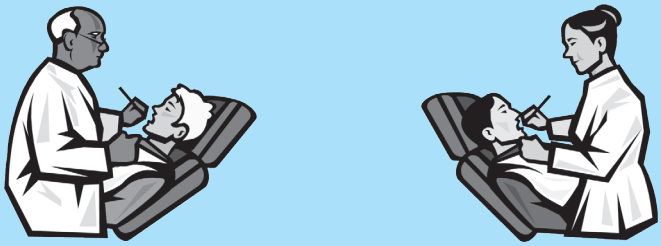
Future Use of Materials for Dental Restoration



World Health Organization

Future Use of Materials for Dental Restoration

Report of the meeting convened at WHO HQ, Geneva, Switzerland

16th to 17th November 2009

World Health Organization

WHO Library Cataloguing-in-Publication Data

Future use of materials for dental restoration: report of the meeting convened at WHO HQ, Geneva, Switzerland 16th to 17th November 2009 / prepared by Dr. Poul Erik Petersen… [et al]

1.Dental materials - analysis. 2.Dental amalgam - restorative use. 3.Mercury - adverse effects. 4. Alternative dental materials 5.Composites and Glass-ionomer. 6.Dental caries - prevention and control. I.Petersen, Poul Erik. II.Baez, Ramon. III.Kwan, Stella. IV.Ogawa, Hiroshi. V.WHO Oral Health Programme.

ISBN 978 92 4 150064 7 (NLM classification: WU 190)

Printed by the WHO Document Production Services, Geneva, Switzerland

Content

Executive summary

Dental caries is a major public health problem globally. Despite much effort in health promotion and disease prevention, dental restorations are still needed. Dental amalgam, a restorative material that contains mercury, has been widely used for some 150 years. In the past decades, the awareness and recognition of the environmental implications of mercury have increased and alternative filling materials have become increasingly more popular.

Jointly with the World Health Organization (WHO), the United Nations Environment Programme (UNEP) has strengthened the work to reduce risks to human health and the environment from the use and release of mercury. UNEP is supporting the work of the Intergovernmental Negotiating Committee established to elaborate a legally binding instrument on mercury. The mandate of this committee is set out in UNEP Governing Council decision 25/5. In seeking to reduce mercury use and release, the treaty may have implications on the delivery of oral health care worldwide.

On this background, the WHO Global Oral Health Programme - in cooperation with UNEP Chemicals - organized a two-day meeting to discuss the implications and the way forward. The aim of the meeting was to assess the scientific evidence available on dental restorative materials and the implications to countries of using alternatives to amalgam for dental restorative care.

Twenty-nine participants from 15 countries of all 6 WHO regions attended the meeting, representing international oral health researchers, scientists, university academics, WHO CCs, ministries of health, Non-Governmental Organizations (NGOs), dental professionals, and UNEP. Following opening statements from Dr Ala Alwan, Assistant Director General, Non-communicable Diseases and Mental Health and Mr Per Bakken, Director, UNEP Chemicals, Dr Poul Erik Petersen outlined the scope, purpose, objectives and structure of the meeting. This was followed by a number of presentations and discussions. Day One discussed the availability of different restorative materials, and their advantages and disadvantages in dental care. Experiences from both developed and developing countries of all WHO regions were shared in Day Two, which highlighted the implications for oral healthcare and future challenges.

The meeting considered the importance of strengthening oral health promotion and disease prevention as the strategy to reduce the use of restorative dental materials. In case of tooth decay, the best care possible should be provided to meet patients' needs. The meeting recognized the variation in dental practice between countries and the challenges faced by middle- and low-income countries providing dental care. This will likely result in different approaches to dental caries management in countries that need to be considered in oral health policy, development and planning

of public health programmes. Implications for training of dental personnel and costs to society as well as the individual are significant.

The meeting noted that only a few countries had phased out the use of amalgam. If not existing, other countries require systems for waste management to prevent release of mercury to the environment.

In several countries dental amalgam is still widely used. The choice of materials for dental caries management in these countries depends on a number of factors such as: the tooth, site and size of the caries lesion, as well as healthcare provision and financing, patient preference, health care provider preference, technology, cost and environmental factors. Following a review of existing evidence and much deliberation, the meeting recognized the huge challenges faced in dental restoration, disease prevention and oral health promotion globally. As a result, the meeting considered that all currently existing methods and materials to manage dental caries would need to remain available to the dental profession in the short- and medium-terms.

Furthermore, the meeting noted that while alternative dental restorative materials are desirable from an environmental health perspective, a progressive move away from dental amalgam would be dependent on adequate quality of these materials. Existing alternative dental materials are not ideal due to limitation in durability, fracture resistance, and wear resistance. Therefore, the meeting recognized the need for strengthening of research into the long-term performance, possible adverse effects, and viability of such materials.

It may be prudent to consider 'phasing down' instead of 'phasing out' of dental amalgam at this stage. A multi-pronged approach with short-, medium- and long-term strategies should be considered. Alternatives to dental amalgam exist but the quality of such materials needs to be further improved for use in public health care. The meeting suggested important strategies that can be put in place while waiting for new materials to be developed. The role of WHO, UNEP, NGOs such as the International Association for Dental Research (IADR) and the World Dental Federation (FDI), user groups and the industry is critical. A further meeting must be convened to discuss the way forward and to develop strategies to address issues in both developed and developing countries.

1. Introduction

1.1 The global burden of dental caries

Dental caries (tooth decay) has historically been considered the most important component of the global oral disease burden. Dental caries is still a major public health problem in most high income countries as the disease affects 60-90% of school-aged children and the vast majority of adults. At present, the distribution and severity of dental caries vary in different parts of the world and within the same region or country (*1-4*). For the permanent dentition, the severity of dental caries is measured by the Decayed, Missing and Filled Teeth index (DMFT). According to the WHO Global Oral Health Data Bank (*5*), the global dental caries index among children aged 12 years is 1.6 teeth on average, however, there are marked differences in severity amongst regions. The disease level in children of this age is relatively high in the Americas and in the European region; the index is somewhat lower among children of the Eastern Mediterranean and Western Pacific regions, while at the moment dental caries is less severe in South East Asia and in the African region. The WHO Global Oral Health Data Bank also provides information on the time trends in dental caries experience of children. In most low and middle income countries, dental caries levels were low until recent years while dental caries prevalence rates and dental caries experience have tended to increase rapidly with changing lifestyles and growing consumption of sugars, inadequate exposures to fluoride, and lack of national programmes for prevention of oral disease (*1,3)*. In contrast, a caries decline has been observed in most high income countries over the past 20 years or so. This pattern is seen as the result of a number of public health measures, including effective use of fluoride, coupled with changing living conditions, lifestyles and improved self-care practices, and establishment of school oral health programmes (*1,3)*.

Worldwide, dental caries prevalence is high among adults as the disease affects nearly 100% of the population in the majority of countries (*1,3)*. Most high income countries and some countries of Latin America show high DMFT values (i.e. 14 teeth affected by caries or more at the age of 35-44 years) while dental caries experience levels at present are lower in the low income countries of Africa and Asia. Meanwhile, reports are now available on a growing burden of dental caries among adults living in low and middle income countries. In several high income countries older people often have had their teeth extracted early in life because of pain or discomfort, leading to reduced quality of life. The proportion of edentulous adults aged 65 years or more is still high in some countries; meanwhile, in several industrialized countries there has been a positive trend of reduction in tooth loss among older adults in recent years. In parallel, an increase in the proportion of adult people with functional dentition (i.e. 20 teeth or more) reflects the growing use of preventive oral health services available (*1,3*).

In low income countries, oral health services are mostly offered from regional or central hospitals of urban centres and little, if any, importance is given to preventive or restorative dental care. Many countries of Africa, Asia and Latin America have a shortage of oral health personnel and generally the capacity of the systems is limited to pain relief or emergency care. In Africa, the dentist to population ratio is approx. 1:150,000 against about 1:2000 in most industrialized countries. Among children and adults suffering from severe tooth decay, teeth are often left untreated or are extracted to relieve pain or discomfort. In the future, tooth loss and impaired oral function are therefore expected to increase as a public health problem in many low and middle income countries.

1.2 Oral health promotion and disease prevention

Dental caries is avoidable, thus the need for dental restorative care can be reduced effectively when disease prevention programmes are established at country and community levels. Firstly, countries and communities should advocate a diet low in sugars in accordance with WHO/FAO recommendations (*6,7*). Among other recommendations, free (added) sugars should remain below 10% of energy intake and the consumption of foods/drinks containing free sugars should be limited to a maximum of four times per day. Secondly, fluoride is most effective in dental caries prevention when a low level of fluoride is constantly maintained in the oral cavity (*8*) There is clear evidence that long-term exposure to an optimal level of fluoride results in diminishing levels of caries in both child and adult populations (*9-12*) Fluorides can be obtained from fluoridated drinking-water, salt, milk, mouth rinse or toothpaste, as well as from professionally applied fluorides; or from combinations of toothpaste containing fluoride with any of the other fluoride sources. Thirdly, development of healthy lifestyles including proper general and oral hygiene behaviour, and healthy environments such as access to clean water and sanitation are essential to oral health (*1*).

Several high income countries having established preventive programmes demonstrate a systematic decline in dental caries in children and improved dentate status in adult populations (*3,5*). In most middle and low income countries oral disease prevention programmes are not yet organized. In addition, the vast majority of people are underserved and the need for comprehensive oral health care is growing dramatically, including dental restorative care. In response to the Bangkok 6th World Conference on Health Promotion (*13*), the Liverpool declaration in 2005 formulated guidelines on appropriate interventions for oral health (*14*). The World Health Assembly in 2007 agreed on a resolution (WHA60.17): Oral health: action plan for promotion and integrated disease prevention (*15*).The resolution gives directions to countries in identifying the opportunities for oral health and the development or adjustment of oral health systems (*16*). The World Health Report 2008 on Primary Health Care (*17*) is a vital instrument to countries in their efforts to

ensure universal coverage and the provision of essential health care to populations. Effective primary oral health care - particularly in middle and low income countries – will focus on the unmet needs for dental care and dental restoration.

1.3 Dental restoration

In spite of the success in the prevention of dental caries, caries in need of restoration still occur. In the case of dental treatment, diseased tissue is removed and teeth restored with appropriate material(s). In high income countries, dental amalgam has been widely used over decades as a dental restorative material. Providers of oral health care in low- and middle income countries also generally consider amalgam of relevance in serving their patients. However, the limited availability of oral health manpower, service facilities and materials for dental restoration, and the high cost of dental restorative treatment induce radical treatment with the extraction of teeth among people suffering from pain and illness. Consequently, unless the access to dental restorative treatment is further improved, the growing burden of dental caries in low and middle income countries will result in even higher numbers of people becoming edentulous in the near future.

1.4 WHO Consultation 1997

1.4.1 Dental amalgam and alternative direct restorative materials

Dental amalgam is widely used in restorative care and is a compound of mercury and silver-based alloys; however, some concerns have been expressed about the possible health effects of mercury in amalgam and to contamination of the environment from mercury. In 1997, the WHO held a Consultation Meeting on the use of dental amalgam (*18*) The objective of this consultation was "To provide more information to the Member States, WHO/ORH was requested to review again the WHO/FDI Consensus Statement and if necessary draft a relevant document on dental amalgam use, taking into account the benefits, but also risks for individual, occupational, and environmental health of restorative materials. The project was thoroughly scrutinized by the WHO Programmes on Environmental Health and Occupational health."

The consensus statement on restorative dental care also emphasized the need for further research on alternatives to dental amalgam.

1.4.2 Research agenda to improve health

The participants of the WHO Consultation in 1997 devoted considerable time to a discussion of a research agenda related to dental restorations (*18*). The Consultation unanimously agreed to establish the following research topics:

- Global registry of biological and adverse health effects for monitoring of dental material related symptoms/diseases in various populations (patients and professionals) including the formation of an international advisory group to establish guidelines and evaluate the collected data.
- Research to develop affordable preventive caries programmes, making any restorative material unnecessary, including studies helping to identify fractions of various populations at high risk of caries, for targeted actions.
- Studies to identify special risk groups and individuals highly sensitive to various restorative materials.
- Development of restoration methods and inexpensive biomaterials that can withstand local climatic, storage and handling limitations.
- Research to develop improved and novel materials, including development of biological materials (biomimetics/tissue engineering) for restorative purposes.
- Development of better diagnostic methods for dental caries and methods for clinical decision making.
- Development of criteria regarding the replacement of failed restorations.
- Improvement in methods for minimal intervention in caries management:
- Improved and affordable methods for recovering and recycling of restorative materials.
- Improved methods to make relevant dental material information available, including use of Internet.
- Development of direct filling materials with easy handling characteristics.

1.5 Use of dental amalgam for restoration

During the past 10 years or so, the awareness and recognition of the environmental implications of mercury have increased and dentistry has gained further attention as being a source of contamination of the environment. In addition, within the dental profession and the oral health research community the interest of serving patients through the use of alternative dental restoration materials has grown markedly. A few high-income countries have introduced a ban on use of dental amalgam in light of the higher availability and accessibility of tooth-coloured dental materials. Others have required or recommended dental practices to manage amalgam wastes so that they are not released to the environment. In some high income countries having introduced preventive dental care, the use of dental amalgam has declined partly due to the fact that dental caries is less prevalent and that caries lesions are less complicated.

It is worth noting, however, that in the majority of countries having third-party payment systems dental schemes do not yet recognize the use of alternative materials and one implication of this is that use of these materials for restoration of tooth structure is more expensive to consumers than dental amalgam. In the vast majority of low- and middle-income countries, the use of dental amalgam remains the preferred material for dental fillings or build-up material as alternative materials are currently far too expensive for people and society. Even today dental restoration is expensive often leading to tooth extraction in the case of dental pain or discomfort.

The research on alternative materials for restorative dental care has grown significantly over the past 10-15 years. Alternatives are now available on the market in some of the wealthiest industrialized countries and some materials have been tested in clinical investigations as well as in population studies. These studies have been conducted on both primary and permanent teeth (*9-22*). However, such research is mainly carried out in high-income countries and research findings from the use of alternative biomaterials may not apply directly to low-and middle income countries.

