particularly beneficial when there is concern about possible airborne transmission of illness, such as during the COVID-19 pandemic *(17)*.
- **Suitable for all**: Application of glass ionomer cement sealants involves minimal intervention and is suitable for use with rural, remote and otherwise vulnerable populations, including people with special needs. Because it is simple to use, it does not require extensive dental training and can be provided through the primary health care system *(19, 20)*.

Briefing note 4. Glass ionomer cement restoration to treat and prevent caries

1. Key facts about glass ionomer cement restoration

- Glass ionomer cement prevents caries both structurally and chemically. Structurally, it can be used to fill cavities caused by caries and restore function. Chemically, it bonds to the enamel and dentine, releases fluoride ions that remineralize carious tooth structures and prevents growth of bacteria.
- Minimally invasive intervention involves preventing and treating caries while preserving as much of the natural tooth structure as possible and avoiding unnecessary pulpal exposure, root canal therapy or extraction. Minimally invasive intervention methods were first established as atraumatic restorative treatment (ART), which involves removing decayed tooth structures from within a cavity using hand instruments only and then restoring tooth function with glass ionomer.
- Minimally invasive intervention restorative treatment using glass ionomer cement is safe, simple to use and cost-effective, making it suitable for oral health care services, primary health care facilities and field settings, including for use with people with special needs.
- Glass ionomer cement restorations are an important mercury-free alternative to conventional dental amalgam fillings. Use of dental amalgam is being phased down globally to protect human health and the environment from the adverse effects of mercury, in accordance with the Minamata Convention on Mercury.

2. What is glass ionomer cement?

- Glass ionomer cement is made up of a powder containing fluoride, aluminum oxide and silicate that, when combined with a mild acidic liquid, can be used as a tooth-coloured dental material *(25, 26)*.
- Low- and high-viscosity glass ionomer cements differ according to their powder-to-liquid ratios as well as their ion compositions. High-viscosity glass ionomer cement is preferred as it is more durable (has higher survival rates) than the low-viscosity alternative *(43)*.
- High-viscosity glass ionomer cement is included in the 2021 WHO Model Lists of Essential Medicines—both the general list and the list specific to children. These lists specify the most efficacious, safe and cost-effective medicines for priority conditions to meet the minimum medicine needs of a basic health care system *(25, 26)*.
- Oral health care providers can apply single-use or multiuse forms of glass ionomer cement. In single-use capsules, one dose of powder is isolated from one dose of liquid, while multiuse bottles have larger quantities of both *(25, 26)*. Capsules offer a consistent and fast mix due to a precise powder-to-liquid ratio, but they require a spring-loaded or electric mixer and are more expensive. The multiuse bottles are less expensive and are mixed by hand, so they do not require a mixer, but the final product can be affected by mix precision and humidity *(19)*.

3. What is minimal intervention and ART with glass ionomer cement?

- Minimal intervention involves preventing and treating caries while preserving as much of the natural tooth as possible and avoiding unnecessary pulpal exposure, root canal therapy or extraction. Minimal intervention approaches remove tooth decay without causing damage to adjacent tissue *(11, 12, 14–16)*.
- Conventional therapy for caries treatment requires substantial resources and may cause more permanent damage to teeth. Conventional methods involve the use of electric drills by trained oral health care personnel. Local anaesthesia is normally injected to prevent pain during the procedure. Drills are used to clear away decayed areas of a tooth as well as healthy tooth tissue. Conventional therapy requires access to electricity and appropriate tools, and it is more time-consuming and expensive than minimally invasive methods *(12, 14–16)*.

- Minimal intervention approaches include removing tooth decay using hand instruments alone, without the use of anaesthesia and electrical equipment. The resultant cavity and adjoining fissures are restored and sealed with an adhesive dental material, usually glass ionomer cement. Minimal intervention treatment causes minimal tissue injury because the shape of the carious lesion defines the cavity and only soft, infected tissue is removed *(11–15)*.
- ART with glass ionomer cement is both restorative and preventive because the cavity and related fissures are filled and sealed, resulting in a sealant restoration. A sealant is a very thin, protective coating that fills the fissures, pits and grooves of teeth, shielding them from food and bacteria *(12, 14, 15)*. A sealant restoration has both structural and chemical properties that protect teeth from becoming decayed *(43)*.

4. Why is glass ionomer cement used for restorations?

- Glass ionomer cement restorations are a tooth-coloured, mercury-free alternative to dental amalgam that have good durability, especially for single-surface restorations and occlusal tooth surfaces (those used for chewing and grinding) *(11, 53)*.
- Glass ionomer cement adheres to the remaining tooth tissue, relying on chemical bonding with tooth dentine and/or enamel for retention, unlike dental amalgam restorations, which depend on mechanical retention from the converged cavity walls *(11, 13, 18, 19, 44)*.
- Glass ionomer cement slowly releases fluoride over time, remineralizing hard tooth tissue, protecting teeth and preventing caries *(11, 13, 18, 19, 44)*.
- Glass ionomer cement has several properties that are favourable for use with all patients, including its chemical bonding to enamel and dentine, uptake and release of fluoride, thermal expansion similar to tooth structure, biocompatibility and decreased moisture sensitivity *(11, 18)*.

