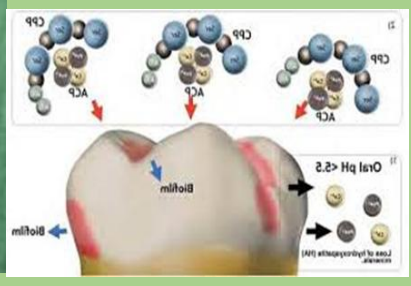
A DENTALAMALGAM PHASE DOWN TRAINING PROGRAMME FOR DENTISTS





Dr B.K Kisumbi, PhD Candidate
University of Nairobi

UNIVERSITY OF NAIROBI

FACULTY OF HEALTH SCIENCES

DEPARTMENT OF DENTAL SCIENCES

UNIT OF CONSERVATIVE AND PROSTHETIC DENTISTRY

A dental amalgam phase down training manual developed for implementation

As part of

PhD IN DENTAL MATERIALS

DEVELOPED BY DR B.K KISUMBI

Edited by supervisors;

PROF. LOICE W. GATHECE, DR. OLIVIAA. OSIRO AND

DR. SUSAN W. MAINA

TABLE OF CONTENTS

ABBREVIATIONS

ART	Atraumatic restorative treatment
ASPA	Aluminosilicate polyacrylic acid
BFRCs	Bulk fill resin composites
BisGMA	Bisphenol A-glycidyl methacrylate
CAD/CAM	Computer aided designing and computer aided machining
DA	Dental amalgam
DAARs	Dental amalgam alternative restoratives
DAPD	Dental amalgam phase down
DCP	Dicalcium phosphate
DRC	Dental resin composites
FDI	World dental Federation, Fédération Dentaire Internationale
FRCs	Flowable resin composites
GH	Glass hybrid
GIC	Glass ionomer cements
GPDM	Glycero Phosphate Dimethacrylate
HEMA	2-hydroxy ethyl methacrylate
Hg	Mercury
IDM	International dental manufacturers
IRCs	Indirect resin composites
LSRCs	Low shrinking resin composites
MCM	Minamata convention on mercury

NIC	Negotiating inter-governmental committees
PEG-400 DMA	Polyethelene glycol dimethacrylate
PFSs	Pit and fissure sealants
PRR	Preventive resin restoration
RIs	Resin infiltrants
RMGIC	Resin modified glass ionomer cements
SDF	Silver diamine fluoride
SDR	Stress decreasing resin
SFRRCs	Short fiber reinforced resin composites
TEGDMA	Triethylene glycol dimethacrylate
UDMA	Urethane dimethacrylate
UNEP	United Nations Environmental programme
USA	United States of America
WHO	World health organisation
ZRGIs	Zinc reinforced glass ionomer
μTBS	Microtensile bond strength

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION TO THE DENTAL AMALGAM PHASE DOWN TRAINING PROGRAMME

Thistraining programmeis intended to serve as a quick reference in modern dental practice as the implementation of dental amalgam phase down continues virtually in all countries. Dental amalgam phase downis embodied in the Minamata convention on mercury (MCM)[1], a global treaty that was signed on 10th January 2013 and came into force on 17th August 2017. Kenya is a signatory tothe MCM, whose objective is to protect human health and the environment from effects of mercury (Hg) existing as pure mercury and in the myriad of Hg containing products one of which is dental amalgam. The mercury content and the lack of best waste management practice makes dental amalgam (DA) contribute to the worlds' anthropogenic mercury (Hg) release to air, soil and water. Kenya is advanced in ratifying the convention,the cabinet has recently considered and approvedthe convention document for consideration by parliament,after which Kenya willjoin the 137 party countries.

Phasing down the use of dental amalgam enjoins a paradigm shift from the traditional dental amalgam model, towards adhesiverestorations and dental caries preventive approaches, that include minimally invasive dentistry employingalternative restorative dental materials. As a dentist, considering the efficacy of dental amalgam for over 150 years as a posterior restorative,perhaps brings to memory howits scientific principles and clinical application were drummed to you as a dental student. On the contrary todaysome dentists may firstly lack adequate knowledge and skills to execute quality alternative restorations particularly in posterior teeth, and secondly may be unaware of the dental caries preventive, non-invasive and micro-invasive model. Therefore, it is conceivable one may be bound to select, manipulate and place certaindental amalgam alternative restorative while lacking requisite competence.