1.6 Recent major international statements on dental restorative materials

In May 2008, a Scientific Committee of the European Commission addressed the use of dental amalgam and the available alternative restorative materials (*23,24*). The committee concluded that dental amalgams are effective and noted that none of the dental materials - amalgam and alternatives- was without clinical limitations and toxicological hazards. Because dental amalgam is neither tooth-coloured nor adhesive to remaining tooth tissues, its use has been decreasing in recent years and the alternative tooth-coloured filling materials have become increasingly more popular. Independent of risk management decisions, a sustained reduction in the use of dental amalgam in oral health care provision is expected in several countries of the European Union, the rate of which is dependent on trends in dental education towards the increasing use of alternative materials in place of amalgam and the possible reduced availability of mercury products in general.

The two major dental organizations have formulated statements on use of amalgam. The recent declaration by the World Dental Federation (FDI) at the General Assembly 2009 (www.fdiworldental.org) states that "amalgam is a safe, widely used and affordable dental filling material and currently serves the oral health needs of the majority of communities around the world, particularly those most disadvantaged and in need of dental treatment". Further, the FDI General Assembly "…acknowledges its responsibilities with regard to mercury and dental amalgam in terms of global health and the environment",….."and reaffirms its commitment

to upholding best environmental practices with regard to dental amalgam". The International Association for Dental Research (IADR) formulated in 2004 a policy statement (www.iadr.org) which reads: "Dental amalgam has a well-documented history of safety and efficacy in dentistry. Its advantages include ease of handling, durability, and relatively low cost. Dental amalgam has numerous indications for use, especially for restorations in stress-bearing areas. Its main disadvantages are poor aesthetics and the necessity for sound tooth structures to be removed in order for retention to be obtained"….. "Scientific evidence indicates that currently used restorative materials, including dental amalgam, cause no or very few significant side-effects". The IADR endorses the use of best management practices for the use of amalgam restorations in dental offices".

1.7 UNEP initiatives on mercury

The United Nations Environment Programme (UNEP) is the focus within the UN for environmental issues. In 2001, the UNEP Governing Council (GC) requested the preparation of a global assessment of mercury and its compounds. At its next meeting, in 2003 GC considered the key findings of the 2002 Global Mercury Assessment and concluded that there was sufficient evidence of significant global adverse impacts from mercury and its compounds to warrant further international action to reduce risks to humans and the environment from the release of mercury and its compounds to the environment. In response to further decisions in 2005 and 2007, UNEP initiated and formalized a Global Mercury Partnership with the following objectives:

- Minimization and, where possible, elimination of mercury supply considering a hierarchy of sources, and retirement of mercury from the market to environmentally sound management.
- Minimization and, where feasible, elimination of unintentional mercury releases to air, water and land from anthropogenic sources.
- Continued minimization and elimination of global use and demand for mercury.
- Promoting the development of non-mercury technologies where suitable economically feasible alternatives do not exist.

To achieve these objectives the partnership areas should also:

- strengthen the capacity of developing countries and countries with economies in transition
- share and exchange information

The Global Mercury Partnership currently has seven partnership areas addressing different aspects of mercury use and release. The business plan of the mercury-containing products partnership area, sets out its objective as:"to phase out and eventually eliminate mercury in products and to eliminate releases during manufacturing and other industrial processes via environmentally sound production, transportation, storage, and disposal procedures" (www.unep.org/hazardoussubstances). Throughout the continuing efforts in relation to mercury, UNEP and WHO have worked jointly to consider the risks to human health posed by mercury and its compounds and to prepare a number of documents such as the document "Guidance for identifying populations at risk from mercury exposure" (*25*).

In 2009, UNEP was requested to convene an intergovernmental negotiating committee (INC) with the mandate to prepare the global legally-binding instrument on mercury, commencing its work in 2010 with the goal of completing it prior to the Governing Council/Global Ministerial Environment Forum in 2013. The GC provided a detailed mandate for the INC and noted that measures could include both binding and voluntary approaches.

2 Objectives of the WHO meeting in 2009

In response to the various initiatives on mercury and the request from Member States for guidance, the WHO Global Oral Health Programme – in cooperation with UNEP Chemicals - organized a two-day meeting to discuss the implications and the way forward. The overall aim of the meeting was:

- To assess the scientific evidence available on use of dental restorative materials, including dental amalgam, and the implications of using alternatives to amalgam for dental restorative care.

Specific objectives were:

- To assess the feasibility (appropriateness, efficacy, safety) of using dental restorative materials alternative to dental amalgam, particularly the potential for use in populations of countries around the world.
- To assess the potential side-effects and hazards to health of existing materials for restorative dental care.
- To highlight the cost implications of alternative dental restorative materials for oral healthcare for different populations, particularly relevant to the situation in low-and middle income countries.
- To highlight the environmental concerns of mercury pollution from the dental sector, and the effect and implications of occupational exposure

from mercury for dental personnel.

- To suggest principal strategies for further reduction in contamination of the environment from mercury due to dentistry.

3 Outline of the structure of the meeting

Twenty-nine participants from 15 countries of all six WHO regions attended the meeting, representing ministries of health, Non-Governmental Organizations (NGOs), dental professionals, university academics, UNEP, scientists, and WHO CCs. A list of participants is appended in Annex 1 and the meeting agenda in Annex 2.

Dr Ala Alwan, Assistant Director-General, Non-communicable Diseases and Mental Health, addressed the welcome introduction and opened the meeting. He emphasized the importance of this meeting and that WHO was giving the issue of oral health care serious consideration. He looked forward to the conclusions and recommendations to be circulated to all member states. Mr Per Bakken, Director, UNEP Chemicals, outlined the work of UNEP leading to this consultation meeting and the implications for future activities. Dr Poul Erik Petersen then summarized the oral health context of restorative dental care and presented the scope, purpose, objectives and structure of the meeting. Professor Ramon J. Baez was elected Chair, while Dr Stella Kwan and Dr Hiroshi Ogawa were elected rapporteurs. A number of presentations and discussion followed (Annex 2).

Day One discussed the availability of different restorative materials, their advantages and disadvantages, and potential adverse effects on health and the environment. Experience from both developed and developing countries of all WHO regions was shared in Day Two, which implications for oral health care were highlighted. The role of WHO, UNEP, NGOs such as IADR and FDI, and the industry was emphasized.

4. Types of dental restorative materials

Two types of restorative materials are commonly used in dentistry; they are designated depending on whether they can be applied directly to the tooth or require fabrication of the restoration in the dental laboratory. Dental materials are used for direct restoration of a tooth in order to save its function while indirect materials include pre-formed metal crowns, dental porcelain, and cast restorations. The principal material types for direct restoration are:

- Dental amalgam (silver-tin-copper alloy and approximately 50% mercury)
- Resin-based composite materials (RBC).

- Modifications of RBCs (poly-acid modified composites); compomers and giomers (glass filler modified composites).
- Glass-ionomer cements/water-based cements: Self-setting ("pure" glass ionomers) or, more usually, light cured (resin modified glass-ionomers).
- Long-term temporary materials e.g. reinforced zinc oxide-eugenol cements.

The indications for use of restorative materials span from small cavities to extensive loss of tooth substance. Materials are employed for cavities in primary teeth; for cavities in permanent teeth, ranging from "minimal interventions" to the need for extensive replacements and/or build-procedures; replacement or repair of failed or less satisfactory restorations, or materials are used in people with compromised health and having dental caries on certain locations, e.g. root caries. The development of 'smart composites', Amorphous Calcium Phosphate Composites that respond to oral microflora by releasing chemotherapeutics or antimicrobials such as calcium and fluoride, may circumvent some of the shortcomings of composite restorations. Research into a material that is based on the technology of glass ionomers, low shrinking resins and high strength filters with simple handling and acceptable longevity is in progress.

4.1 Strengths and weaknesses of different materials

While tooth-coloured restorative materials are generally more expensive than amalgam, they offer an aesthetic alternative to traditional amalgam fillings. However there are concerns about their longevity and wear particularly in areas subjected to masticatory forces. In a study conducted on the longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth, the repair rate was seven times greater for composites than for amalgams (2.8 percent of composites versus 0.4 percent of amalgams) *(26)* Micro leakage is also a disadvantage but it can be reduced with proper manipulation and strict clinical procedures. Important advantages and disadvantages of amalgam, composites, glass ionomers and resin ionomers are presented in **Table 1.**

Table 1. Advantages and disadvantages of different types of restorative materials.

Amalgam	Composites	Glass ionomers	Resin ionomers
Principal uses			
Dental fillings	Aesthetic dental fillings	Small non-load fillings	Small non-load fillings
Heavily loaded posterior restorations	Veneers	Cavity liners	Cavity liners
		Cements for crowns and bridges	Cements for crowns and bridges
Leakage and recurrent decay			
Moderate leakage	Low leakage if properly bonded	Low leakage generally	Low leakage if properly bonded
Recurrent decay same as other materials	Recurrent decay depends on maintenance of tooth-material bond	Recurrent decay comparable to other materials	Recurrent decay comparable to other materials
		Fluoride release may be beneficial	Fluoride release may be beneficial
Overall durability, fracture resistance & wear resistance			
Good to excellent durability in large load bearing restorations	Good durability in small to moderate restorations	Moderate to good durability in non load-bearing restorations; poor in load-bearing	Moderate to good durability in non load-bearing restorations; poor in load-bearing
Brittle, subject to chipping on filling edges; good bulk strength in large high-load restorations	Moderate resistance to fracture in high load restorations	Low resistance to fracture	Low to moderate resistance to fracture
High resistance to wear	Moderate resistance to wear	High wear on chewing surfaces	High wear on chewing surfaces
Cavity preparation and clinical consideration			
Require removal of tooth structure	Adhesive bonding permits removal of less tooth structure	Adhesive bonding permits removal of less tooth structure	Adhesive bonding permits removal of less tooth structure
Tolerant to wide range of clinical conditions	Requires well-controlled field of operation	Requires well-controlled field of operation	Requires well-controlled field of operation
Moderately tolerant to moisture during placement	Very little tolerance to moisture during placement	Very little tolerance to moisture during placement	Very little tolerance to moisture during placement

4.2 Restoration longevity

The longevity of different materials is not easily established because the data depends on a multitude of factors, where material selection is just one. Study design, cavity selection, the operators' experience, non-standardized evaluation criteria, and the study cohorts play a role for the clinical outcome (*27*). However, several studies indicate that amalgam tend to last longer than other materials available (*28, 29*), whereas recent data suggest that RBCs perform equally well (*29*). The most prevalent reasons for failure of fillings are secondary caries and fracture (*29, 30*).

The longevity of glass-ionomers is lower than that of amalgam or RBCs (*31-33*), however, these materials have frequently been assessed in primary teeth. In fillings subjected to low chewing forces, the composite materials perform better than a glass ionomer cement (*34*). The Atraumatic Restorative Treatment (ART) procedure appears to provide some positive results in primary teeth (*35*). Reinforced zinc-oxide-based cements are recommended for "semi-permanent" restoration lasting up to approximately one year (*36*).

In general, dental amalgam outlasts resin composites (*37*) with median ages of 10-15 years for amalgam, compared with <5 to 8 years for composites (*38, 39*). Similarly, a study indicated that starting at 5 years after initial treatment, the need for additional restorative treatment was approximately 50% higher in the composite group (*40*). Annual failure rates of different restorative materials are given in **Table 2**, with glass ionomers having the highest failure rate of 7.6% (*19, 22, 39, 41*).

Espelid and colleagues (*42*) compared the clinical behaviour of silver reinforced glass ionomers and resin modified glass ionomers. After 24 months, the resin modified glass ionomers have the best overall performance with respect to retention, marginal integrity and secondary caries.

Table 2. Annual failure rates of dental restorations[42]

Material	Age at replacement	Annual failure rate
Resin-based composites	8 years	2.3%
Poly-acid modified composites	7 years	3.5%
Resin-modified glass ionomers	2 years	3.1%
Glass ionomers	4 years	7.6%
Amalgam	10 years	2.2.%

According to the Norwegian KVIT project (*43*) 95% of compomer, 92% of amalgam, 85% of composite and 69% of glass ionomer restorations survive after 4 years. The high success rate of compomer may be attributed to limited inter-operators variability as only one dentist used this material. Only 4.6% of all restorations are amalgam, reflecting dentists' preference in dental restorative materials. Secondary caries is by far the most common reason for failure.

4.3 Biological considerations

All artificial materials release substances into the oral environment and imply some risk of side effects and adverse reactions (44, 45). Amalgam has been associated with general health concerns (*46*), while local oral effects from different restorative materials are reported (*47*). The biocompatibility of dental restorative materials is being evaluated in different test settings (*48*). RBCs and associated materials have been elucidated with respect to effect on cellular and sub-cellular levels related to resin constituents (*49-51*) and also filler particles (*52*).

According to the Norwegian Dental Biomaterials Adverse Reaction Unit, the majority of cases of side-effects of dental filling materials are linked with dental amalgam (*54*). However, there is an increase in adverse reaction reports related to composites and cements following the amalgam ban in 2008. The majority of the reactions reported occurred within one week after treatment. Skin reactions and pain are the most commonly reported complaints, among a long list of general health problems and oro-facial lesions and conditions. However, the information gathered is based on voluntary reporting. There is a need to establish a more objective global registry of adverse effects for dental restorative materials. Long-term monitoring is also needed.

5. Effects of mercury on health and the environment

Mercury is highly toxic and harmful to health. Approximately 80% of inhaled mercury vapour is absorbed in the blood through the lungs, causing damages to lungs, kidneys and the nervous, digestive, respiratory and immune systems. Health effects from excessive mercury exposure include tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental deficits during fetal development, and attention deficit and developmental delays during childhood.

In spite of its potential risks, mercury continues to be used in a variety of products and processes all over the world. Elemental mercury is used in artisanal and small-scale mining of gold and silver; chlor-alkali production; manometers for measurement

and control; thermometers; electrical switches; fluorescent lamp bulbs; back lights of computers; and in dental amalgam fillings. Occupational exposures have been reported to arise from work in several industries and from work in dental clinics with poor mercury handling practices (*25*).

The UNEP-WHO report "Guidance for identifying populations at risk from mercury exposure" (*25*) notes that the naturally occurring element mercury is toxic and is distributed throughout the environment by both natural and anthropogenic processes and that most people have some exposure to elemental, inorganic or methylmercury as a result of normal daily activities.

The report considered that dental personnel may experience occupational exposure in dental clinics with poor mercury handling practices and that dental fillings made with amalgam can be a source of human exposure to elemental mercury vapours for many populations (25). Amalgam surfaces release mercury vapour into the mouth and lung. Depending upon the number of amalgam fillings and other factors, the estimated average daily absorption of mercury vapour from dental fillings varies between 3 and 17 μg mercury.