5. Is glass ionomer cement simple to use for ART?

- Yes. Clinical application of glass ionomer cement is quick, easy and painless. It can be done without complex equipment in an oral health care service, primary care facility or community setting such as a school or day-care centre for the elderly. Diagnosis is done using visual/tactile methods, not radiographs. Application by a trained dental therapist, dental nurse, dental hygienist or dentist is required *(14, 19, 20)*.
- Minimal intervention caries treatment with a glass ionomer cement filling is simple. Soft decay is removed with a toothbrush, and hand instruments can be used to increase access. A polyacrylic acid conditioner is then applied to the tooth and dabbed dry, and high-viscosity glass ionomer cement is applied to fill the cavity. The restoration is then contoured and excess glass ionomer cement removed before the restoration is covered with a thin layer of hydrophobic material, such as petroleum jelly or cocoa butter *(14, 19)*.

6. What are the benefits of using glass ionomer cement in ART?

- **Effectiveness against caries**: The efficacy of high-viscosity glass ionomer cement restorations is estimated at 80%. This means that, under ideal circumstances, teeth treated with glass ionomer cement restorations are about 80% less likely to develop caries *(20)*.
  - High-viscosity glass ionomer cement fillings placed with ART also have a survival rate (durability) of 80% after five years for single-surface carious lesions and 77% after five years for multiple-surface restorations in permanent teeth *(54)*.
  - When used with ART and conventional techniques, glass ionomer cement fillings result in similar or lower rates of recurring caries when compared with composite resin or dental amalgam fillings *(52, 55–58)*.
  - Glass ionomer cement is unique in its slow release of fluoride. This makes it one of several important public health tools providing appropriate levels of fluoride to protect the dental health of the population and address early childhood caries. The main other restorative dental materials do not have this inherent ability to reduce caries through chemical action *(13, 18, 19, 44)*.

- **Minimally invasive and preserves more of the tooth**: ART using glass ionomer cement protects more of the natural tooth structure than conventional methods because the shape of the carious lesion defines the cavity and only soft, infected tissue is removed *(14, 15)*. Furthermore, the remaining deep grooves are protected from becoming decayed by the sealant part of the restoration.
- **Improved health and quality of life**: By protecting teeth and preventing caries, glass ionomer cement sealant restorations reduce infection, pain, tooth damage and the need to fill cavities. This decreases financial burdens on individuals as well as health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life.
- **Aesthetics**: Unlike dental amalgam, glass ionomer cement is tooth-coloured, so sealant restorations are not easily visible in the mouth *(11)*.
- **Durability**: ART with glass ionomer cement is most effective and durable on occlusal tooth surfaces (those used for chewing and grinding). Durability is reduced when used on proximal surfaces (those between adjacent teeth).
- **Environmental protection and public health**: Glass ionomer cement fillings are an important mercury-free alternative to conventional dental amalgam fillings. Use of dental amalgam is being phased down globally to protect human health and the environment from the adverse effects of mercury, in accordance with the Minamata Convention on Mercury *(9, 10, 59)*.
- **Safety and cost-effectiveness**: Use of glass ionomer cement for ART is minimally invasive, cost-effective and potentially widely available, and it has negligible risks or adverse effects, based on intensive study over 40 years of use around the world *(11, 12, 18, 20, 50, 51)*. ART also does not generate aerosols, which is particularly beneficial when there is concern about possible airborne transmission of illness, such as during the COVID-19 pandemic *(17)*.
- **Suitable for all**: ART using glass ionomer cement is suitable for use with urban, rural, remote and otherwise vulnerable populations. This includes children, older people, anxious patients and/or those with special needs. ART using glass ionomer cement is simpler and less invasive than conventional methods, and it does not require extensive dental training, so treatment can be provided through the primary health care system *(14, 15, 19, 20)*.

Briefing note 5. Topical silver diamine fluoride to arrest caries

1. Key facts about silver diamine fluoride

- Silver diamine fluoride is a dental material that prevents and arrests dental caries. It can be applied topically to pits and fissures and to open cavities. Application can be repeated over several days, semiannually or annually. Care can be provided in community settings (e.g., schools), primary care facilities or oral health care services. No special equipment is needed.
- Silver diamine fluoride is safe, simple to use and cost-effective, making it suitable for use in primary care facilities and field settings, including for people with special needs and older people.
- Silver diamine fluoride may be most useful when it is not possible to remove tooth decay and fill the resultant cavity with restorative material. This may occur, for example, when there are limited resources or limited access to dental restorative care, when people have a high risk of caries or cavities that are difficult to treat (such as those in partially erupted teeth and root caries) or when patients are not able to tolerate conventional treatment.