The Kenya's National Oral health survey 2015 revealed an unmet dental caries burden of 46.3% and 35.5% among children and adults respectively, hence the need for use of restorative dental materials is with u**s**[2]. You may rightly view this training programme as a continuous professional developmenttool, as it takes cognizance of corporeal literacy and focusses only new dental materials, and novel prevention techniques made possible by dental amalgam alternative restorative dental materials. As you may have gathered, the use of dental amalgam alternative

restoratives (DAARs) has increased steadily due to patients demanding foraesthetic restorations, therefore adding dental amalgam phase down (DAPD) catalyses the eclipse of dental amalgam which at last has dawned[3], ushering the need for all dentists to master new techniques.

Module I covers dental amalgam phase down as it is stipulated in Article 4 of the Minamata convention text and summarises its impact on dental practice today. In Module II the dental amalgam alternative restorative materials are discussed with attention being given to new biomaterials, categorized under resin composite and glass ionomer and related biomaterials. Module III demonstrates the selection and manipulation techniques. This programme has designed module IV to highlight the congruence of theuse of adhesive alternative restorative materials and the novel restorative philosophy that prioritizes prevention, early detection, and noninvasive and microinvasive treatment. **Thus, steering away from the 'drill and fill' dental amalgam approach**. The overall gains of dental amalgam phase down and minimally invasive dentistry include reduced dental caries burden, smaller cavity sizes and reduced need for restorative materials. Subsequently, reduced expenditure thus improvementof oral health of the population, which is the *holy grail*of global prevention of dental caries in populations.

As a dentist you have a significant role in deciding between using dental amalgam or its' alternatives. Nonetheless that should be moderated by patients' decision, availability of quality alternative materials, clinic setting and of your capacity to utilize the DAARs. Though dental amalgam has served and still continues to serve the profession well, the neglected ingress of its' waste into the environment has led to a global phased down of its' use. **Furthermore,the need to manage dental amalgam waste will remain with the profession for a long time. Since replacements of defective amalgam fillings and disposal of extracted teeth with dental amalgam fillings will persist beyond its phase out.**

TRAINING PROGRAMME OUTCOMES

The intended outcomes for the DAPD training programme; the participants will;

1. Delineate the scope of the on-going global dental amalgam phase down
2. Anchor dental caries prevention moment in use of DAARs in DAPD.
3. List and discuss the new dental amalgam alternative restorative dental materials respective properties and subsequent clinical performance
4. Decisively contraindicate DAARs
5. Perform restorativeprocedures competently in dental amalgam phase down process

MODULE I

1.0 LECTURE ONE

GENESIS AND NEGOTIATION OF MINAMATA CONVENTION ON MERCURY 2013, GLOBAL AND KENYA'S POSITION ON DENTAL AMALGAM PHASE DOWN

1.1Introduction

Welcome to lecture one of the dental amalgam training programme. In this lecture we are going to discuss what informed the Minamata convention on mercury and how it was negotiated by 128 governments of the world Kenya included. We will discuss what dental amalgam phase down entails, the impact it has had on dental practice today, one of which is embracing dental caries prevention and alternative restorative dental materials. As you may be aware, although the implementation of dental amalgam phase down is voluntary and tailor-made to meet country's needs, dental amalgam will not always be available.Since the convention has ushered the final conclusion of the protracted dental amalgam debate. We shall review the implementation of dental amalgam phase down which is disproportionate as countries are at varied levels of dental caries disease prevention and burden, prioritisation and support of oral health and legislation on dental materials.

In one of the sections of this lecture, we are going to highlighthow the uptake and use of adhesive dental amalgam alternatives allows for micro-conservative restorations, preventive restorationsthus dental amalgam phase down (DAPD)enjoins minimally invasive dentistry philosophy.

At the tail end of this lecture,we shall hold a discussion on the perceived status of dental amalgam phase down in Kenya and get your views on thedirectionthe national process should adopt.