Attention to reducing dental amalgam use in order to contribute to overall mercury use is not limited to the immediate concerns related to direct human exposure. A significant amount of mercury is estimated to be released to the environment from the use of dental amalgam either as an indirect result of the diversion of traded amalgam for other purposes or as a result of improper waste management practices or through cremation. **Table 3** sets out some of the major releases and pathways of mercury that result from use of dental amalgam. When released from dental amalgam use into the environment through these pathways, mercury is transported globally and deposited. Mercury releases may then enter the human food chain especially via fish consumption.

Table 3. Major pathways of mercury due to use of dental amalgam every year

Main releases/pathways	Mercury (metric tonnes/year)
Atmosphere	50 – 70
Surface water	35 – 45
Groundwater	20 – 25
Soil	75 – 100
Recycling of dental amalgam	40 – 50
Sequestered, secure disposal	40 – 50
Total	260 – 340

Source: UNEP

6. Best Management Practices (BMP) for amalgam waste

Best Management Practices (BMP) are a series of amalgam waste handling and disposal practices that include, but are not limited to, initiating bulk mercury collection programmes, using chair side traps, amalgam separators compliant with ISO 11143 and vacuum collection, inspecting and cleaning traps, and recycling or using a commercial waste disposal service to dispose of the amalgam collected. Recycling is one of the BMP for dental offices (**Table 4**) and a practical guide for the dental practice is given in **Table 5**. Using amalgam separators, together with other measures of BMP, can significantly reduce mercury discharge to the environment.

Table 4. Best Management Practices for dental offices using amalgam.

DO	DON'T
Do use pre-capsulated alloys and stock a variety of capsule sizes	***Don't*** use bulk mercury
Do recycle used disposable amalgam capsules	***Don't*** put used disposable amalgam capsules in biohazard containers, infectious waste containers or regular garbage
Do salvage, store and recycle non-contact amalgam (scrap amalgam)	***Don't*** put non-contact amalgam waste in biohazard containers, infectious waste containers or regular garbage
Do salvage (contact) amalgam pieces from restorations after removal and recycle the amalgam waste	***Don't*** put contact amalgam waste in biohazard containers, infectious waste containers or regular garbage
Do use chair-side traps, vacuum pump filters and amalgam separators to retain amalgam and recycle their contents	***Don't*** rinse devices containing amalgam over drains or sinks
Do recycle teeth that contain amalgam restoration. (Note: Ask your recycler whether or not extracted teeth with amalgam restorations require disinfection)	***Don't*** dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers, sharps containers or regular garbage
Do manage amalgam waste through recycling as much as possible	***Don't*** flush amalgam waste down the drain or toilet
Do use line cleaners that minimize dissolution of amalgam	***Don't*** use bleach or chorine-containing cleaners to flush wastewater lines

Table 5. Practical guide to integrating BMPs into the dental practice

Non-contact (scrap) amalgam

- Place non-contact, scrap amalgam in a wide-mouthed container that is marked "Non-contact Amalgam Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.

Amalgam capsules

- Stock amalgam capsules in a variety of sizes.
- After mixing amalgam, place the empty capsules in a wide-mouthed, airtight container that is marked "Amalgam Capsules Waste for Recycling".
- Capsules that cannot be emptied should likewise be placed in a wide-mouthed airtight container that is marked "Amalgam Capsules Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.

Disposal chair-side traps

- Open the chair-side unit to expose the trap.
- Remove the trap and place it directly into a wide-mouthed, airtight container that is marked "Contact Amalgam Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.
- Traps from dental units dedicated strictly to hygiene may be placed in with the regular garbage.

Reusable chair-side traps

- Open the chair-side unit to expose the trap.
- Remove the trap and empty the contents into a wide-mouthed, airtight container that is marked "Contact Amalgam Waste for Recycling".
- Make sure the container lid is well sealed.
- When the container is full, send it to a recycler.
- Replace the trap into the chair-side unit (Do not rinse the trap under running water as this could introduce dental amalgam into the waste stream.

Vacuum pump filters

- Change the filter according to the manufacturer's recommended schedule. Note: The following instructions assume that your recycler will accept whole filters; some recyclers require different handling of this material, so check with your recycler first.
- Remove the filter.
- Put the lid on the filter and place the sealed container in the box in which it was originally shipped. When the box is full, the filters should be recycled.

Amalgam separators

- Select an amalgam separator that complies with ISO 11143.
- Follow the manufacturer's recommendations for maintenance and recycling producers.

Line cleaners

- Use non-bleach, non-chlorine-containing line cleaners, which will minimize amalgam dissolution.

7. Training of dental health professionals

Given the increasing popularity of tooth-coloured restorative materials, dental schools worldwide are revising their training and education curricula to equip students with the appropriate skills to perform the procedures. However, variations in teaching, and techniques and technologies used are observed (*55-60*). The challenges are significant. For example, staff themselves may not have sufficient training to teach the techniques and their attitudes and the remuneration systems may influence the teaching of different techniques. While some dental schools place more emphasis on composite resins, amalgam restorations are still taught if the State only funds these materials in dental practices. Fostering the philosophy of preserving the tooth structure and improving the survival of the tooth is also imperative, as is oral health promotion. Clinical performance of posterior resin composites placed by dental students has been shown to be satisfactory (*61*). If they are taught composite resins prior to amalgam, they may find amalgam difficult to handle. Using adhesive systems prepares them for many other procedures in restorative dentistry. Adhesive resin materials allow for less tooth destruction and, as a result, a longer survival of the tooth itself. Funding agencies should take the initiative and encourage the replacement of amalgam as the material of choice for posterior teeth with adhesive systems. Staff training is a major component for success.

8. Implications for future research

Amalgam has been used for about 150 years, although a declining trend is expected for the future. In order to reduce the use of dental amalgam in the future, the meeting emphasizes that prevention is of paramount importance, including community interventions, proper use of fluorides, fissure sealants, and re-mineralization strategies. In the near term, alternative restorative materials including composites will need to be improved, as will the 'next generation' materials. In the longer term, tissue engineering approaches could be considered.

Research into the development of improved and novel alternative restorative materials remains unsatisfactory since the 1997 WHO Consultation meeting; little progress has been observed. Further research is also needed to assess the safety and adverse effects of restorative materials alternative to dental amalgam. Collaboration between material scientists, computer scientists, toxicologists, synthesis chemists and industry is critical. IADR Taskforce on Dental Materials comprising material scientists, clinicians and manufacturers has been formed to accelerate the development of improved materials, to provide clinicians with viable alternatives to greatly reduce the use of dental amalgam and, partnering with FDI, to promote BMPs until such time that amalgam use and amalgam replacement has discontinued.

9. Country experience

9.1 African Region

There is limited information about the use of restorative materials in the developing countries of Africa. In low resource communities oral health services are either not available or poor, especially in rural and remote areas. Oral health services are available in major urban centres but have little outreach to the underprivileged, disadvantaged population groups. Restorative dental care is extremely expensive to people living in poverty. When oral health service exists, dental amalgam may be in restorative dental care, although in certain countries the sale of composite materials has been noted over the last few years. The few existing dental schools focus on the control of infectious disease transmission; issues regarding mercury from dental amalgam are not always considered as a priority. Very few countries have a formal policy on the use of dental restorative materials. Given the high prevalence of severe and large carious lesions, the use of dental amalgam is highly indicated. For smaller lesions, composites may be more suitable but their use depends on availability and cost. Composites are more commonly used by private dental practitioners and, for aesthetic reasons, are more popular with patients. Patients' preferences, "not the science", may phase out amalgam. However, dental amalgam is considered to be a more predictable and forgiving material by dentists. In conclusion, dental amalgam has an important and continuing role to play in the provision of oral healthcare because of its indication for the severe and large carious lesions, affordability, ease of use and longevity.

9.2 Region of the Americas

Dental amalgam has been used for about 150 years; the first American Dental Association (ADA) specification was developed about 70 years ago. Amalgam has been used for restoration of posterior teeth in children and adults. Thirty years ago 80% of all restorations were amalgam. The use of amalgam has decreased to some extent. Various groups have opposed the use of amalgam in dentistry based on claims of an adverse effect on patient's health and as a factor in occupational health. Earlier in 2009, the Food and Drug Administration (FDA) issued a final regulation regarding classification of amalgam as the same as other restorative materials such as gold and composites. Labelling requirements were included in the regulation. Specifically, the FDA recommended that the product labelling include a warning against the use of dental amalgam in patients with mercury allergy; a warning that dental professionals use adequate ventilation when handling dental amalgam; and a statement discussing the scientific evidence on the benefits and risks of dental amalgam, including the risk of inhaled mercury vapour. This statement should help dentists and patients make informed decisions about the use of dental amalgam.

Dental amalgam is a "pre-amendment device," which means that it was in use prior to 28th May 1976, when the FDA was given broad authority to regulate medical devices. That law required the FDA to issue regulations classifying pre-amendment devices according to their risk into class I, II, or III. Although the FDA previously had classified the two separate parts of amalgam – elemental mercury and the metal powder alloy – it had not issued a separate regulation classifying the combination of the two, dental amalgam. The ADA has made various statements on this and, being concerned about possible impact on the environment, issued best management practices for amalgam waste in 2007. The intention is that 99% of mercury released to the environment is captured. This may be accomplished by use of amalgam separators. The American National Standards Institute (ANSI), ADA and ISO have currently a draft international standard DIS 11143 for amalgam separators. Requirements in the standard specify that separators shall be at least 95% (mass fraction) effective, have a warning system, an alarm system and an alarm for malfunctioning. According to the US Environmental Protection Agency (EPA), 3.7 tons of mercury are discharged to the environment each year from dental practices. In 2008 a memorandum of understanding (MOU) on reducing dental amalgam discharges was jointly signed by ADA, EPA and the National Association of Clean Water Agencies (NACWA).

Factors that affect the cost as disseminated by private practitioners are related to "the dentist who performs the procedure, the location where it is performed, type of dental insurance (some insurance schemes do not cover composite restorations) and the number of tooth surfaces". Some clinicians claim that it takes twice as long to insert composite resins than amalgam. Typical cost of amalgam restoration in a pre-doctoral dental clinic range from $32 to $47 depending on complexity and from $113 to $207 if the procedure is conducted in a faculty practice clinic, compared with $42 to $62 and $129 to $275 respectively for composite resin restorations. In terms of longevity, amalgams are known to last 12 years as an average (*19*); however, there are restorations that are 40-50 years old. Composite resins have been reported to last 12-15 years. Implications for oral health are considerable if amalgam were to be banned. Fewer people will have access to dental care because of cost, particularly among communities in the US that are already underserved according to United States Public Health Service. Insurance coverage will need to be modified to cover alternate materials. Services in public clinics would need to be offered to all population groups.

For Canada, while medical care is provided by the government under the federal act and is administered by the provinces, 60% of Canadians receive oral health services under the fee-for-item-of-service from private dental clinics. Social and children programmes vary from province to province. However, access to oral healthcare is a growing problem particularly in remote areas and among the disadvantaged. While the oral health needs of 80% of the Canadian population are met, the challenge of addressing the needs of the remaining 20% is almost intractable. In addition, the

situation could be worsened by changes in the economy or increases in costs of oral healthcare.

There is no dental material industry in Canada. Although oral health services are not dictated by private insurance, dentists can only work with materials that are available. However, the use of amalgam is declining. According to the Dental Industry Association of Canada, the sale of amalgam dropped from 3000 kg in 1999 to 2500 kg in 2006. In 2003, about 5000 kg of amalgam were removed in 2003 and 4700 kg placed, while removal and placement figures of 5400 kg and 4100 kg respectively were reported in 2007*(62.63)*.There is no Total Daily Intake (TDI) for mercury from dental amalgam in Canada and the removal of serviceable amalgams is not warranted. The reduction of use of amalgam through diagnostic, preventive and restorative strategies aimed at tooth preservation is recommended. Nonetheless, more research and improved public information are still needed. While there are regulations on prohibition of mercury-containing products, dental amalgam and lamps are exempted based on the need and successful management of environmental concern through the Canadian Wide Standard (CWS) for mercury. The Canadian Council of the Minister of the Environment launched an initiative in 1998 targeting a number of sectors to reduce mercury exposure. CWS for mercury from dental amalgam waste was adopted in 2001, which was followed by a MOU signed by the Canadian Dental Association (CDA) and Environment Canada (EC) in 2002. Since then, 70% of dental offices in Canada have 'voluntarily' implemented the BMPs of the CWS. In the future, CDA will continue to cooperate with EC to achieve the targets of the CWS and formal monitoring of BMPs has been proposed. Ongoing public consultations have been initiated. Until there is no more demand for amalgam, a pragmatic approach has been employed to promote the use of most appropriate material, to educate dentists on the impact of mercury and to implement mitigation strategies in the meantime.

In Latin American countries, the burden of dental caries is generally high (*64*) The caries prevalence and experience vary between countries with differing risk factors, scope of services provided, availability of community prevention programmes, economics, education and human resources available. Variations in public expenditure on health are observed between countries (*65*) Services provided to the individuals focus on treatment of disease and prevention. Prevention activities include risk assessment, application of sealants and fluoride, professional measures to reinforce habits, elimination of inadequate retentive elements, monitoring and control. Functional or restorative services are provided using amalgam, resins, glass-ionomers and compomers. Endodontic and periodontal treatments are available for selected cases. Surgery is provided for simple and complicated surgical procedures and, in some countries, prosthetic rehabilitation is also available. In regards to the use of amalgam and resins, amalgam is mainly for restoration of posterior teeth and resin restorations are limited to upper and lower anterior teeth in public health services and social security clinics. This is covered under the social security services

programme. In private clinics, resins are provided even in posterior teeth. In the case of Colombia, for each glass ionomer restoration inserted, 6 composite resins and 14 amalgam fillings are placed. Given the high restorative treatment needs and the contrasting costs of different dental restorative materials, using composites and glass ionomers instead of dental amalgam would lead to exorbitant extra health spending(over $936 million dollars), a budget that most developing countries in this region do not have.

Regarding impact on the environment, there is no quantification of the proportion of consumption of mercury by dental services. It is known that the main focus is in the mining operations that have led to regulatory and legislative regulation of trade and use of significant amounts of mercury. In health services, countries already have standards for bio-safety and waste management. Distribution of alloy and mercury (pre-dispensed) in capsules is better than supplying alloy in powder form and mercury in bottles. Norms and regulations have been issued about the processes of production and consumption in services including registration, labelling, trade, storage, handling, collection, disposal, storage, transportation and recycling of material and spill management. When considering a restorative material, it is crucial to consider the economical cost, functional, scope and coverage of services and health public policies. If there is a need for transition, it is important to decrease the cost of the new dental material and maintain the model of Primary Health Care.