2. What is silver diamine fluoride?

- Silver diamine fluoride is a clear liquid containing high concentrations of fluoride and silver that work together to arrest cavities when applied to teeth. Silver diamine fluoride is commonly used with a fluoride concentration of 38% *(20, 60, 61)*.
- Application of silver diamine fluoride creates a highly mineralized surface on carious lesions that is rich in calcium fluoride and silver phosphate.
- Both the general 2021 WHO Model List of Essential Medicines and the list specific to children include 38% silver diamine fluoride. These lists specify the most efficacious, safe and cost-effective medicines for priority conditions to meet the minimum medicine needs of a basic health care system *(25, 26)*.
- The main indication for the use of silver diamine fluoride is to arrest caries by applying it to the surface of teeth on either root or coronal cavities. However, in some countries, manufacturers recommend its use only for root caries and desensitization (strengthening dentine to reduce tooth sensitivity and pain), and its approved use in those countries is limited to this. *(27, 60, 61)*.
- Silver diamine fluoride application results in a temporary dark stain on arrested carious lesions. While this may cause aesthetic concerns for some, the visual appearance and colour are similar to dental amalgam, which is acceptable to most people *(63–66)*.

3. Why is silver diamine fluoride used to arrest carious lesions?

- Silver diamine fluoride has two benefits. It kills the caries-causing bacteria, thereby arresting decay. It also remineralizes the enamel and dentine, hardening the tooth and preventing further decay or pain *(27, 62, 67)*.
- Silver diamine fluoride can potentially prevent the development of new caries. Its fluoride component can remineralize carious tooth structures and prevent growth of bacteria, while its silver component also inhibits the growth of the bacteria that cause caries *(27, 62, 67)*.
- Silver diamine fluoride may be most useful when it is not possible to remove tooth decay and fill the resultant cavity with restorative material. This may occur, for example, when there is limited access to dental restorative care, when children have a high risk of caries or cavities that are difficult to treat (such as cavities in partially erupted teeth) and root caries, or when children are not able to tolerate conventional treatment because of young age. Silver diamine fluoride also may be suitable when aesthetics are not a primary concern, such as when carious teeth are in nonvisible molars and premolars *(19, 27, 62, 67)*.

4. Is silver diamine fluoride simple to use to arrest carious lesions?

- Yes. Clinical application of silver diamine fluoride is quick, easy and painless *(27, 61)*. It can be applied topically as soon as pits, fissures or caries are clinically diagnosed *(27, 68)*. Application can be done without complex or specialized equipment in an oral health care service, primary care facility or community setting such as a school or home for older people *(61, 68)*. Limited training for non-dental community health workers can suffice to apply silver diamine fluoride topically *(19, 20)*.
- Applying silver diamine fluoride is simple. A practitioner places a drop of silver diamine fluoride solution in a dental dappen dish and then applies a small amount on a dried decayed tooth surface (cavity) with a disposable microbrush or applicator for approximately one minute without removal of carious tissue *(19)*.
- Application doses are the same across all age groups, and no monitoring system is required after application *(19)*.

5. What are the benefits of using silver diamine fluoride?

- **Effectiveness against caries**: Silver diamine fluoride's efficacy in preventing and arresting caries lesions is approximately 80%. This means that, under ideal circumstances, teeth treated with silver diamine fluoride are about 80% less likely to develop caries *(20, 37, 69)*. When applied to carious lesions in primary teeth, silver diamine fluoride appears to prevent caries effectively compared with placebo, no treatment or fluoride varnish *(66)*.
  - Regarding preschool children, adoption of a 38% silver diamine fluoride intervention with comprehensive oral health education has been found to reduce the rate of preventable dental hospitalizations for high-risk children significantly *(70)*.
  - Regarding older people, annual silver diamine fluoride application was found to arrest root caries at 30-month follow-up by 90% *(71–73)*.
- **Improved health and quality of life**: By arresting carious cavities and potentially preventing caries, silver diamine fluoride reduces pain, tooth damage and the need to fill cavities. This decreases financial burdens on individuals as well as health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life *(70)*.
- **Safety and cost-effectiveness**: Silver diamine fluoride is minimally invasive, cost-effective and widely available, and it has negligible risks or adverse effects, based on intensive study over 30 years of use around the world *(20, 37, 62–64, 74–77)*. The dose of fluoride used and biannual application ensure that there is no risk of dental fluorosis, which is hypomineralization of tooth enamel caused by ingestion of excessive fluoride levels during tooth formation *(27, 61)*. The application of silver diamine fluoride also does not generate aerosols, which is particularly beneficial when there is concern about possible airborne transmission of illness, such as during the COVID-19 pandemic *(17)*.
- **Suitable for all**: Application of silver diamine fluoride involves minimal intervention and is suitable for children, older people and urban, rural, remote and vulnerable populations (including with people with special needs) because it is simple to use and does not require extensive dental training *(13, 19, 62, 74)*.

Briefing note 6. Composite resin restoration to treat caries

1. Key facts about composite resin restoration

- Composite resin can be used to prevent and treat caries structurally by filling cavities.
- Composite resin can be applied using minimally invasive intervention procedures. Minimally invasive intervention involves treating cavitated carious lesions while preserving as much of the natural tooth structure as possible and avoiding unnecessary extraction and negative consequences.
- Composite restorations are a mercury-free alternative to conventional dental amalgam fillings. Use of dental amalgam is being phased down globally to protect human health and the environment from the adverse effects of mercury, in accordance with the Minamata Convention on Mercury.
- Composite resin restoration is safe, cost-effective and suitable for use with minimal intervention in oral health care services or primary care facilities.