1.2 Learning outcomes

For this Minamata convention on mercury and Dental amalgam phase down lecture is;

1.0 Locate the genesis and text for Minamata convention on mercury
2.0 Lay out the components of dental amalgam phase down
3.0 Discuss the impact of dental amalgam phase down in today's dental practice
4.0 Decideon up takingthe global dental amalgam phase down
5.0 Participate in national discussion on dental amalgam phase down.

1.3 Definition of the Minamata convention on mercury

It is a global legally binding instrument on mercury aimed at protecting human health and the environment from the effects of mercury. The convention targets reducing and eventually eradicating anthropogenic emissions and releases of mercury and mercury containing products to air, soil and water. It came to force on 17th August 2017.

1.4 Genesis and negotiation of the Minamata convention on mercury

1.4.1 Genesis of the Minamata convention

Mercury metal abbreviated Hg and number 80 in the periodic table though used in many domestic, medical and industrial application has been a known toxin that bio-accumulates in ecosystems. Two major mercury poisons recorded in historyinclude methyl mercury discharged into the Minamata bay and Siranui Sea and bio accumulated in fish that was consumed by the local population in Minamata city in Japan affecting over 2,000 between 1932 and 1968. In Iraq, alkylmercury containing pesticide sprayed on wheat led to poisoning from consumption of bread or porridge made from treated seedsin 1972[4–6]. As we may be aware, the largest source of Hg by humans is via Artisanal and small-scale gold mining sector 1,000 tonnes annually. Dental amalgam is not pure mercury per-se, however lack of best management practice by dental facilities adds240-340 tonnes annually as human contributed mercury containing waste, hence the inclusion in the convention.

	**In text question** The world has used mercury and mercury containing products for many years, what sparked the negotiation of the Minamata convention on mercury?

It was not until February 2009 when a decision was made by the Governing council of UNEP to bring mercury science to policy, to protect human health and environment from the effects of mercury. This was to be the beginning of the journeythat led to the negotiating path and strategy that culminated in the global Minamata convention of mercury in 2013. I invite you to access the MCM at:

google.com/search?q=Unep.+minamataconvention+on+mercury+texts+and+annexes+UNEP+2013a&oq.

1.4.2 Negotiation of the Minamata convention on mercury

Now let us briefly view the road map that yieldedtheMinamata convention on mercury (MCM), and the embeddeddental amalgam phase down that has ushered the future exit of dental amalgam.

The process was voluntary, 128 countries formed intergovernmental negotiating committees (NIC's), Non-governmental organisations, WHO, FDI, IDM, led by UNEP held the first meeting in Stockholm, Sweden 7th to 11th June 2010. In total five meetings were held in a duration of 31 months and 7 days culminating into the signing of the convention on 10th January 2013. Kenya participated in all the meeting hosting the 3rd meeting in Nairobi Table 1.1 and Figure 1.1

Table 1. 1Global roadmap and conferences held to discuss the MCM

CITY	DATE
1 Stockholm	7-11 June 2010
2. Chiba	24-28 Jan' 2011
3. Nairobi	31st Oct' – 4th Nov' 2011
4. Punta del Este	27 June - 2nd July 2012
5. Geneva	13th – 18th January 2013.

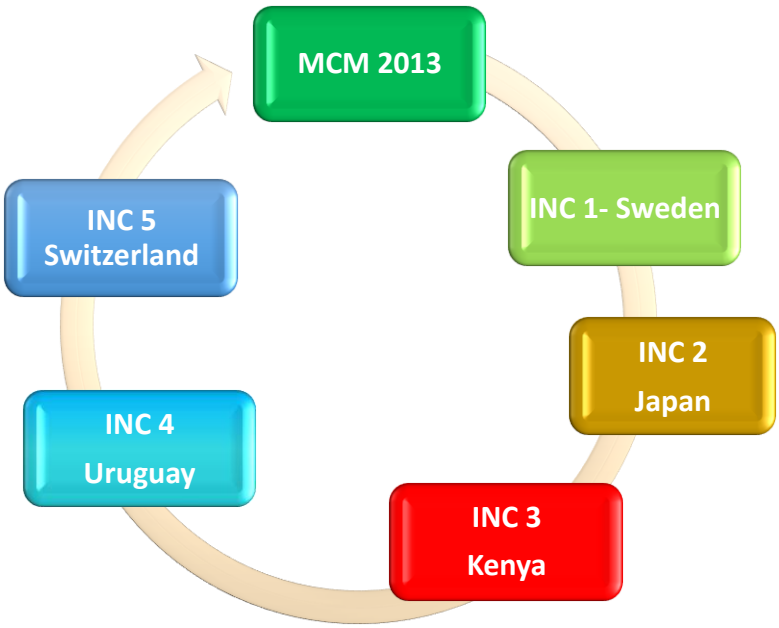


Figure1. 1The countries that hosted intergovernmental committee meetings

The convention came into force on 17th August 2017, and continues to be ratified by countries across the world, as at September 2022 137 party countries have discussed and endorsed it (https://www.mercuryconvention.org/en/parties).