9.3 South-East Asia Region

Dental caries, especially in primary dentition, is a growing public health problem. Despite the high levels of treatment needs, an estimated 90% of caries remains untreated (*66*). The types of restorative materials used in dental schools vary between countries. While dental amalgam restorations are still taught in the dental curriculum, much emphasis is placed on tooth-coloured restorative materials, leading to an increasing trend in using more composite resins and glass ionomers than amalgam in the future. Costs of materials also vary between countries. Composites may be twice as expensive as amalgam and, as a result, the use of dental amalgam is still common. Manufacturers have an important part to play in ensuring that the materials are readily accessible, easy to use and cost-effective. Local producers can serve to reduce costs of, and improve access to, materials. In Indonesia, where local production has reduced costs and improved access, composites and glass ionomers are being used. In Myanmar 50% of restorations are made in amalgam.

Patients' preference and demand, site of lesions, type of dentition, cost, cost-effectiveness, training and treatment philosophy are some of the influencing factors. Glass ionomers based on Atraumatic Restorative Treatment (ART) are used in certain countries of this region, particularly in the primary dentition.

9.4 European Region

The use of amalgam has been restricted in some countries. There has been a complete ban on amalgam in Norway since January 2008. In Sweden, the use of dental amalgam declined dramatically over the past decade because of a "phasing-out policy"; Denmark has introduced a partial "phasing-down" practice in the use of amalgam as this material is generally not recommended for children. In Finland 5% of restorations are in amalgam. In the Netherlands less than 10% restorations are amalgam and over 81% are composites. In countries of Central and Eastern Europe, no systematic data are available on the use of dental restorative dental materials.

While there is a trend towards the reduced use of amalgam in some European countries, many chief dental officers believe that a ban on amalgam would be problematic, particularly for low resource countries.

According to an ad hoc study prepared for the meeting less than half of dentists in Norway would prefer dental amalgam even if it were legal. Some 23% of dentists surveyed have no experience with amalgam at all. However, while composite is the most commonly used material; Norwegian dentists are not convinced that the alternatives can fully replace amalgam. Elsewhere many dentists feel that amalgam cannot be entirely replaced. The choice of materials is influenced by the training and education of dental professionals, policies and legislations, professionals' attitudes, costs and patient preference. Hence, the role of dental professionals, research communities, industry and third party payers is critical.

The funding and remuneration of dental treatment also impact on the type of restorative treatment provided. For example, as reported at the meeting, in Ireland the state funded dental practices insert mainly amalgam restorations for posterior teeth in children and adults, whilst semi-state funded practices use both amalgams and composites. In contrast, private practices place 70% of composite and 30% amalgam restorations on posterior teeth.

The majority of Cochrane oral health reviews fail to provide sufficient quality evidence to inform the use of various materials for dental treatment. However, the European Commission stresses that the relative risks and benefits of different restorative materials should be explained to patients for them to make an informed decision (*23,24*).

9.5 Eastern Mediterranean Region

The burden of dental caries is significant in this region although there are variations between countries. In some countries, the situation is worsening, for example in

Kuwait the proportion of children who are caries free is decreasing and the mean numbers of Decayed Missing and Filled Teeth (DMFT) are increasing over time *(67)*. It was reported at the meeting that according to a recent impromptu survey on the use of restorative materials in the region, dental amalgam is more commonly used in government clinics than in private dental practices. The percentage varies among countries, for instance in Kuwait 50% of restorations are made in amalgam in government dental clinics, 20% in private practices and 25% in dental schools. In Jordan, amalgam is used in over 90% of restorations made in government clinics, 70-80% of restorations made in dental schools and 60-70% of restorations made in dental practices. Nonetheless, the use of amalgam is considered to be declining, while tooth-coloured materials are on the increase. ART is also used in some locations of this region. Information obtained from the survey regarding how countries deal with waste and other pertinent issues on restorative materials indicates that in Kuwait, for instance, amalgam separators are used and practitioners recycle amalgam, whereas in Jordan there are no recycling facilities and in Syria amalgam waste is disposed in the water sewer. Problems with other restorative materials identified were as follows: in Kuwait reports have been made on contact allergy with composite; no major problems with composites or glass ionomers are found in Syria. In Bahrain, difficulty in the delivery by local dealers was reported as a problem.

9.6 Western Pacific Region

There is a long history of using amalgam and precious metals for dental restorations in China. Dental amalgam products are manufactured locally and are regulated by national authorities. The use of dental amalgam varies between regions and provinces in China; it is more commonly used in Hong Kong and less so in Xian and Shanxi Province. The following information summarizes use of restorative materials in various provinces/regions.

Hong Kong	The choice of restorative materials is mainly based on clinical need. Dental amalgam is the most commonly used, particularly in government clinics.
Xian and Shanxi Province	Composite resins are commonly used in large hospitals (70%), middle level hospitals (60%) and small hospitals and private dental clinics (50%). The decreasing trend of amalgam use continues.
Guangxi Province	Dental amalgam is still used in every public hospital, but only for 8-10% of dental restorations. The majority of private dental clinics (80%) still use dental amalgam based on patients' needs.
Beijing	Composite resins are used in large hospitals instead of amalgam. Dental amalgam is still in use in other hospitals and private dental clinics, although the trend is decreasing.

Shanghai	Dental amalgam is used in hospitals and private dental clinics in about 45% of dental restorations. Hospitals and dental clinics have certain measures for waste handling to reduce mercury pollution, but some of them do not have guidelines to deal with the problems.
Anhui Province	Dental amalgam is the most popular restorative material of choice for posterior teeth because it is cost-effective.
Dalian	Dental amalgam restorations are not used in children. Few are used in other hospitals and dental clinics.
Zhengzhou	Dental amalgam is commonly used for dental restorations. It costs about 50 Chinese dollars per filling; the cost is double for composite resins. There are no adverse reactions to dental amalgam reported by local experts.

In spite of being cheaper than composite restorations, the use of dental amalgam is declining in general. The declining trend could be attributed to the improved dental health of people and the increased availability of other low-cost restorative materials. In China, dental amalgam is considered to be an effective filling material**.** Adverse effect on health is rare, oral lichenoid lesion is the most common allergic reaction to dental amalgam.

For other countries in the region, the use of dental amalgam is still common while the use of composite resins and glass ionomers is becoming more popular. The percentage of dental material use varies in countries and in practice settings. For instance in Mongolia 10% of restorations are in amalgam, 60% composite and 30% glass ionomers whereas in the Philippines 70% are placed in amalgam, 20% in composites and 10% in glass ionomers. In private practices in Malaysia 50% of restorations are amalgams, 30% composites and 20% ionomers while in Singapore and Vietnam amalgams only amount to 20% but composites reach 60% and ionomers 20%.

10. Partners in relation to use of dental restorative materials

10.1 The role of the dental profession

The dental profession has an important role to play in shaping the future use of dental restorative materials. The profession has led the move from wide-scale extraction of teeth in response to pain and infection to restoration and maintenance of the dentition, resulting in a decline in tooth loss and an improvement in oral health and quality of life among people in high income countries. Dental amalgam has played an important element in restorative dentistry worldwide. In low- and middle-income countries, restorative materials are rationed by price, manpower and technology.

The FDI World Dental Federation coordinates its members in 144 countries worldwide to promote the following strategies:

1. Investigate safe affordable alternative restorative materials to dental amalgam through effective collaboration with the research communities, governments, industry, educators and practitioners.
2. Employ a responsible approach to protecting the environment, in accordance with BMPs including bulk collection programmes, chair-side trap and vacuum filters, use of amalgam separators (ISO 11143) and waste disposal services.
3. Adopt a Minimal Intervention Approach (MIA) to oral healthcare: modification of the oral flora, patient education, remineralisation of non-cavitated lesions, minimal operative intervention of cavitated lesions and repair of defective restorations.
4. Promote a new paradigm among dental practitioners, shifting from a restorative to a preventive/health promotion model.

10.2 The role of the International Association for Dental Research (IADR)

The mission of IADR is to advance research and increase knowledge for the improvement of oral health worldwide. The role of IADR is to support and represent the oral health research community and to facilitate the communication and application of research findings. Coordination of IADR activities is undertaken through Divisions and Sections. Regions with less developed research programmes are identified for specific support and include countries of Africa and the Middle East, Asia, Europe, Latin America, and North America. A number of interest groups are established, the Dental Materials group being one of them. This group coordinates global research in restorative dental materials. This scientific group also interacts with the dental materials industry. The aim of IADR is to expand and further develop the Association's partnership with international dental associations, industry, health agencies, and scientific and educational professional organizations.

10.3 The role of UNEP

UNEP has been mandated to work with governments and other stakeholders to protect human health and the environment from mercury and its compounds through a twin-track approach.

Firstly, UNEP has convened, and provides the secretariat for, the intergovernmental negotiating committee (INC) mandated by the UNEP Governing Council to develop

a global legally-binding instrument on mercury. The INC process commenced in 2010 with the goal of completing it by 2013.

Secondly, the seven partnership areas of the UNEP Global Mercury Partnership address particular aspects of mercury use and release. Governments, intergovernmental organizations, industry, civil society organizations, academia and individuals who support the overall goal of, and commit to contribute resources or expertise towards, the Partnership can become partners. As many actions to address releases are targeted at sources, industry and the professions have key roles to play within the Partnership.

The goal of the Partnership is to minimize and, where possible, eliminate global anthropogenic mercury uses and releases. All major uses and releases of mercury are targeted, including releases from coal combustion, use in artisanal small scale gold mining, mercury-containing products including dental amalgam and lamps; and use in industrial processes such as mercury cell electrolysis and as a catalyst. Best practices for waste management and storage are being addressed.

Through these processes, a comprehensive strategic approach to mercury has been developed. UNEP supports global, regional and country-based projects that tackle mercury risk reduction and risk management; provides capacity building and makes provisions for technical and financial assistance; and promotes awareness-raising and information exchange.

10.4 The role of WHO

Mercury is one of the ten chemicals of major public health concern that WHO prioritizes. Dental amalgam is a significant source of exposure. Technical work for reduction of mercury is carried out by the WHO Programmes of Water, Sanitation and Health, Department of Protection of the Health Environment, and the WHO Global Oral Health Programme, Health Promotion, Department of Chronic Disease and Health Promotion. National, regional and global actions, both immediate and long-term, are needed to reduce or eliminate releases of mercury and its compounds to the environment. WHO is committed to work with the health sector and national, regional and global health partners to:

- reduce mercury exposure;
- eliminate the use of mercury wherever possible;
- promote the development of alternatives to the use of mercury.
- lead the profession in the negotiations of the development of the legally binding instrument on mercury.

The WHO Global Oral Health Programme provides advice to national and supra-national health authorities in appropriate dental care. Several low and middle income countries are in process of strengthening oral health systems in response to the growing burden of dental caries and the provision of restorative dental care is a matter of public health concern. Increasingly, WHO interacts with public health administrators and oral health professionals in those countries.

Elimination of mercury-related health problems requires strategic action to:

- Conduct national assessments of mercury use and disposal and implement educational activities for the health, environment and other sectors.
- Promote the use of mercury-free alternatives and ensure that mercury-containing devices are taken back by the manufacturer or properly disposed.
- Develop mercury clean-up and waste-handling, storage and safe-handling procedures; promote environmentally sound management of health-related waste containing mercury.
- Encourage countries to develop and implement policies and legislation on mercury; highlight the role of the health sector in dealing with mercury-containing material, health-care waste and emission reduction; and promote effective ways to control mercury emissions from cremation.
- Encourage international agencies to work with manufacturers, wholesalers and retailers to develop and make widely available inexpensive mercury-free products, and facilitate their procurement.
- Assist countries in preparing advice for pregnant and lactating women and children, about the risks and benefits of fish consumption, indicating the type of fish that may be eaten and how often. WHO strongly recommends breastfeeding since the presence of methylmercury in breast milk is not sufficient to outweigh its benefits.
- Identify traditional practices, folk medicines and cosmetics involving mercury, and disseminate information on mercury hazards, exposure prevention and how to clean up spillages.
- Promote long-term monitoring (including biological measurements of exposure) and programmes to reduce occupational exposure.

11. Summary of discussions at the meeting

During the meeting several points of relevance to the use of dental restorative materials were discussed and the participant's views are summarised as follows:

- In an environmental health perspective it is desirable that the use of dental amalgam is reduced. This may be achieved effectively by strengthening the prevention of dental caries and by encouraging better use of quality alternatives to dental amalgam.
- In many countries throughout the world amalgam is still widely used for dental restoration. Alternatives to dental amalgam are available, e.g. glass-ionomers and composite but they would need higher quality when used in public health care.
- While the harmful effects on health and the environment from mercury have been a major concern, the adverse effects of the alternative materials remain unclear and further research is still needed.
- Studies on adverse reactions to restorative materials lack validity as they rely on subjective and voluntary reporting, there is no robust mechanism to examine and verify reactions.
- An alternative dental restorative material should have the technology of glass ionomers, low shrinking resins and high strength fillers.
- Relying on a single universal material may be problematic. It may be necessary to investigate different materials and develop appropriate criteria for different categories.
- At present, amalgam restorations are more likely to be part of basic oral health care scheme that are financed by the State or third-payers, whilst it may not be the case for composites.
- The choice of materials may depend on the tooth, site and size of cavity, as well as health care financing, patient preference, technology, cost and environmental factors.
- Data on material longevity in some studies may need to be treated with some caution as different types of restorations may have been used and compared with poor standardization and consistency.
- There is a paucity of research evidence. More quality studies and systematic reviews are needed in the case of dental materials alternative to amalgam.
- It may be more important to examine tooth survival and to preserve tooth structure than filling survival. Health services will need to be reoriented to focus on disease prevention and minimize intervention.