2. What are composite resins?

- Composite resins are a class of dental restorative materials that are a mixture of resin and other organic components as well as a filler (such as silica) and other inorganic components. Many different composite resin dental materials can be made by modifying the formulation or ratio of these components *(78, 79)*.
- Composite resins vary in multiple ways, including their mechanical properties (such as strength and fracture toughness), which are generally very favourable, and aesthetic considerations (such as colour matching) *(80, 81)*.

3. What is minimal intervention with composite resin?

- Minimal intervention involves preventing and treating caries while preserving as much of the natural tooth as possible and avoiding unnecessary extraction and negative consequences. Minimal intervention excisions are very precise to remove tooth decay without causing damage to adjacent tissue *(11, 12, 14–16)*.
- Conventional methods of treating caries require more expense and resources and may cause more permanent damage to teeth. Conventional methods involve the use of electric drills by trained dental health personnel. Drills are used to clear away decayed areas of a tooth before filling it, but they may remove healthy tooth tissue as well. Local anaesthesia is normally injected to prevent pain during the procedure. Conventional treatments require access to electricity and appropriate tools and are more expensive than minimally invasive methods *(12, 14–16)*.

4. Why is composite resin used for dental restoration?

- Composite resin restorations are a tooth-coloured, mercury-free alternative to dental amalgam that have moderate to good durability *(11)*.
- Composite resin adheres to the tooth tissue, relying on chemical etching and bonding to tooth dentine and/or enamel for retention, unlike dental amalgam restorations, which depend on mechanical retention from the converged cavity walls and involve more removal of tooth structure during restoration ***(11)***.
- Smart composite resins that release fluoride have the added benefit of remineralizing hard tooth tissue, protecting teeth and preventing caries *(11, 13, 18, 19, 43, 44, 79, 82, 83)*.
- If used as a sealant, composite resin provides a very thin, protective covering that fills the biting surface (the fissures, pits and grooves) of back teeth. Compared with a control with no sealant, composite resin sealants prevent caries *(11, 84, 85)*.

5. Is it possible to restore teeth with minimal intervention using composite resin?

- Yes. Composite resin restorations can be placed with minimal intervention in oral health care services or primary care facilities. Minimally invasive intervention techniques include box-only restoration with fissure sealant and tunnel preparation with restoration *(12, 19, 86)*.
- Training for a dentist is required to restore teeth with composite resin. The restoration technique can be sensitive and time-consuming. Absolute isolation of the tooth from saliva with a rubber dam is necessary, as are one or more types of setting mechanism (such as a light or chemical cure) *(14, 19, 87, 88)*.
- Restorative treatment requires a series of carefully administered steps following preparation of the tooth. An acid-etching gel is applied to the cavity walls (37% phosphate acid) for 15 seconds, then rinsed and dried thoroughly. A universal bonding agent is then applied to the cavity walls and set using a curing light. Following this, the cavity is filled incrementally using an oblique layering technique, ensuring that each layer is light cured before adding the next layer.

6. What are the benefits of using composite resin?

- **Effectiveness against caries**: Composite resin fillings are estimated to have good durability in small to moderate restorations, lasting for approximately eight years *(11)*. Composite resin is a more durable option for large, multisurface, load-bearing restorations than the main mercury-free, tooth-coloured alternative, glass ionomer cement *(11, 43)*.
- **Minimally invasive and preserves more of the tooth**: Minimal intervention restoration with composite resin protects more of the natural tooth structure than conventional methods do. Composite resin relies on chemical etching and bonding to tooth dentine and/or enamel for retention, not mechanical retention within a cavity, which may require removal of healthy tooth tissue for placement of dental amalgam *(11, 14, 15)*.
- **Improved health and quality of life**: In protecting teeth and preventing caries, composite resin restorations reduce infection, pain, tooth damage and the need to fill future cavities. This decreases financial burdens on individuals as well as health systems. Other potential positive impacts include reduced absence from school and work and improved quality of life.
- **Aesthetics**: Unlike dental amalgam, composite resin can match the colour and translucency of natural teeth, so restorations are not easily visible in the mouth. Indeed, for aesthetic reasons, composite resin is often a first choice for restorative veneers of teeth that are easily visible in the mouth *(11)*.
- **Environmental protection and public health**: Composite restorations are an important mercury-free alternative to conventional dental amalgam fillings. Use of dental amalgam is being phased down globally to protect human health and the environment from the adverse effects of mercury, in accordance with the Minamata Convention on Mercury *(9–11, 59)*.
- **Safety and cost-effectiveness**: Use of composite resin is cost-effective and potentially widely available, and it has low risks or adverse effects, based on intensive study over 60 years of use around the world. However, composite resin contains monomers, can cause allergic reactions and hypersensitivity, and may affect long-term pulp vitality.
- **Suitable for use in primary care**: Treatment with composite resin fillings can be provided through primary care facilities by trained dentists, improving the availability, accessibility and acceptability of essential restorative dental care *(19)*. However, in rural and remote settings, health facilities' sustainable provision of supplies may be a challenge, as well as continued availability of electricity and water, which are necessary for the proper use of resin-based composites *(10, 89)*.