	Take Note Kenya's MCM document is at an advanced stage, it is awaiting discussion by parliament, if approved Kenya will become a party. Party countries consent to the convention and lay out domestic regulations and policies.

1.4.3 Dental amalgam phase down verses phase out

In the introduction to the module, we alluded to the lack of best practice management in dental facilities leading to ingress of dental amalgam waste into the environment as the main reason why DAPD is addressed in the MCM. However,as a restorative dental material dental amalgam has drawbacks that have led to a progressive natural decline in its use over the last four decades, that most dentists have noted over the years. Let us enumerated these in Table 1.2.

Table 1. 2 Drawbacks of dental amalgam[7,8]

S/No	Drawback
i.	Lack of aesthetics
ii.	High biologic cost (mechanical design for retention and strength at the expense of natural tissues).
i.	Mercury containing - controversy since its' introduction
ii.	Resultant Hg containing waste >>> DAPD
iii.	Lack of adhesion
iv.	Low flexural strength
v.	Application limited to posterior teeth

Thankfully, at the negotiation of the MCM, the dental organisations were successful to push for a phased down of dental amalgam over a phase out as the alternative restorative material fell short of dental amalgam in key properties. Additionally, use of alternatives comes with increased cost of care and a phase out would have disadvantaged low- income countries[9]. Kenya was among the many dental associations that participated through FDI bysubmission of a position paper in support of phase down verses phase out of dental amalgam. .

1.5 What does dental amalgam phase down entail?

We will begin by defining dental amalgam phase down. A reduction in use of dental amalgam the long term efficacious posterior restorative, in favour of alternative restorative dental materials, while embracing oral health promotion and prevention of dental caries[9].

Some of the advantageous properties of DAARs like aesthetics, adhesion to tooth structure, rapid hardening and attainment of strength, and varied consistencies have led to broad applications of these materials. These include preventive restorations approaches over and above posterior restoration in place of dental amalgam. Preventive philosophy merges with tooth preservation which is engrained in the non-invasive, microinvasive restorations thus DAPD enjoins and catalyses minimally invasive dentistry.[9,10,11].

	**In text question** What does dental amalgam phase down entail?

The 9 measures that encompass the DAPD Table 1.3. Inorder to reduce the use of dental amalgam and prevent deterioration of oral health, a multipronged approach with strategic interventions; knowledge management andwaste management and health system strengthening have been summarized from the nine measures, to assure a sustainable phase down.[12]

Table 1. 3The nine measures of dental amalgam phase down[1]

(i)	Setting national objectives aiming at dental caries prevention and health promotion thereby minimizing the need for dental restoration;
(ii)	Setting national objectives aiming at minimizing its use;
(iii)	Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration;
(iv)	Promoting research and development of quality mercury-free materials for dental restoration;

(v)	Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices;
(vi)	Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration;
(vii)	Encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration;
(viii)	Restricting the use of dental amalgam to its encapsulated form;
(ix)	Promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

1.6 Global status of dental amalgam phase down

As we embark on this section, a reminder of the voluntary nature of dental amalgam phase down is appropriate, it partly explains the diverse levels of implementation of DAPD globally. Three factors stand out: Firstly, there are countries that had started restricting the use dental amalgam years before the MCMdue to concerns on environmental releases of mercury and Hg containing products. Some of these are in post-dental amalgam era like Norway[13] and Sweden[14,15] 2011 and 2012 respectively. Secondly, the demand for aesthetic restorations has increased globally. Thirdly, countries tailor-make their DAPD processes including guidelines, policies, protocols, phase out dates, cessation of teaching DA and allocation of additional resources. In Norway it is patients' groups raising concerns in the media, guidelines calling for mercury free alternatives as first choice filling that nailed the phase out while in Sweden it was stakeholder participation that set goals and objectives[15].