- Implications for training in use of materials alternative to dental amalgam are considerable. In dental schools, teachers and students will need to be trained properly to keep up with the technology. Dental professionals will need to be made aware of the environmental impact of dental materials. Similarly, educating other stakeholders, governments, insurance companies and manufacturers is needed.
- Variations between countries must be taken into consideration. Countries with limited resources may be less likely to replace amalgam readily.
- Studies in some high income countries, whose dental disease level is low, may not be representative and findings may not be generalizable to countries worldwide. Similarly, most studies on dental restorative materials are conducted in high-income countries with a history of dental care, whereas there is little evidence from middle- and low-income countries.
- The cost implications must not be underestimated, for example the cost of manufacturing the materials, implementing best management practices and training dental professionals.
- The challenges faced by middle- and low-income countries may be significant. Pain relief may be the most pressing need.
- Given the lack of infrastructure for dental care, the implementation of BMP may be an important challenge, particularly where there are no safe waste disposal systems.
- The needs of middle-aged and older generations who may have many amalgam fillings and those with lots of advanced caries lesions must not be ignored.
- It may be prudent to consider 'phasing down' instead of 'phasing out' of dental amalgam at this stage. A multi-pronged approach should be considered. Short-, medium- and long-term strategies should be developed.
- Elements of strategies can be put in place while waiting for the new quality materials to be developed.

12. Recommendations

The participants of meeting formulated a number of recommendations of relevance to restorative dental care in the future.

12.1 Strengthening the prevention of dental caries

It is anticipated that the burden of dental caries will grow less severe in high income

countries having established preventive programmes while the incidence of dental caries presumably will increase rapidly in several middle and low income countries having not introduced prevention. In most low and middle income countries dental caries often involves pain and discomfort leading to extraction of teeth. The need for dental care is still substantial in numerous countries, in particular among the poor and disadvantaged population groups.

Strengthening of disease prevention and health promotion is the most relevant approach to reduce the need for restorative care and most efficient way to phase down the use of dental amalgam. Public health intervention is needed for development of healthy lifestyles, such as healthy diet low in sugars and personal hygiene; effective use of fluoride, and development or adjustment of oral health systems that are oriented towards oral disease prevention and health promotion.

Countries are encouraged to establish population directed disease prevention programmes incorporating dental caries prevention. At the World Health Assembly, May 2007, the Member States agreed on Resolution WHA60.17 entitled "Oral health: Action plan for promotion and integrated disease prevention. The resolution (*15, 16*) provides guidelines to countries in implementation of public health programmes including oral health.

12.2 Information available on materials for dental restoration

Unfortunately, populations in numerous countries still show a high need for control of dental caries through restorative care whereby dental materials are used. Glass ionomer and composite have great potential for use as alternative to dental amalgam, but there is a need for minimizing failures. Particularly glass-ionomers appear to be relevant alternative in dental care of children; however it remains uncertain whether such alternatives would be applicable to adults in general and older patients. Longevity and failures of restorations may be affected by the extension of disease; restorations placed in small cavity lesions in occlusal surfaces have a higher life expectancy than those placed to restore severe Class II lesions. Thus, it is important to further investigate the practical implications of alternative materials being used in posterior teeth.

12.3 Indicators of success of restoration

Indicators for evaluation of success of restorative dental care should be health outcome oriented. Preservation of the tooth in a functional state should be taken into consideration rather than retention of the material used for restoration; this is in line with goals for oral health suggested by WHO (*1*), which focus on quality

of life related measures such as dentate status. Criteria should be developed on whether dental materials alternative to amalgam successfully contribute to restore tooth function and thereby maintain dentate status.

12.4 Challenges to research

It is a matter of urgency that the oral health research community strengthens operational research in relation to use of dental restorative materials. Clinical research must emphasize risk assessment, criteria for use of restoration materials alternative to dental amalgam, development of standardized and reliable criteria for assessment of quality of restorations, occupational hazards, and development and dissemination of clinical guidelines for making dental restorations. It is critical that oral health research strengthens the measurement of the evidence of using restorative materials alternative to dental amalgam through population-wide studies. In addition, it is imperative that research documents the cost-effectiveness of non-amalgam restoration in public health care.

There is a call for dental schools and the International Association for Dental Research to encourage operational research on alternative materials for dental restoration and to coordinate such activity at international level.

Effective training of dental students and practitioners is based on research. In dental schools undergraduate training must better consider the safety of the environment, characteristics of dental amalgam and existing alternatives to amalgam for restorative dental care, development of skills in application of new quality materials for restoration, and the safety of dental materials to the provider of care.

12.5 Cost of dental care

In the vast majority of countries around the globe the current cost of applying glass ionomer or composite is high to the patient and society compared to the cost of using dental amalgam for restoration. For low resource people in most countries, high expenses on dental care often will lead to extraction of teeth which impairs quality of life. Therefore, in countries actions are needed to ensure that dental care services are financially fair. Countries having third-party payment systems in operation would need to adjust such schemes to cover the costs of dental care using alternatives to dental amalgam. In countries with third-party payment systems being introduced health authorities should give priority to balanced reimbursement schemes in restorative dental care.

12.6 Health service facilities

The status of facilities for provision of oral health care must be taken into account. In high income countries health care conditions and availability of advanced equipment allow the alteration of practices towards effective use of restoration materials alternative to dental amalgam. In countries where facilities for provision of oral health care are poor and where essential requirements such as water, electricity, suction and equipment are restricted or lacking, efforts should be made for improving such conditions. Best Management Practices would need to be adapted accordingly and a phase down programme for amalgam should be instituted. Availability of alternative restorative materials that do not require sophisticated for manipulation and placement must be encouraged.

12.7 The providers of dental care

It is important to differentiate that in high income countries the key health care provider is the dentist. In middle income countries, in addition to dentists, ancillary dental personnel and primary health workers are significant health care providers while in low income countries with shortage of oral health personnel the primary health care worker will play an instrumental role in serving the population in oral health care.

In light of the high burden of dental caries around the globe it is vital that oral health care providers develop and maintain skills in dental restorative care. In many low and middle income countries there is a great need to enhance skills of ancillary personnel and primary health workers in providing essential dental health care. Efforts should be made that personnel is properly trained in minimal intervention techniques which will reduce the need for dental amalgam.

12.8 Dental care provider-patient interaction

The dental health care provider should be able to identify suitable material for the restorative process that is best for the patient and provide accurate information to patients about the advantages/benefits and disadvantages of dental materials available as well as information regarding safety of different dental restorative materials. It is most important that decisions on the use of dental restoration materials are made through informed interaction between patient and provider of dental care; the choice of dental materials should take cost factors to the patient and third party payment into consideration.

12.9 Responsibility of the dental industry

Industry can contribute to appropriate dental care by improving the standard of existing tooth-coloured materials and development of new materials of high-quality. In low resource communities it is imperative to increase the availability of new dental materials and develop the market for alternatives to amalgam. Better supply and distribution of materials should be established.

The dental industry must also collaborate with health authorities and oral health professionals on reducing price of dental materials alternative to amalgam. Thus, the dental industry plays an important role ensuring that restorative materials, including alternatives to amalgam, are available and affordable to all population groups in countries.

12.10 The dental profession

It is highly recommended that the Federation Dentaire Internationale (FDI) strengthens its work for translation of sound knowledge about dental materials to oral health practitioners. The following activities should be given special attention:

- Promote a new paradigm among oral health professionals, shifting from a restorative to preventive and health promotion models.
- Advocate affordable restorative materials alternative to dental amalgam through effective collaboration with the research community, governments, industry, educators, and oral health practitioners.
- Employ a responsible approach to protecting the environment, in accordance with Best Management Practices, including bulk collection programmes, chair-side trap and vacuum filters, use of amalgam separators (ISO 11143) and waste disposal services.
- Adopt a Minimal Intervention Approach (MIA) to oral healthcare of the patient, i.e. remineralisation of non-cavitated lesions, minimal operative intervention of cavitated lesions, repair of defective restorations, and patient education.

12.11 Responsibility of UNEP

The mandate for the work of UNEP on mercury derives from successive decisions of its Governing Council over the past 10 years or so. Most recently, the 25th session of GC in 2009 requested, in decision 25/5, the UNEP Executive Director to convene an intergovernmental negotiating committee (INC) to prepare a global legally-binding instrument on mercury. That decision also requested the Executive

Director to continue and enhance, as part of the international action on mercury, the existing work in a number of areas, including through the Global Mercury Partnership. Within this context, UNEP will continue consultations with all concerned sectors. Consultations with the oral health sector, including in particular WHO, will be to examine opportunities to reduce mercury use and release from the use of dental amalgam through the introduction and promotion of appropriate and viable oral health strategies and best management practices.

12.12 Responsibility of WHO

WHO is committed to work for reduction of mercury and the development of a healthy environment. Work for reduction of mercury is carried out by the WHO Programmes of Water, Sanitation and Health, Department of Protection of the Health Environment, and the WHO Global Oral Health Programme, Health Promotion, Department of Chronic Disease and Health Promotion. WHO is dedicated to work with the oral health sector and national, regional and global health partners to promote the development and use of restoration materials alternative to dental amalgam. In addition, WHO will lead the oral health profession in negotiations and development of a legally binding instrument on mercury. The WHO Global Oral Health Programme provides advice to national and supra-national health authorities in appropriate dental care. The Programme will provide advice to countries in strengthening of oral health systems, including the building of infrastructures needed for optimal dental care. WHO must provide advice on use of appropriate restorative dental materials, with a focus on materials alternative of dental amalgam.

Country-based information on use of dental restorative materials and their impact to health is necessary. Data systems should allow assessment of trends in use of dental restorative materials indicating nature of materials, type and site of restoration, and type patient (e.g. child, adult, and old age).

13. Conclusions

In the recent decades, the awareness and recognition of the human health and environmental implications of mercury has increased. The World Health Organization (WHO) and the United Nations Environment Programme (UNEP) have strengthened the work for reduction of the mercury releases, including mercury release related to the use of dental amalgam.

- In response to the global initiatives on mercury reduction WHO supported by UNEP organized a two-day meeting in Geneva, Switzerland to discuss the implications to dental care of reduction in mercury release and usage.

- The aims of the meeting were to assess the scientific evidence available on dental restorative materials, and the practical and public health implications of using alternatives to amalgam for dental restorative care. The meeting aimed to share country experiences on dental care practices and the opportunities and barriers in relation to phasing-down the use of dental amalgam and the introduction of alternative dental restorative materials.

The following observations were made during the Geneva meeting:

- Dental amalgam, a compound of mercury and silver-based alloys, has been widely used in dental care for some 150 years. Meanwhile, for many reasons restorative materials alternative to dental amalgam are desirable.
- There is a need to prepare for a treaty on mercury use. The Geneva meeting encourages a global "phasing-down" of the use of dental amalgam and actively supporting the introduction of dental materials alternative to amalgam. A global "phasing-down" of dental amalgam will contribute considerably to reduction of mercury use and release; meanwhile, a complete ban is not yet appropriate. The issue of equity in dental health care needs to be carefully considered.
- The Geneva meeting highlighted country experiences in dental care and certain challenges to countries in "phasing-down" the use of dental amalgam were noted. In particular, the challenges to low and middle income are important as these countries have shortage of oral manpower, trouble in supply of dental materials, problems as to affordability of materials for dental restoration, and limitations as regards dental care facilities, appropriate equipment, and infrastructure.
- In high income countries dental caries is generally under control as the population at large enjoys the benefits of preventive strategies and have access to dental care. Significant proportions of people participate in regular dental care and may receive restorative dental care in case of manifest dental caries. However, dental care is less accessible to underprivileged population groups, in consequence poor dental conditions are often noted in people having received suboptimal dental care.
- In some high income countries the use of dental amalgam has decreased while the use of alternative dental materials has increased. Emphasis on oral health promotion and disease prevention are major reasons of these trends in dental restoration practices. Tooth-coloured dental restorative materials have also become increasingly more popular for aesthetic reasons.
- In middle and low income countries, public health policies on oral health promotion and disease prevention may not exist and low economic resources may preclude implementation. Access to dental care is low due to shortage of dentists and other dental personnel and due to the fact that

the cost of dental care is extremely high. People often suffer from pain or discomfort related to dental caries, and the seeking of health care is mostly prompted by symptoms. Problems by teeth and costly dental treatment may often lead to tooth extractions rather than tooth restoration.

- Third-party payment systems for dental care exist in several countries. Very often such systems do not consider dental materials alternative to amalgam and it is therefore needed to incorporate these materials into reimbursement schemes.
- Materials alternative to dental amalgam are available and particularly used in certain patient groups mainly of high income countries. Alternative restorative materials of sufficient quality are available for use in the deciduous dentition of children. However, current evidence indicates that the quality of materials alternative to amalgam is lower than for dental restoration based on use of amalgam. Materials such as glass ionomers or composites are promising in future dental care but there remains a need to promote the development of quality dental restorative materials for use in public health programmes.
- All types of materials may have adverse side-effects; components of amalgam as well as other alternative dental restorative materials may, in rare instances, cause local side-effects or allergic reactions. Reporting systems on adverse side-effects of dental materials are important for dental care.
- The Geneva meeting discussed important ways forward in the work for continuous reduction of exposure to mercury. The responsibilities of the research community, the dental profession, public health authorities, third-party payers, industry, UNEP, and WHO were emphasized.

A multi-pronged approach with short-, medium- and long-term strategies should be considered. In order to prepare for phasing-down of amalgam several actions must be undertaken by stakeholders.

International Association for Dental Research (IADR)

The global research community must strengthen intensively research on dental materials alternative to dental amalgam. Basic, clinical and in particular public health research must be undertaken in support of improving the quality of existing dental materials alternative to amalgam and developing new appropriate materials for dental care. The International Association for Dental Research (IADR) is committed to establishment and coordination of such research and the Biomaterials Science Group under IADR plays a vital role in implementation of relevant research.

The dental profession – Federation Dentaire Internationale (FDI)

FDI expresses commitment to the work for changing the current professional paradigm from treatment of disease to prevention and health promotion. FDI has a vital role to play in continuing education whereby dental professionals can adopt the available evidence on use of dental restorative materials and implement Best Management Practices. The global implication for training of oral health personnel is huge. FDI must organize systematic training programmes in use of dental materials alternative to amalgam and assist national dental associations in the preparation of relevant action plans for education. Credits should be earned from participation in such continuing education programmes. FDI also must play an active community role in advocating the evidence on using new quality dental materials for restorative care.

Policy makers and public health authorities

Policy makers and public health authorities should strengthen oral health systems as regards development or adjustment of programmes so they are effectively oriented towards oral health promotion and disease prevention. Capacity building and work for appropriate infrastructure for dental care are needed in several low resource communities around the globe. Health authorities can play an active role in advocacy for use of dental materials alternative to amalgam when indicated from a professional point of view. Directives can be set up for provision of dental care incorporating concerns for oral health and the environment. The protection of the environment through Best Management Practices is important to consider by national health authorities; the challenges to implementation of such practices are particularly imperative in low and middle income countries.