References

1. World Health Organization. Sugars and dental caries. Geneva: World Health Organization, 2017 (https://apps.who.int/iris/handle/10665/259413, accessed 1 March 2022).
2. World Health Organization. Guideline: sugars intake for adults and children. Geneva: World Health Organization, 2015 (https://apps.who.int/iris/handle/10665/149782, accessed 1 March 2022).
3. GBD 2017 Oral Disorders Collaborators et al. Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: a systematic analysis for the Global Burden of Disease 2017 Study. *J Dent Res* 2020; **99**(4):362–73. doi:10.1177/0022034520908533.
4. Peres, MA, et al. Oral diseases: a global public health challenge. *Lancet* 2019; **394**(10194):249–60. doi:10.1016/s0140-6736(19)31146-8.
5. Tanner, L, et al. Does dental caries increase risk of undernutrition in children? *JDR Clin Trans Res* 2021:23800844211003529. doi:10.1177/23800844211003529.
6. Haag, DG, et al. Oral conditions and health-related quality of life: a systematic review. *J Dent Res* 2017; **96**(8):864–74. doi: 10.1177/0022034517709737.
7. Prüss-Üstün, A, et al. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. Geneva: World Health Organization, 2016 (https://apps.who.int/iris/handle/10665/204585).
8. United Nations Environment Programme and World Health Organization. Promoting the phase down approach of dental amalgam in developing countries. Nairobi: United Nations Environment Programme, 2014 (https://wedocs.unep.org/handle/20.500.11822/13849).
9. United Nations Environment Programme. Minamata Convention on Mercury: texts and annexes. Nairobi: United Nations Environment Programme, 2013 (https://wedocs.unep.org/20.500.11822/8541).
10. Fisher, J, et al. The Minamata Convention and the phase down of dental amalgam. *Bulletin of the World Health Organization* 2018; **96**(6):436–38. doi:10.2471/BLT.17.203141.
11. World Health Organization et al. Future use of materials for dental restoration: report of the meeting convened at WHO HQ, Geneva, Switzerland 16th to 17th November 2009. Geneva: World Health Organization, 2010 (https://apps.who.int/iris/handle/10665/202500, accessed 1 March 2022).
12. Frencken, JE, Leal, SC, Navarro, MF. Twenty-five-year atraumatic restorative treatment (ART) approach: a comprehensive overview. *Clin Oral Investig* 2012; **16**(5):1337–46. doi:10.1007/s00784-012-0783-4.
13. World Health Organization. Preventing disease through healthy environments: inadequate or excess fluoride: a major public health concern. Geneva: World Health Organization, 2019 (https://apps.who.int/iris/handle/10665/329484, accessed 1 March 2022).
14. Holmgren, CJ, Roux, D, Doméjean, S. Minimal intervention dentistry: part 5. Atraumatic restorative treatment (ART)--a minimum intervention and minimally invasive approach for the management of dental caries. *Br Dent J* 2013; **214**(1):11–18. doi:10.1038/sj.bdj.2012.1175.
15. World Health Organization. Atraumatic restorative treatment (ART) for tooth decay: a global initiative 1998–2000. Geneva: World Health Organization, 1998 (https://apps.who.int/iris/handle/10665/64325, accessed 1 March 2022).
16. Walsh, LJ, and Brostek, AM. Minimum intervention dentistry principles and objectives. *Aust Dent J* 2013; **58 Suppl 1**:3–16. doi:10.1111/adj.12045.
17. Eden, E, et al. Managing dental caries against the backdrop of COVID-19: approaches to reduce aerosol generation. *Br Dent J* 2020; **229**(7):411–16. doi:10.1038/s41415-020-2153-y.
18. World Health Organization. *WHO expert consultation on public health intervention against early childhood caries: report of a meeting, Bangkok, Thailand, 26–28 January 2016*. Geneva: World Health Organization, 2017 (https://apps.who.int/iris/handle/10665/255627, accessed 1 March 2022).
19. World Health Organization. Ending childhood dental caries: WHO implementation manual. Geneva: World Health Organization, 2019 (https://apps.who.int/iris/handle/10665/330643, accessed 1 March 2022).

20. Niederman, R, Feres, M, Ogunbodede, E. Dentistry. In: Debas, HT, et al., editors. *Essential surgery: disease control priorities*, third edition (volume 1). Washington (DC): World Bank: 2015 (https://www.ncbi.nlm.nih.gov/books/NBK333500/).

21. O'Mullane, DM, et al. Fluoride and oral health. *Community Dent Health* 2016; **33**(2):69–99 (https://eprints.whiterose.ac.uk/101379/).

22. World Health Organization. *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation, Geneva, 28 January–1 February, 2002*. Geneva: World Health Organization, 2003 (https://apps.who.int/iris/handle/10665/42665, accessed 1 March 2022).

23. Marinho, VC, et al. Fluoride toothpastes for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev* 2003; **2003**(1):Cd002278. doi:10.1002/14651858.Cd002278.

24. Walsh, T, et al. Fluoride toothpastes of different concentrations for preventing dental caries. *Cochrane Database Syst Rev* 2019; **3**(3):Cd007868. doi:10.1002/14651858.CD007868.pub3.