Notably, many countries have commenced implementation of DAPD via strategic interventions while teaching and the use of DA has declined in dental schools.

1.6.1 Dental amalgam phase down in high- and middle-income countries

We will consider an overview of the DAPD process,whichrevealsmarked reduction in the use of dental amalgam in Netherlands (1%), Finland (3%) Japan (4%) and Denmark (5%), whereas both German and Switzerland have realized significant success in phasing DA down to 10%[16,17]. Added to these are Spain, Mexico, Italy, Singapore, Austria, Canada, Japan, Germany and USA[14,18]. Parallel to thisis the change in teaching dental amalgam Austria, German and Switzerland 89.6% allocated to alternatives, while in Japan it is 93% and in Malaysia 74.1%[19]. In Oceania dental schools pre-clinical teaching of DA amounted to 29% against 39% for dental resin composites (DRCs) in 2019. Some countries have also set possible dental amalgam phase out dates, the year 2030 being shared by European union, Oceanian countries[20]. We can say the DAPD clock started ticking at different times across the globe and the onus is for each country to legislate and chart their outlined process.

1.6.2 Dental amalgam phase down in low- income countries

The situation in these countries is high dental caries disease burdens, lack of prioritization of oral health and limited access to oral care by populations. In most low-income countries, dental amalgam is still in use for posterior restorations, it is reported as disproportionately applied, higher in public than in private sector. We can appreciate the levels as shown in Table 1.4 from available reports by countries.

Table 1. 4Status of dental amalgam in low-income countries

Country	**Dental amalgam phase down status**
Jordan Al-Asmar et al[21]	Awareness of DAPD low, declining use of DA in private but prevalent in public institutions 43% n=

Nigeria Arotiba*et al* [22]	Amalgam use 57.5%. Commencement of phase down, cessation in use in pregnant mothers and children under 16, 2020. DAPD Policy development Human capacity development and training of dentists on the use of mercury alternatives
India Karthik et al[23]	DA still in use 57.3% usage, best waste management enacted
Iraq Faraj BM et al [24]	57.8%) of DA
Pakistan Khan S et al[25]	Use of DA reducing is at 41.6%, most dentists lack knowledge on best waste management practice

1.6.3 Global dental amalgam phase down Kenyan situation

Let us now delve into the situation in Kenya, the dental amalgam process is still at discussion level with an aim of bringing together stakeholders under the leadership of Ministry on health. Parallel to this in conjunction Ministry of Environment and other stakeholders crafted for endorsement of the convention which has now been approved by cabinet and awaits ratification by parliament.

	**In text question** What is the status of dental amalgam use in Kenya?

To date the Kenyan studies have captured small study samples and only one study by Osiro *et al*[26] singled out the application of the most commonly used DAAR dental resin composites DRCsin posterior restorations reporting low usage at 25.2% for Class I restorations and 18.5% for II restorations in 2014 Table 1.5. While unpublished data on two institutions in Nairobi recordedin 2019 recorded66 (18.8%) amalgam restorations in posterior teeth against 286 (81.2%) resin composites.

Phase down in use of dental amalgam in deciduous teeth was first reported by Ganatra et al[27] in 2009, glass ionomer cement being over dental amalgam in 2009 GIC use 58% versus 20.6% DA. The trend continues and in 2014 Osiro *et al*[26]study showed GIC use to be 47% verses less than 9% DA Table 1.5. Established status at Mombasa county report that they have phased out dental amalgam use, with a similar status reported among restorations in children in Kenyatta National Hospital. Hence a glaring disparity and lack of a nationwide DAPD approach defines the status in Kenya.

Table 1. 5Status of dental amalgam use in Kenya

Reference	**Sample size/year**	**DA use %**	**DRC use %**	**Remark**
Kiaoet al*	n=83 2021	-	51%	Nairobi (Bulk fill)
Osiro et al[26]	n=89 2014	39% in class II 30.3% in class I	25.2 in class I & 18.5 in class II	In permanent teeth
Kisumbi et al[28] (n=69)	n=69 2012	91.2%	92.6*	*All Composite applications East Africa DA phase down project data
Ganatra et al[27]2009 (n=145)	N=145 2009	56%	10%	In permanent teeth

*unpublished data

1.7 Dental amalgam phase down and oral health status of populations

Now that we have reviewed what dental amalgam phase down entails and its status globally, we will proceed and discuss how it impacts oral health. Basing on a report by Norwegian dentists, patients are satisfied with alternative restoratives.