Third-party payment

In the majority of countries dental care is not financially fair. Around the globe underprivileged and disadvantaged population groups are either underserved or they do not benefit from optimal dental care. Third-party payment can help solve inequity in dental care. Most importantly, existing or planned third-party payment systems must consider reimbursement schemes incorporating dental care which make use of materials alternative to dental amalgam.

Manufacturers

The dental industry must adapt to a future situation of lower use of dental amalgam and higher use of materials alternative to amalgam. Improving the quality and affordability of dental restorative materials are the social responsibilities of the

dental industry. In order for dental care to be financially fair, prices on alternative materials must be reduced. It is a vital role of the dental manufacturers to ensure supply and distribution of materials for restorative dental care in all countries.

UNEP

In addition to supporting the work of the intergovernmental negotiating committee on mercury, UNEP will continue its work, including through the Global Mercury Partnership, to address aspects of mercury use and release in order to provide information and guidance on good practices and, where possible, to take immediate action promoting reduced mercury use and release. In doing so, UNEP will work within its mandate and competence, partnering with other stakeholders to ensure that information and actions are appropriate. With regard to human health, UNEP will continue its close collaborative efforts with WHO.

WHO

WHO plays an important role in global coordination of the work for phasing-down the use of dental amalgam and the introduction of quality alternative materials for restorative dental care.

- WHO will support the research activities undertaken by IADR, and the work by FDI for establishment of continuing education programmes.
- Public health experience from restorative dental care in countries of all WHO regions is important. Operational research on community dental care based on use of restorative materials alternative to dental amalgam has been discussed by WHO and UNEP and demonstration programmes are considered for certain low and middle income countries.
- WHO will facilitate the work for a switch in use of dental materials through consultations with important stakeholders, dental manufacturers, and third-party payers. WHO, in collaboration with UNEP, will organize consultations with country public health representatives in order to learn from experiences gained from the transition in dental care and to gather information of relevance to the further development of a mercury treaty.

A further meeting including public health administrators and relevant NGOs must be convened to discuss the way forward and to develop strategies to address issues in both developed and developing countries.

14. References

1. World Health Organization. *The World Oral Health Report 2003: Continuous Improvement of Oral Health in the 21st Century - the Approach of the WHO Global Oral Health Programme.* Geneva: WHO, 2003.

2. Bratthall D, Petersen PE, Stjernswärd JR *et al.* Oral and craniofacial diseases and disorders. *In* Jamison DT, Breman JG, Measham AR, et al., (eds). *Disease Control Piorities in Developing Countries*. pp 723-736. New York: World Bank Health and Oxford University Press, 2006.

3. Petersen PE, Bourgeois D, Ogawa H *et al.* The global burden of oral diseases and risks to oral health. *Bull World Health Organ.* 2005; 83: 661-669.

4. Petersen PE. Sociobehavioural risk factors in dental caries - international perspectives. *Community Dent Oral Epidemiol.* 2005; 33: 274-279.

5. World Health Organization/WHO CC, Malmö University. WHO Oral health Country Programme/Area Profile Programme. Geneva and Malmö. www.whocollab.od.mah.se

6. Moynihan P, Petersen PE. Diet, nutrition and the prevention of dental diseases. *Public Health Nutr.* 2004; 7(1A): 201-226.

7. World Health Organization. *Diet, Nutrition and the Prevention of Chronic Diseases*. WHO Technical Report Series 916. Geneva. WHO, 2003.

8. World Health Organization. *Fluoride and Oral Health*. WHO Technical Report Series 846. WHO: Geneva, 1994.

9. Petersen PE, Lennon MA. Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. *Community Dent Oral Epidemiol.* 2004; 32: 319-321.

10. Marthaler TM, Petersen PE. Salt fluoridation - an alternative in automatic prevention of dental caries. *Int Dent J.* 2005; 55: 351-358.

11. Jones S, Burt BA, Petersen PE *et a*l. The effective use of fluorides in public health. *Bull World Health Organ.* 2005; 83: 670-676.

12. Pan-American Health Organization. *Promoting oral health. The use of salt fluoridation to prevent dental caries.* Washington: PAHO, 2005.

13. World Health Organization. The Bangkok Charter for Health Promotion in a Globalized World. Bangkok, Thailand, August 2006.

14. IADR/WHO/BASCD. The Liverpool Declaration: Promoting Oral Health in the 21st Century. Liverpool, 2005. (www.who.int/oral_health).

15. World Health Organization. World Health Assembly. Oral health: action plan for promotion and integrated disease prevention WHA60.17. Geneva: WHO, 2007.

16. Petersen PE. World Health Organization global policy for improvement of oral health -World Health Assembly 2007. *Int Dent J*. 2008; 58:115-121

17. World Health Organization. *The World Health Report 2008. Primary Health Care*. Geneva: WHO, 2008.

18. Mjör IA, Pakhomov GN. *Dental Amalgam and Alternative Direct Restorative Materials*. Geneva: WHO, 1997

19. Manhart J, Garcia-Godoy F, Hickel R. Direct posterior restorations: clinical results and new developments. *Dent Clin N Am*. 2002; 46: 303-339.

20. Yengopal V, Harneker SY, Patel N, Siegfried N. Dental fillings for the treatment of caries in the primary dentition. *Cochrane Database Syst Rev*. 2009: CD004483.

21. Frencken JE, Pilot T, Songpaisan Y, Phantumvanit P. Atraumatic restorative treatment (ART): rationale, technique, and development. *J Public Health Dent*. 1996; 56: 135-140.

22. Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. *Oper Dent*. 2004; 29: 481-508.

23. Scientific Committee on Emerging and Newly Identified Health Risks - SCENIHR. The safety of dental amalgam and alternative dental restoration materials for patients and users EU: Health and Consumer Protection. Directorate General; 2008. 6 May 2008.

24. Scientific Committee on Health and Environmental Risks - SCHER. Opinion on the environmental risks and indirect health effects of mercury in dental amalgam EU: Health and Consumer Protection. Directorate General; 2008. 6 May 2008.

25. IOMCC/UNEP/WHO. *Guidance for identifying populations at risk from mercury exposure*. UNEP DTIE Chemicals Branch and WHO Department of Food Safety, Zoonoses and Foodborne Diseases. Geneva, 2008.

26. Soncini JA, Maserejian NN, Trachtenberg F, Tavares M, Hayes C. The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: Findings from the New England Children's Amalgam Trial. *J Am Dent Assoc*. 2007; 138(6):763-772.

27. Mjör IA. The reasons for replacement and the age of failed restorations in general dental practice. *Acta Odontol Scand*. 1997; 55: 58-63.

28. Forss H, Widström E. Reasons for restorative therapy and the longevity of restorations in adults. *Acta Odontol Scand*. 2004; 62: 82-86.

29. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater.* 2007; 23: 2-8.

30. Mjör IA, Moorhead JE, Dahl JE. Reasons for replacement of restorations in permanent teeth in general dental practice. *Int Dent J.* 2000; 50: 361-6.

31. Qvist V, Manscher E, Teglers PT. Resin-modified and conventional glass ionomer restorations in primary teeth: 8-year results. *J Dent.* 2004; 32: 285-294.

32. Qvist V, Laurberg L, Poulsen A, Teglers PT. Eight-year study on conventional glass ionomer and amalgam restorations in primary teeth. *Acta Odontol Scand.* 2004; 62: 37-45.

33. Burke FJ, Siddons C, Cripps S, Bardha J, Crisp RJ, Dopheide B. Clinical performance of reinforced glass ionomer restorations placed in UK dental practices. *Br Dent J.* 2007; 203: 1-4.

34. van Dijken JWV. Durability of new restorative materials in class III cavities. J *Adhesive Dent.* 2001; 3: 65-70.

35. Faccin ES, Ferreira SH, Kramer PF, Ardenghi TM, Feldens CA. Clinical performance of ART restorations in primary teeth: a survival analysis. *J Clin Pediatr Dent.* 2009; 33: 295-298.

36. Slutzky H, Slutzky-Goldberg I, Weiss EI, Matalon S. Antibacterial properties of temporary filling materials. *J Endod.* 2006; 32: 214-217.

37. Burke FJ, Cheung SW, Mjör IA, Wilson NH. Restoration longevity and analysis of reasons for the placement and replacement of restorations provided by vocational dental practitioners and their trainers in the United Kingdom. *Quintessence Int.* 1999; 30: 234-242.

38. Forss H, Widstrom E. From amalgam to composite: selection of restorative materials and restorative longevity in Finland. *Acta Onontol Scand.* 2001; 59: 57-62.

39. Mjör IA, Dahl JE, Morehead JE. Age of restorations at replacement in permanent teeth in general dental practice. *Acta Odontol Scand.* 2000; 58: 97-101.

40. DeRouen TA, Martin MD, Leroux BG, Townes BD, Woods JS, Leitão J, Castro-Caldas A, Luis H, Bernardo M, Rosenbaum G, Martins IP. Neurobehavioral effects of dental amalgam in children: a randomized controlled trial. *JAMA.* 2006; 295(15):1784-1792.

41. van Dijken JW, Pallesen U. Fracture frequency and longevity of fractured resin composite, polyacid-modified resin composiste, and resin-modified glass ionomer cement class IV restorations: an up to 14 years of follow-up. *Clin Oral Investig.* 2010; 14: 217-222.

42. Espelid I, Tveit AB, Tornes KH, Alvheim H. Clinical behaviour of glass ionomer restorations in primary teeth. *J Dent.* 1999; 27: 437-442.

43. Vidnes-Kopperud S, Tveit AB, Gaarden T, Sanvik L, Espelid I. Factors influencing dentists' choice of amalgam and tooth-colored restorative materials for Class II preparations in younger patients. *Acta Odontol Scand.* 2009; 67: 74-79.

44. van Noort R, Gjerdet NR, Schedle A, Björkman L, Berglund A. An overview of the current status of national reporting systems for adverse reactions to dental materials. *J Dent.* 2004; 32: 351-358.

45. Tillberg A, Järvholm B, Berglund A. Risks with dental materials. *Dent Mater.* 2008; 24: 940-943.

46. Melchart D, Vogt S, Köhler W, Streng A, Weidenhammer W, Kremers L, et al. Treatment of health complaints attributed to amalgam. *J Dent Res.* 2008; 87: 349-353.

47. Cobos-Fuentes MJ, Martinez-Sahuquillo-Marquez A, Gallardo-Castillo I, Armas-Padron JR, Moreno-Fernandez A, Bullon-Fernandez P. Oral lichenoid lesions related to contact with dental materials: A literature review. *Med Oral Patol Oral Cir Bucal.* 2009; 14: e514-520.

48. St John KR. Biocompatibility of dental materials. *Dental Clinics of North America.* 2007; 51: 747-760, viii.

49. Schweikl H, Hiller KA, Bolay C, Kreissl M, Kreismann W, Nusser A, et al. Cytotoxic and mutagenic effects of dental composite materials. *Biomaterials.* 2005; 26: 1713-1719.

50. Becher R, Kopperud HM, Al RH, Samuelsen JT, Morisbak E, Dahlman HJ, et al. Pattern of cell death after in vitro exposure to GDMA, TEGDMA, HEMA and two compomer extracts. *Dent Mater.* 2006; 22: 630-640.

51. Goldberg M. In vitro and in vivo studies on the toxicity of dental resin components: a review. *Clin Oral Investig.* 2008; 12: 1-8.

52. Ansteinsson VE, Samuelsen JT, Dahl JE. Filler particles used in dental biomaterials induce production and release of inflammatory mediators in vitro. *J Biomed Mater Res B Appl Biomater.* 2009; 89: 86-92.

53. Lassen C, Holt Andersen B, Maag J, Maxson P. Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society. COWI and Concorde East/West for the European Commission 2008; (ENV.G.2/ETU/2007/0021)

54. Bivirkningsgruppen for odontologiske biomaterialer. Oegning av bivirkningsrapporter relateret til plastfyllningsmaterialer. *Nor Tannlegeforen Tid.* 2009;119: 856-858.

55. Jones DW. Has dental amalgam been torpedoed and sunk? *J Dent Res.* 2008; 87: 101-102.

56. Lynch CD, McConnell RJ, Wilson NH. Teaching the replacement of posterior resin-based composite restorations in US dental schools. *J Am Dent Assoc.* 2006; 137: 619-625.

57. Lynch CD, McConnell RJ, Wilson NH. Teaching of posterior composite resin restorations in undergraduate dental schools in Ireland and the United Kingdom. *Eur J Dent Educ.* 2006; 10: 38-43.

58. Lynch CD, McConnell RJ, Hannigan A, Wilson NH. Teaching the use of resin composites in Canadian dental schools: how do current educational practices compare with North American Trends? *J Can Dent Assoc.* 2006; 72: 321.

59. Lynch CD, McConnell RJ, Wilson NH. Challenges to teaching posterior composites in the United Kingdom and Ireland. *Br Dent J.* 2006; 201: 747-750.

60. Lynch CD, McConnell RJ, Wilson NH. Trends in the placement of posterior composites in dental schools. *Dent Educ.* 2007; 71: 430-434.

61. Opdam NJ, Loomans BA, Roeters FJ, Bronkhorst EM. Five-year clinical performance of posterior resin composite restorations placed by dental students. J Dent. 2004; 32: 379-383.

62. Watson PA, Adegbembo AO, Soucy B. The Use of Dental Amalgam and the Determination of Mercury in Dental Waste Streams. Report of a National Survey of Canadian Dentists commissioned by Environment Canada. February 2004.

63. Adegbembo AO, Watson PA. Dental Amalgam Use and Determination of Mercury in Dental Waste Streams in Canada. Report of a Follow-up National Survey commissioned by Environment Canada and the Canadian Council of Ministry of the Environment. June 2007.

64. Comisión Económica para América Latina y el Caribe. Anuario Estadístico Población 2008. Available from: www.one.cu/publicaciones/cepal/aecepal2008/ANUARIO2008_CEPAL%2021-2.pdf.

65. Comisión Económica para América Latina y el Caribe (CEPAL). Publicado: 2009-02-23 18:28:38. Available from www.bnamericas.com/.../en/Comision_Economica_para_America_Latina_y_el_Caribe-CEPAL

66. World Health Organization. Formulating Oral Health Strategy for South-East Asia. Report of a regional consultation, Chiang Mai, Thailand, 28-31 October 2008. New Delhi: WHO SEARO, 2009.