25. World Health Organization. *World Health Organization model list of essential medicines: 22nd list (2021)*. Geneva: World Health Organization, 2021 (https://apps.who.int/iris/handle/10665/345533, accessed 1 March 2022).

26. World Health Organization. *World Health Organization model list of essential medicines for children: 8th list (2021)*. Geneva: World Health Organization, 2021 (https://apps.who.int/iris/handle/10665/345534, accessed 1 March 2022).

27. Urquhart, O, et al. Nonrestorative treatments for caries: systematic review and network meta-analysis. *J Dent Res* 2019; **98**(1):14–26. doi:10.1177/0022034518800014.

28. World Health Organization Regional Office for Africa. Regional oral health strategy 2016–2025: addressing oral diseases as part of noncommunicable diseases: report of the Secretariat. Brazzaville: WHO Regional Office for Africa, 2016 (https://apps.who.int/iris/handle/10665/250994, accessed 1 March 2022).

29. World Health Organization Regional Office for South-East Asia. Strategy for oral health in South-East Asia, 2013–2020. New Delhi: WHO Regional Office for South-East Asia, 2013 (https://apps.who.int/iris/handle/10665/205929, accessed 1 March 2022).

30. Goldman, AS, et al. Global affordability of fluoride toothpaste. *Global Health* 2008; **4**:7. doi:10.1186/1744-8603-4-7.

31. FDI General Assembly. Promoting oral health through fluoride toothpaste: Adopted by the FDI General Assembly: 7 September 2018, Buenos Aires, Argentina. Original version adopted by the FDI General Assembly: November 2000, Paris, France. *Int Dent J* 2019; **69**(1):17–18. doi:10.1111/idj.12469.

32. Marinho, VC, et al. Combinations of topical fluoride (toothpastes, mouthrinses, gels, varnishes) versus single topical fluoride for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev* 2004; **2004**(1):Cd002781. doi:10.1002/14651858.CD002781.pub2.

33. Villena, RS, Pesaressi, E, Frencken, JE. Reducing carious lesions during the first 4 years of life: An interprofessional approach. *J Am Dent Assoc* 2019; **150**(12):1004–14. doi:10.1016/j.adaj.2019.04.003.

34. Watt, RG, et al. Ending the neglect of global oral health: time for radical action. *Lancet* 2019; **394**(10194):261–72. doi:10.1016/s0140-6736(19)31133-x.

35. Wong, MC, et al. Cochrane reviews on the benefits/risks of fluoride toothpastes. *J Dent Res* 2011; **90**(5):573–79. doi:10.1177/0022034510393346.

36. Wong, MC, et al. Topical fluoride as a cause of dental fluorosis in children. *Cochrane Database Syst Rev* 2010; **2010**(1):CD007693-CD007693. doi:10.1002/14651858.CD007693.pub2.

37. Gao, SS, et al. Caries remineralisation and arresting effect in children by professionally applied fluoride treatment—a systematic review. *BMC Oral Health* 2016; **16**:12. doi:10.1186/s12903-016-0171-6.

38. Oliveira, BH, et al. Biannual fluoride varnish applications and caries incidence in preschoolers: a 24-month follow-up randomized placebo-controlled clinical trial. *Caries Res* 2014; **48**(3):228–36. doi:10.1159/000356863.

39. Dholam, KP, et al., Effectiveness of fluoride varnish application as cariostatic and desensitizing agent in irradiated head and neck cancer patients. *Int J Dent* 2013; **2013**:824982. doi:10.1155/2013/824982.

40. Mishra, P, et al. Role of fluoride varnish in preventing early childhood caries: a systematic review. *Dent Res J (Isfahan)* 2017; **14**(3):169–76. doi:10.4103/1735-3327.208766.

41. Petersson, LG, Twetman, S, Pakhomov, GN. Fluoride varnish for community-based caries prevention in children. Geneva: World Health Organization, 1997 (https://apps.who.int/iris/handle/10665/63483).

42. Marinho, VC, et al. Fluoride varnishes for preventing dental caries in children and adolescents. *Cochrane Database Syst Rev* 2013; **2013**(7):Cd002279. doi:10.1002/14651858.CD002279.pub2.

43. Holmgren, C, et al. Minimal intervention dentistry II: part 3. Management of non-cavitated (initial) occlusal caries lesions—non-invasive approaches through remineralisation and therapeutic sealants. *Br Dent J* 2014; **216**(5):237–43. doi:10.1038/sj.bdj.2014.147.

44. Phantumvanit, P, et al. WHO global consultation on public health intervention against early childhood caries. *Community Dent Oral Epidemiol* 2018; **46**(3):280–87. doi:10.1111/cdoe.12362.

45. Ahovuo-Saloranta, A, et al. Pit and fissure sealants for preventing dental decay in permanent teeth. *Cochrane Database Syst Rev* 2017; **2017**(7):Cd001830. doi:10.1002/14651858.CD001830.pub5.

46. Mickenautsch, S, Yengopal, V. Caries-preventive effect of high-viscosity glass ionomer and resin-based fissure sealants on permanent teeth: a systematic review of clinical trials. *PLoS One* 2016; **11**(1):e0146512. doi:10.1371/journal.pone.0146512.

47. Griffin, SO, et al. The effectiveness of sealants in managing caries lesions. *J Dent Res* 2008; **87**(2):169–74. doi:10.1177/154405910808700211.

48. Locker, D, Jokovic, A, Kay, EJ. Prevention. Part 8: The use of pit and fissure sealants in preventing caries in the permanent dentition of children. *Br Dent J* 2003; **195**(7):375–78. doi:10.1038/sj.bdj.4810556.

49. Wright, JT, et al. Evidence-based clinical practice guideline for the use of pit-and-fissure sealants: A report of the American Dental Association and the American Academy of Pediatric Dentistry. *J Am Dent Assoc* 2016; **147**(8):672–82.e12. doi:10.1016/j.adaj.2016.06.001.

50. Kashbour, W, et al. Pit and fissure sealants versus fluoride varnishes for preventing dental decay in the permanent teeth of children and adolescents. *Cochrane Database Syst Rev* 2020; **11**:Cd003067. doi:10.1002/14651858.CD003067.pub5.

51. Kielbassa, AM, et al. Systematic review on highly viscous glass-ionomer cement/resin coating restorations (Part I): do they merge Minamata Convention and minimum intervention dentistry? *Quintessence Int* 2016; **47**(10):813–23. doi:10.3290/j.qi.a36884.

52. Kielbassa, AM, et al. Systematic review on highly viscous glass-ionomer cement/resin coating restorations (Part II): do they merge Minamata Convention and minimum intervention dentistry? *Quintessence Int* 2017; **48**(1):9–18. doi:10.3290/j.qi.a37211.

53. Frencken, JE, Liang, S, and Zhang, Q. Survival estimates of atraumatic restorative treatment versus traditional restorative treatment: a systematic review with meta-analyses. *Br Dent J* 2021. doi: 10.1038/s41415-021-2701-0

54. de Amorim, RG, et al. Survival percentages of atraumatic restorative treatment (ART) restorations and sealants in posterior teeth: an updated systematic review and meta-analysis. *Clin Oral Investig* 2018; **22**(8):2703–25. doi:10.1007/s00784-018-2625-5.

55. Corrêa-Faria, P, et al. Recommended procedures for the management of early childhood caries lesions - a scoping review by the Children Experiencing Dental Anxiety: Collaboration on Research and Education (CEDACORE). *BMC Oral Health* 2020; **20**(1):75. doi:10.1186/s12903-020-01067-w.

56. Frencken, JE. Atraumatic restorative treatment and minimal intervention dentistry. *Br Dent J* 2017; **223**(3):183–89. doi:10.1038/sj.bdj.2017.664.

57. Mickenautsch, S. High-viscosity glass-ionomer cements for direct posterior tooth restorations in permanent teeth: the evidence in brief. *J Dent* 2016; **55**:121–23. doi:10.1016/j.jdent.2016.10.007.

58. Mickenautsch, S, Yengopal, V. Failure rate of direct high-viscosity glass-ionomer versus hybrid resin composite restorations in posterior permanent teeth—a systematic review. *Open Dent J* 2015; **9**:438–48. doi:10.2174/1874210601509010438.

59. Ferracane, J, et al. Ensuring the global availability of high-quality dental restorative materials. *Adv Dent Res* 2013; **25**(1):41–45. doi:10.1177/0022034513502208.

60. Schmoeckel, J, et al. How to intervene in the caries process: early childhood caries—a systematic review. *Caries Res* 2020; **54**(2):102–12. doi:10.1159/000504335.

61. Seifo, N, et al. Silver diamine fluoride for managing carious lesions: an umbrella review. *BMC Oral Health* 2019; **19**(1):145. doi:10.1186/s12903-019-0830-5.

62. Slayton, RL, et al. Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions: A report from the American Dental Association. *J Am Dent Assoc* 2018; **149**(10):837–49.e19. doi: 10.1016/j.adaj.2018.07.002.

63. Duangthip, D, et al. Adverse effects of silver diamine fluoride treatment among preschool children. *J Dent Res* 2018; **97**(4):395–401. doi:10.1177/0022034517746678.

64. Crystal, YO, Niederman, R. Evidence-based dentistry update on silver diamine fluoride. *Dent Clin North Am* 2019; **63**(1):45–68. doi:10.1016/j.cden.2018.08.011.

65. Jiang, M, et al. A 24-month randomized controlled trial on the success rates of restoring untreated and SDF-treated dentine caries lesions in primary teeth with the ART approach. *J Dent* 2020; **100**:103435. doi10.1016/j.jdent.2020.103435.

66. Oliveira, BH, et al. The effect of silver diamine fluoride in preventing caries in the primary dentition: a systematic review and meta-analysis. *Caries Res* 2019; **53**(1):24–32. doi:10.1159/000488686.

67. Zhao, IS, et al. Mechanisms of silver diamine fluoride on arresting caries: a literature review. *Int Dent J* 2018; **68**(2):67–76. doi:10.1111/idj.12320.

68. Lo, ECM, Duangthip, D. Non-restorative approaches for managing cavitated dentin carious lesions. In: Coelho, LS, Takeshita, E, editors. *Pediatric restorative dentistry*. Springer, Cham; 2019 (https://link.springer.com/chapter/10.1007/978-3-319-93426-6_10).