67. Behbehani JM, Scheutz F. Oral health in Kuwait. *Int Dent J.* 2004; 54: 401-408.

Annex 1. List of participants

World Health Organization

Meeting on Future Use of Materials for Dental Restoration

Geneva, Switzerland - 16 to 17 November 2009

16 November 2009 - Meeting Room M205
17 November 2009 - Meeting Room G

1. Dr David Alexander
FDI World Dental Federation
Tour de Cointrin
Avenue Louis Casai 84
Case Postale 3
1216 Cointrin
Switzerland
Tel: + 41 22 560 81 50
Fax: + 41 22 560 81 40
e-mail:dalexander@fdiworldental.org

2. Professor Ramon J. Baez
Director Multicultural Affairs
University of Texas Health Science Center at San Antonio
Dental School – Office of the Dean 4.320R
7703 Floyd Curl Drive
San Antonio, Texas 78229-3900
USA
email: rjbaez@gvtc.com

3. Mr Per Bakken
Head, Chemicals Branch
Division of Technology, Industry and Economics
United Nations Environment Programme
International Environment House
11-13 chemin des Anémones
1219 Châtelaine
Switzerland
Tel: +41 22 917 8192
email:pbakken@chemicals.unep.ch

4. Dr Eugenio Beltran (unable to attend)
Team Leader, Senior Epidemiologist
Surveillance Investigation and Research Team
Division of Oral Health
National Center for Chronic Disease Prevention and Health Promotion
Centers for Disease Control and Prevention
4770 Buford Highway MS F-10
Atlanta GA 30341
USA
Tel: +1 770 488 6069
e-mail: eugenio.beltran@cdc.hhs.gov

5. Professor Bian Jin You
School of Stomatology
Peking University
22 Zhongguancun Nandajie
Haidian District
Beijing 100081
People's Republic of China

Tel: +8610 6217 3404
email: bjy410@163.com

6. Professor Lars Björkman
Centre for Side-effects of Dental Materials
Årstadveien 17
5009 Bergen
Norway

Tel: +47 55 58 64 95
Fax: + 47 55 58 98 62
email: Lars.Bjorkman@iko.uib.no

7. Professor Jon E. Dahl
Nordic Institute of Dental Materials
NIOM - Nordisk institutt for odontologiske materialer
P.O. Box 70
1305 Haslum
Norway

Tel: +47 6751 2200 / 36
email: Jon.E.Dahl@niom.no

8. Professor Ivar Espelid (unable to attend)
Department of Paediatric Dentistry
Faculty of Dentistry
University of Oslo
Geitmyrsveien 71
0455 Oslo
Norway

Tel: +47 77 78 9136
email: ivare@odont.uio.no

9. Professor Eino Honkala
Faculty of Dentistry
University of Kuwait
P.O. Box 24923
Safat 13110
Kuwait

Tel: +965 24986718
Fax:+965 25326049
email: eino.honkala@hsc.edu.kw

10. Dr Febronia Kahabuka (unable to attend)
University College of Health Sciences (MUCHS)
and Allied Sciences, School of Dentistry,
Dental Building, 1ST Floor, Room 110,
P.O. Box 65014
Dar es Salaam
United Republic of Tanzania

Tel: +255 222 15 11 35
email: fkahabuka@muhas.ac.tz

11. Dr Stella Kwan
WHO Collaborating Centre for Research and
Development for Oral Health, Migration and
Inequalities
Department of Child Dental Health
Leeds Dental Institute, Clarendon Way
Leeds LS2 9LU , UK

Tel: +44 113 343 6329
email: S.Kwan@leeds.ac.uk

12. Professor Robert McConnell
School of Dentistry
University of Cork
Wilton
Cork
Ireland

Tel: +353 21 4901140
e-mail: r.mcconnell@ucc.ie

13. Dr Daniel Meyer
Senior Vice President
Science/Professional Affairs
American Dental Association
211 E Chicago Avenue
Chicago, IL 60611
USA

email: meyerd@ada.org

14. Professor Sue Naidoo
Department of Oral Health
University of Western Cape
Private Bag X1, Tygerberg, Cape Town 7705
Western Cape Province
South Africa

Tel: +27 21 937 3148
email: suenaidoo@uwc.ac.za

15. Dr Desiree Narvaez
Programme Officer
Mercury and other Metals Programme
UNEP Chemicals DTIE
11-13 chemin des Anémones
1219 Chatelaine
Switzerland

Tel: +41 22 917 8865
Fax: +41 22 797 3460
email:dnarvaez@chemicals.unep.ch

16. Dr Hiroshi Ogawa
Division of Preventive Dentistry
Department of Oral Health Science
Niigata University Medical and Dental Hospital
2-5274 Gakkocho-dori Niigata 951-8514 Japan
Niigata
Japan

Tel: +81 25 227 2858
email: ogahpre@dent.niigata-u.ac.jp

17. Professor Prathip Phantumvanit
Faculty of Dentistry
Thammasat University
Rangsit Campus
Patumthani 12121
Thailand

Tel: +66 81 833 0273
Fax: +66 2 986 9051
email: prathip@tu.ac.th

18. Dr Sandra Tovar Valencia
Asesora para Salud Bucal
Dirección de Salud Pública
Grupo de Promoción y Prevención
Componente de Salud Bucal
Ministerio de Protección Social
Carrera 13 No. 32-76
Bogota

Tel: +57 1 336 5066 Ext 1240/1242
Fax: +5713360182
email: stovar@minproteccionsocial.gov.co

Colombia

19. Dr Jos van den Heuvel
Stadionkade 30 1st floor
1077 VN Amsterdam
The Netherlands
Tel: +31 6 51400982
email: jl.vd.heuvel@tiscali.nl

20. Professor David Williams

Biomedical Sciences Building
University of Southampton
Bassett Crescent East
Southampton SO16 7PX
U.K.
Tel: +44 2380 59 6702
email: D.M.Williams@soton.ac.uk

21. Professor Lars Hylander
Department of Earth Sciences
Uppsala University
Villavägen 16,
752 36 Uppsala
Sweden.
Tel: +46 18 471 22 65
Tel: +46 18 14 84 06
Fax: +46 18 55 11 24
email: Lars.Hylander@hyd.uu.se

22. Mr Peter A. Maxson
10 Avenue René Gobert
1180 Brussels
Belgium
Tel: +32 2 374 3647

23. Dr Benoit Soucy
Director, Clinical and Scientific Affairs
Canadian Dental Association
Canadian Dental Association
1815 Alta Vista Dr.
Ottawa, ON
Canada K1G 3Y6
email: bsoucy@cda-adc.ca

On behalf of Dr. Peter Cooney
Chief Dental Officer of Canada
A.L. 1501A, Tunney's Pasture
Ottawa, Ontario K1A 0K9
Canada
e-mail: peter_cooney@hc-sc.gc.ca

24. Mr Michael Bender
Mercury Policy Project/
Zero Mercury Working Group
1420 North St.
Montpelier
VT 05602
USA
Tel: +1 802 223 9000

25. Dr Roberto Vianna
FDI World Dental Federation
Tour de Cointrin
Avenue Louis Casai 84
Case Postale 3
Tel: + 41 22 560 81 50
Fax: + 41 22 560 81 40
email: roberto.vianna@terra.com.br

1216 Cointrin
FDI World Dental Federation
Tour de Cointrin
Switzerland

26. Mr David Piper
UNEP Chemicals DTIE
United Nation Environment Programme
International Environment House
11-13 chemin des Anémones
1219 Chatelaine
Switzerland
Tel: +41 22 917 8345
email : dpiper@chemicals.unep.ch

27. Ms Brenda Koekkoek
Programme Officer
UNEP Chemicals DTIE
United Nation Environment Programme
International Environment House
11-13 chemin des Anémones
1219 Chatelaine
Switzerland
Tel: +41 22 917 8867
email: bkoekkoek@chemicals.unep.ch

28. Ms Elena Lymberidi
Project coordinator
European Environment Bureau
34 Boulevard de Waterloo
1000 Brussels
Belgium
Tel: +322 289 1301
Fax: +322 289 1099
email: Elena.lymberidi@eeb.org

WHO Secretariat

Dr Ala Alwan, Assistant Director-General/NMN

NMH/CHP - Health Promotion - HPR
Dr Gauden Galea
Coordinator
Tel.: +41 22 7912582
Email: galeag@who.int

NMH/CHP - Health Promotion - HPR
Dr Poul Erik Petersen
Responsible Officer
Global Oral Health Programme
Tel.: +41 22 7913475
Tel.: +41 22 7914866
Email: petersenpe@who.int

Dr C. Ndiaye (unable to attend)
WHO Regional Office for Africa
WHO Representative, Cameroun
Tel: +237 22211078
email: ndiayec@afro.who.int

Dr S. Estupinan Day (unable to attend)
WHO Regional Office for the Americas
Regional Adviser, Oral Health, AMRO
Tel: + 1 202 9743809
email: estupins@paho.org

Ms Carolyn Vickers
Chemical Safety
Team Leader
Tel: +41 22 791 1286
Fax: +41 22 791 4848
email: vickersc@who.int

Annex 2. Meeting agenda

Meeting on the future use of materials for dental restoration **B**

16 to 17 November 2009, WHO/HQ, Geneva, Switzerland **15 October 2009**

16 November 2009 - Meeting Room M.205

17 November 2009 - Meeting Room G

AGENDA

Monday, 16 November 2009

09:00 - 09:30	Welcome and Introduction. Dr Ala Alwan, Assistant Director-General, Noncommunicable Diseases and Mental Health (OR) Mr Per Bakken, Head, Chemical Branch, United Nations Environment Programme (UNEP) Dr Poul Erik Petersen, Health Promotion/Oral Health Programme Scope and purpose Election of Chairman and Rapporteurs
09:30 - 09:50	Feasibility of dental restorative materials Professor Jon Dahl
09:50 - 10:10	Evidence on use of tooth-coloured restorative materials - Clinical and population based experiences Professor Ivar Espelid
10:10 - 10:30	Restorative practices and training of oral health professionals - the case of Ireland Professor Robert McConnell
10:30 - 11:00	Coffee
11:00 - 11:20	Use of dental restorative materials in a global perspective Dr Daniel Meyer
11:20-11:40	Side-effects and health hazards of dental restorative materials - information based on a national registry Professor Lars Björkman

11:40 - 12:30	Discussion
12:30 - 14:00	Lunch
14:00 - 14:20	Research on dental restorative materials - current activities and future priorities (International Association for Dental Research IADR) Professor David Williams
14:20 - 14:40	Dental restorative materials in clinical practice - views of the dental profession (FDI World Dental Federation) Dr Roberto Vienna and Dr David Alexander
14:40 - 15:00	Best Management Practices on the use of dental amalgam separators and waste management Dr Lars Hylander
15:00 - 15.20	Mercury releases to the environment and mercury trade - global perspectives Mr Peter Maxson
15:20 - 15:50	Coffee
15:50 - 17:00	Discussion

Tuesday, 17 November 2009	**The situation of restorative dental care in countries/regions**
09:00 - 09:20	USA Dr Eugenio Beltran
09:20 - 090:40	Latin America Dr Sandra Tovar Valencia /Professor Ramon Baez
09:40 - 10:00	Canada Dr B. Soucy
10:00 - 10:20	Europe and Chief Dental Officers Forum Dr Jos van den Heuvel
10:20 - 10:40	Coffee
10:40 - 11:00	People's Republic of China /Western Pacific Professor Bian Jin You
11:00 - 11:20	South-East Asia Professor Prathip Phantumvanit

11:20 - 11:40	Middle East Professor Eino Honkala
11:40 - 12:00	Africa /low-income countries Dr Febronia Kahabuka
12:00 - 12:20	Africa/middle-income countries Professor Sue Naidoo
12:20 - 13.00	Discussions
13.00- 14:00	Lunch
14:00 - 14:30	The role of the UNEP Global Mercury Global Partnership Dr Desiree M. Narvaez, UNEP and Mr Michael Bender
14:30 - 14:45	The role of the WHO Chemical Safety and Global Oral Health Programmes Dr Carolyn Vickers and Dr Poul Erik Petersen
14:45 - 15:15	Coffee
15:15 - 16:00	Discussions and recommendations
	Meeting ends

Annex 3. Bibliography – other useful publications

- Bellinger DC, Daniel D, Trachtenberg F, Tavares M, McKinlay S. Dental amalgam restorations and children's neuropsychological function: the New England Children's Amalgam Trial. *Environ Health Perspect*. 2007 Mar;115(3):440-6. Epub 2006 Oct 30.
- Bellinger DC, Trachtenberg F, Barregard L, Tavares M, Cernichiari E, Daniel D, McKinlay S. Neuropsychological and renal effects of dental amalgam in children: a randomized clinical trial. *JAMA*. 2006 Apr 19;295(15):1775-83.
- Bernardo M, Luis H, Martin MD, Leroux BG, Rue T, Leitão J, DeRouen TA. Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. *J Am Dent Assoc*. 2007 Jun;138(6):775-83.
- Brambilla E, Cagetti MG, Gagliani M, Fadini L, García-Godoy F, Strohmenger L. Influence of different adhesive restorative materials on mutans streptococci colonization. *Am J Dent*. 2005 Jun;18(3):173-6.
- Brambilla E, Gagliani M, Ionescu A, Fadini L, García-Godoy F. The influence of light-curing time on the bacterial colonization of resin composite surfaces. *Dent Mater*. 2009 Sep;25(9):1067-72. Epub 2009 Apr 17.
- Cobos-Fuentes MJ, Martínez-Sahuquillo-Márquez A, Gallardo-Castillo I, Armas-Padrón JR, Moreno-Fernández A, Bullón-Fernández P. Oral lichenoid lesions related to contact with dental materials: a literature review. *Med Oral Patol Oral Cir Bucal*. 2009 Oct 1;14(10):e514-20.
- Donly KJ, Segura A, Kanellis M, Erickson RL. Clinical performance and caries inhibition of resin-modified glass ionomer cement and amalgam restorations. *J Am Dent Assoc*. 1999 Oct;130(10):1459-66.
- Dorri M, Sheiham A, Marinho VCC. Atraumatic restorative treatment versus conventional restorative treatment for the management of dental caries (Protocol). *Cochrane Database of Systematic Reviews* 2009, Issue 4. Art. No.: CD008072
- Ercan E, Dülgergil CT, Soyman M, Dalli M, Yildirim I. A field-trial of two restorative materials used with atraumatic restorative treatment in rural Turkey: 24-month results. J *Appl Oral Sci*. 2009 Aug;17(4):307-14.
- Ernst CP, Martin M, Stuff S, Willershausen B. Clinical performance of a packable resin composite for posterior teeth after 3 years. *Clin Oral Investig*. 2001 Sep;5(3):148-55.
- Ersin NK, Candan U, Aykut A, Onça O, Eronat C, Kose T. A clinical evaluation of resin-based composite and glass ionomer cement restorations placed in primary teeth using the ART approach: results at 24 months. *J Am Dent Assoc*. 2006 Nov;137(11):1529-36.
- Espelid I, Tveit AB, Mejàre I, Sundberg H, Hallonsten AL. Restorative treatment decisions on occlusal caries in Scandinavia. *Acta Odontol Scand*. 2001 Feb;59(1): 21-7.