69. Chibinski, AC, et al. Silver diamine fluoride has efficacy in controlling caries progression in primary teeth: a systematic review and meta-analysis. *Caries Res* 2017; **51**(5):527–41. doi:10.1159/000478668.

70. Yawary, R, Hegde, S. Silver diamine fluoride protocol for reducing preventable dental hospitalisations in Victorian children. *Int Dent J* 2021. doi:10.1016/j.identj.2021.05.009.

71. Subbiah, GK, Gopinathan, NM. Is silver diamine fluoride effective in preventing and arresting caries in elderly adults? A systematic review. *J Int Soc Prev Community Dent* 2018; **8**(3):191–99. doi:10.4103/jispcd.JISPCD_99_18.

72. Zhang, J, et al. Topical fluoride to prevent root caries: systematic review with network meta-analysis. *J Dent Res* 2020; **99**(5):506–13. doi:10.1177/0022034520906384.

73. Li, R, et al. Randomized clinical trial on arresting dental root caries through silver diammine fluoride applications in community-dwelling elders. J Dent 2016; **51**:15–20. doi:10.1016/j.jdent.2016.05.005.

74. Crystal, YO, et al. Use of silver diamine fluoride for dental caries management in children and adolescents, including those with special health care needs. *Pediatr Dent* 2017; **39**(5):135–45 (https://www.ingentaconnect.com/content/aapd/pd/2017/00000039/00000005/art00014).

75. Johhnson, B, et al. Projecting the economic impact of silver diamine fluoride on caries treatment expenditures and outcomes in young U.S. children. *J Public Health Dent* 2019; **79**(3):215–21. doi:10.1111/jphd.12312.

76. Rosenblatt, A, Stamford, TC, Niederman, R. Silver diamine fluoride: a caries "silver-fluoride bullet." *J Dent Res* 2009; **88**(2):116–25. doi:10.1177/0022034508329406.

77. Schwendicke, F, Göstemeyer, G. Cost-effectiveness of root caries preventive treatments. *J Dent* 2017; **56**:58–64. doi:10.1016/j.jdent.2016.10.016.

78. Schricker, SR. Composite resin polymerization and relevant parameters. In: Eliades, T, Brantley, W, editors. *Orthodontic Applications of Biomaterials, 1st Edition: A Clinical Guide*. Cambridge: Woodhead Publishing; 2016 (https://www.elsevier.com/books/orthodontic-applications-of-biomaterials/eliades/978-0-08-100383-1).

79. Nicholson, J, Czarnecka, B. Composite resins. In: *Materials for the Direct Restoration of Teeth*. Cambridge: Woodhead Publishing; 2016 (https://www.elsevier.com/books/materials-for-the-direct-restoration-of-teeth/nicholson/978-0-08-100491-3).

80. Ilie, N, Hickel, R. Resin composite restorative materials. *Aust Dent J* 2011; **56 Suppl 1**:59–66. doi:10.1111/j.1834-7819.2010.01296.x.

81. Fugolin, APP, Pfeifer, CS. New resins for dental composites. *J Dent Res* 2017; **96**(10):1085–91. doi:10.1177/0022034517720658.

82. Francois, P, et al. Commercially available fluoride-releasing restorative materials: a review and a proposal for classification. *Materials (Basel)* 2020; **13**(10). doi:10.3390/ma13102313.

83. Dorri, M, et al. Atraumatic restorative treatment versus conventional restorative treatment for managing dental caries. *Cochrane Database Syst Rev* 2017; **12**(12):Cd008072. doi:10.1002/14651858.CD008072.pub2.

84. Wright, JT, et al. Sealants for preventing and arresting pit-and-fissure occlusal caries in primary and permanent molars. *Pediatr Dent* 2016; **38**(4):282–308. Doi:10.1016/j.adaj.2016.06.003.

85. Ahovuo-Saloranta, A, et al. Pit and fissure sealants for preventing dental decay in permanent teeth. *Cochrane Database Syst Rev* 2017; **2017**(7):Cd001830. doi:10.1002/14651858.CD001830.pub5.

86. Yu, OY, et al. Conservative composite resin restoration for proximal caries—two case reports. *Clin Cosmet Investig Dent* 2020; **12**:415–22. doi:10.2147/ccide.S270453.

87. Heintze, S, Rousson, V. Clinical effectiveness of direct Class II restorations—a meta-analysis. *J Adhes Dent* 2012; **14**(5):407–31. doi:10.3290/j.jad.a28390.

88. Ladewig, NM, et al. Efficacy of conventional treatment with composite resin and atraumatic restorative treatment in posterior primary teeth: study protocol for a randomised controlled trial. *BMJ Open* 2017; **7**(7):e015542. doi:10.1136/bmjopen-2016-015542.

89. United Nations Environment Programme. Lessons from countries phasing down dental amalgam use. Nairobi: United Nations Environment Programme; 2016 (https://wedocs.unep.org/handle/20.500.11822/31212).

World Health Organization

Avenue Appia 20
1211 Geneva 27
Switzerland
www.who.int

9789240046184