- Fedorowicz Z, NasserM,Wilson N. Adhesively bonded versus non-bonded amalgam restorations for dental caries(Review). *Cochrane Database of Systematic Reviews* 2009, Issue 4. Art. No.: CD007517.
- Forss H, Widström E. From amalgam to composite: selection of restorative materials and restoration longevity in Finland. *Acta Odontol Scand.* 2001 Apr;59(2):57-62.
- Forss H, Widström E. Reasons for restorative therapy and the longevity of restorations in adults. *Acta Odontol Scand.* 2004 Apr;62(2):82-6.
- Forss H, Widström E. The post-amalgam era: a selection of materials and their longevity in the primary and young permanent dentitions. *Int J Paediatr Dent.* 2003 May;13(3)
- Frencken JE, Holmgren CJ. How effective is ART in the management of dental caries? *Community Dent Oral Epidemiol.* 1999 Dec;27(6):423-30.
- Frencken JE, Makoni F, Sithole WD. Atraumatic restorative treatment and glass-ionomer sealants in a school oral health programme in Zimbabwe: evaluation after 1 year. *Caries Res.* 1996;30(6):428-33.
- Frencken JE, Songpaisan Y, Phantumvanit P, Pilot T. An atraumatic restorative treatment (ART) technique: evaluation after one year. *Int Dent J.* 1994 Oct;44(5):460-4.
- Frencken JE, Van 't Hof MA, Van Amerongen WE, Holmgren CJ. Effectiveness of single-surface ART restorations in the permanent dentition: a meta-analysis. *J Dent Res.* 2004 Feb;83(2):120-3.
- Frencken JE, van't Hof MA, Taifour D, Al-Zaher I. Effectiveness of ART and traditional amalgam approach in restoring single-surface cavities in posterior teeth of permanent dentitions in school children after 6.3 years. *Community Dent Oral Epidemiol.* 2007 Jun;35(3):207-14.
- Friedl KH, Hiller KA, Schmalz G. Placement and replacement of composite restorations in Germany. *Oper Dent.* 1995 Jan-Feb;20(1):34-8.
- Gaengler P, Hoyer I, Montag R, Gaebler P. Micromorphological evaluation of posterior composite restorations - a 10-year report. *J Oral Rehabil.* 2004 Oct;31(10):991-1000.
- Goldberg M. In vitro and in vivo studies on the toxicity of dental resin components: a review. *Clin Oral Investig.* 2008 Mar;12(1):1-8. Epub 2007 Nov 27.
- Hayashi M, Tsuchitani Y, Kawamura Y, Miura M, Takeshige F, Ebisu S. Eight-year clinical evaluation of fired ceramic inlays. *Oper Dent.* 2000 Nov-Dec;25(6):473-81.
- Hayashi M, Wilson NH. Failure risk of posterior composites with post-operative sensitivity. *Oper Dent.* 2003 Nov-Dec;28(6):681-8
- Hayashi M, Yeung A. Ceramic inlays for restoring posterior teeth(review). *Cochrane Database of Systematic Reviews* 2003, Issue 1. Art. No.: CD003450.
- Heintze SD, Twetman S. Interdental mutans streptococci suppression in vivo: a comparison of different chlorhexidine regimens in relation to restorative material. *Am J Dent.* 2002 Apr;15(2):103-8.

- Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. *J Adhes Dent*. 2001 Spring;3(1):45-64.
- Ho TF, Smales RJ, Fang DT. A 2-year clinical study of two glass ionomer cements used in the atraumatic restorative treatment (ART) technique. *Community Dent Oral Epidemiol*. 1999 Jun;27(3):195-201.
- Honkala E, Behbehani J, Ibricevic H, Kerosuo E, Al-Jame G. The atraumatic restorative treatment (ART) approach to restoring primary teeth in a standard dental clinic. *Int J Paediatr Dent*. 2003 May;13(3):172-9.
- Kemoli AM, van Amerongen WE. Influence of the cavity-size on the survival rate of proximal ART restorations in primary molars. *Int J Paediatr Dent*. 2009 Nov;19(6):423-30. Epub 2009 Sep 1
- Kidd EA, Beighton D. Prediction of secondary caries around tooth-colored restorations: a clinical and microbiological study. *J Dent Res*. 1996 Dec;75(12):1942-6.
- Kidd EA, Joyston-Bechal S, Beighton D. Marginal ditching and staining as a predictor of secondary caries around amalgam restorations: a clinical and microbiological study. *J Dent Res*. 1995 May;74(5):1206-11
- Kolker JL, Damiano PC, Flach SD, Bentler SE, Armstrong SR, Caplan DJ, Kuthy RA, Warren JJ, Jones MP, Dawson DV. The cost-effectiveness of large amalgam and crown restorations over a 10-year period. *J Public Health Dent*. 2006 Winter;66(1):57-63.
- Köhler B, Rasmusson CG, Odman P. A five-year clinical evaluation of Class II composite resin restorations. *J Dent*. 2000 Feb;28(2):111-6.
- Lo EC, Holmgren CJ, Hu D, van Palenstein Helderman W. Six-year follow up of atraumatic restorative treatment restorations placed in Chinese school children. *Community Dent Oral Epidemiol*. 2007 Oct;35(5):387-92.
- Lo EC, Luo Y, Fan MW, Wei SH. Clinical investigation of two glass-ionomer restoratives used with the atraumatic restorative treatment approach in China: two-years results. *Caries Res*. 2001 Nov-Dec;35(6):458-63.
- Lu H, Koh H, Rasines Alcaraz MG, Schmidlin PR, Davis D. Direct composite resin fillings versus amalgam fillings for permanent or adult posterior teeth (Protocol). *Cochrane Database of Systematic Reviews* 2006, Issue 1. Art. No.: CD005620.
- Maggs-Rapport FL, Treasure ET, Chadwick BL. Community dental officers' use and knowledge of restorative techniques for primary molars: an audit of two Trusts in Wales. *Int J Paediatr Dent*. 2000 Jun;10(2):133-9.
- Melchart D, Vogt S, Köhler W, Streng A, Weidenhammer W, Kremers L, Hickel R, Felgenhauer N, Zilker T, Wühr E, Halbach S. Treatment of health complaints attributed to amalgam. *J Dent Res*. 2008 Apr;87(4):349-53.
- Menezes JP, Rosenblatt A, Medeiros E. Clinical evaluation of atraumatic restorations in primary molars: a comparison between 2 glass ionomer cements. *J Dent Child (Chic)*. 2006 May-Aug;73(2):91-7.

- Mertz-Fairhurst EJ, Curtis JW Jr, Ergle JW, Rueggeberg FA, Adair SM. Ultraconservative and cariostatic sealed restorations: results at year 10. *J Am Dent Assoc*. 1998 Jan;129(1):55-66.
- Mickenautsch S, Kopsala J, Rudolph MJ, Ogunbodede EO. Clinical evaluation of the ART approach and materials in peri-urban farm schools of the Johannesburg area. *SADJ*. 2000 Jul;55(7):364-8.
- Milsom KM, Tickle M, Blinkhorn A. The prescription and relative outcomes of different materials used in general dental practice in the north west region of England to restore the primary dentition. *J Dent*. 2002 Feb-Mar;30(2-3):77-82.
- Mjör IA, Moorhead JE, Dahl JE.Selection of restorative materials in permanent teeth in general dental practice. *Acta Odontol Scand*. 1999 Oct;57(5):257-62.
- Mjör IA, Moorhead JE. Selection of restorative materials, reasons for replacement, and longevity of restorations in Florida. *J Am Coll Dent*. 1998 Fall;65(3):27-33.
- Mjör IA, Qvist V. Marginal failures of amalgam and composite restorations. J Dent. 1997 Jan;25(1):25-30
- Mount GJ. A new paradigm for operative dentistry. *Aust Dent J*. 2007 Dec;52(4):264-70; quiz 342.
- Oberländer H, Hiller KA, Thonemann B, Schmalz G. Clinical evaluation of packable composite resins in Class-II restorations. *Clin Oral Investig*. 2001 Jun;5(2):102-7.
- Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. *Dent Mater*. 2007 Jan;23(1):2-8. Epub 2006 Jan 18.
- Peters MC, McLean ME. Minimally invasive operative care. I. Minimal intervention and concepts for minimally invasive cavity preparations. *J Adhes Dent*. 2001 Spring;3(1):7-16
- Phantumvanit P, Songpaisan Y, Pilot T, Frencken JE. Atraumatic restorative treatment (ART): a three-year community field trial in Thailand--survival of one-surface restorations in the permanent dentition. *J Public Health Dent*. 1996;56(3 Spec No):141-5; discussion 161-3.
- Pink FE, Minden NJ, Simmonds S. Decisions of practitioners regarding placement of amalgam and composite restorations in general practice settings. *Oper Dent*. 1994 Jul-Aug;19(4):127-32.
- Poulsen S, Laurberg L, Vaeth M, Jensen U, Haubek D. A field trial of resin-based and glass-ionomer fissure sealants: clinical and radiographic assessment of caries. *Community Dent Oral Epidemiol*. 2006 Feb;34(1):36-40.
- Qvist V, Laurberg L, Poulsen A, Teglers PT. Longevity and cariostatic effects of everyday conventional glass-ionomer and amalgam restorations in primary teeth: three-year results. *J Dent Res*. 1997 Jul;76(7):1387-96.
- Roulet JF. Benefits and disadvantages of tooth-coloured alternatives to amalgam. *J Dent*. 1997 Nov;25(6):459-73.

- Sarrett DC. Clinical challenges and the relevance of materials testing for posterior composite restorations. *Dent Mater.* 2005 Jan;21(1):9-20.
- Smales RJ, Hawthorne WS. Long-term survival of repaired amalgams, recemented crowns and gold castings. *Oper Dent.* 2004 May-Jun;29(3):249-53.
- Smales RJ, Ngo HC, Yip KH, Yu C. Clinical effects of glass ionomer restorations on residual carious dentin in primary molars. *Am J Dent.* 2005 Jun;18(3):188-93.
- Songpaisan Y, Bratthall D, Phantumvanit P, Somridhivej Y. Effects of glass ionomer cement, resin-based pit and fissure sealant and HF applications on occlusal caries in a developing country field trial. *Community Dent Oral Epidemiol.* 1995 Feb;23(1):25-9.
- Spencer AJ. Dental amalgam and mercury in dentistry. *Aust Dent J.* 2000 Dec;45(4):224-34.
- Taifour D, Frencken JE, Beiruti N, van 't Hof MA, Truin GJ. Effectiveness of glass-ionomer (ART) and amalgam restorations in the deciduous dentition: results after 3 years. *Caries Res.* 2002 Nov-Dec;36(6):437-44.
- Tobi H, Kreulen CM, Vondeling H, van Amerongen WE. Cost-effectiveness of composite resins and amalgam in the replacement of amalgam Class II restorations. *Community Dent Oral Epidemiol.* 1999 Apr;27(2):137-43.
- Trachtenberg F, Maserejian NN, Tavares M, Soncini JA, Hayes C. Extent of tooth decay in the mouth and increased need for replacement of dental restorations: the New England Children's Amalgam Trial. *Pediatr Dent.* 2008 Sep-Oct;30(5):388-92.
- Tran LA, Messer LB. Clinicians' choices of restorative materials for children. *Aust Dent J.* 2003 Dec;48(4):221-32.
- Trip L. Canada-wide standards: a pollution prevention program for dental amalgam waste. *J Can Dent Assoc.* 2001 May;67(5):270-3.
- Tyas MJ. Cariostatic effect of glass ionomer cement: a five-year clinical study. *Aust Dent J.* 1991 Jun;36(3):236-9.
- Vidnes-Kopperud S, Tveit AB, Gaarden T, Sandvik L, Espelid I. Factors influencing dentists' choice of amalgam and tooth-colored restorative materials for Class II preparations in younger patients. *Acta Odontol Scand.* 2009;67(2):74-9.
- Vij R, Coll JA, Shelton P, Farooq NS. Caries control and other variables associated with success of primary molar vital pulp therapy. *Pediatr Dent.* 2004 May-Jun;26(3):214-20.
- Yengopal V, Harneker SY, Patel N, Siegfried N. Dental fillings for the treatment of caries in the primary dentition. *Cochrane Database Systematic Review.* 2009 Apr 15;(2):CD004483.
- Yu C, Gao XJ, Deng DM, Yip HK, Smales RJ. Survival of glass ionomer restorations placed in primary molars using atraumatic restorative treatment (ART) and conventional cavity preparations: 2-year results. *Int Dent J.* 2004 Feb;54(1):42-6.

- Zanata RL, Navarro MF, Barbosa SH, Lauris JR, Franco EB. Clinical evaluation of three restorative materials applied in a minimal intervention caries treatment approach. *J Public Health Dent.* 2003 Fall;63(4):221-6.
- Zimmer S, Göhlich O, Rüttermann S, Lang H, Raab WH, Barthel CR. Long-term survival of Cerec restorations: a 10-year study. *Oper Dent.* 2008 Sep-Oct;33(5):484-7.

Dental caries is a major public health problem globally. Despite much effort in health promotion and disease prevention, dental restorations are still needed to re-establish tooth function.

In the past decades, the recognition of the environmental implications of mercury has increased and alternatives to dental amalgam are desirable. The World Health Organization and the United Nations Environment Programme have strengthened the work for reduction of the mercury releases and usage.

This report from a technical meeting provides information about the current evidence on use of dental restorative materials and some major challenges in relation to future use of materials alternative to dental amalgam are discussed.

More information about oral health:

World Health Organization

Chronic Disease and Health Promotion
20 Avenue Appia
CH1211 Geneva Switzerland
www.who.int/oral_health

ISBN 978 92 4 150064 7