	**Take Note** Due to the preventive components DAPD translates to benefits namely; reduced dental caries disease rates, smaller cavities with eventual reduced need of use of filling, ushering culminating into better oral health and a decrease in expenditure on oral health care for countries.

1.8 Impact of DAPD on dental practice today

We can summarize the impact of DAPD on dental practice today in the following ten bullets. It translates into a paradigm shift departing from the traditional model based on dental amalgam the so termed 'drill and fill' surgical approaches. Based mechanistic amalgam, all sizes of cavities

i. Addition of dental caries prevention component in restorative care.
ii. Increase the use of alternative restoratives in place of dental amalgam.
iii. Reduction in the use of dental amalgam.
iv. Use of capsulated DA.
v. Best waste management practice Storage of waste dental amalgam and extracted teeth with dental amalgam fillings in tightly closed containers.
vi. Adopt minimally invasive dentistry (re-minerisation, non-invasive and micro invasive approaches using alternative restorative materials).
vii. Patient education on choice of filling material & allay alarm on dental amalgam.
viii. Dental school Curriculum review and Continuous Professional Development for dentists in need of capacity building.
ix. Participate in national policy formulation.

1.9 How to commence dental amalgam phase down

Gathering from our discussion thus far, there is no standardized outfit for countries to phase down the use of dental amalgam. To start with, the call for a custom-made process by nations is voluntary and it requires ownership by stakeholders particularly the dental sector and statutory allocations to enable the process and provision of oral health care. Additionally,to capacity build the significant stakeholders; dentists in practice, academia and dental students while government ministries are needed in order to manage national decision making.

Sharing form my interaction with dental amalgam processes, approval of the convention document to become policy is the one major milestone towards the process of DAPD in a country. Once the bill has been approved and Kenya becomes a party to the MCM, a national steering committee composed of all stakeholders has been reported as the best approach by Fisher *et al*.[12,14]The committee becomes the sole communicating body to ward off alarming information to the millions of patients who have dental amalgam fillings. In my view it would then lay options for identifying partners and collaborators in charting the DAPD national plan.

MODULE II

2.0 LECTURE TWO

DENTAL AMALGAM ALTERNATIVE RESTORATIVE DENTAL MATERIALS – DENTAL RESIN COMPOSITES

2.1Introduction

Welcome to the second lecture of the training where we will discuss one of the most widely used categories of alternative restorative dental materials. We can rightly say that the DAPD measure no.(iv)“promoting research and development of quality mercury-free materials for dental restoration”escalatedtheexisting research interest in DRCs.Realizing improvements in properties,for instance formulation, adhesion, aesthetics and rheology that has seen this material depart from relegation to anterior restorations to vast applications that resonate with DAPD. These include preventive restorations, posterior restorations in place of dental amalgam and micro-conservative approaches as the mechanically driven ‘*drill and fill’* dental amalgam model eclipses. Parallel to this has been the demand for aesthetic restorations by patients over the last few decades.

We are going to discuss the different versions of DRCsand considering your professional position, we will skew the discussion towards new DRCs modifications,application techniques and indications. In this lecture,we will review the performance of highly filled conventional DRCsand depict their co-utilisation with some of the new versions. In particularwith the base or low-viscosity bulk fill wit; bulk fill full-body or short-fiber reinforced resin composites to form the parts of the filling subjected to high-stress bearing areas. One of the new techniques is possessed by the bulk fill resin composites which are flowable and applicable with 4-6mm depth of cure, reducing technique sensitivity and subsequently redeeming clinicians’ time. In one of the sections of thislecture we will discuss how research advancement has yielded bio-smart resin composites. For instance the alkasites that display anticariogenic properties when pH drops below 5.8, neutralizing acid attack and promotingtooth re-minerisation thence averting tooth de-mineralisation in the dental caries process. One of the few available products is available in Kenya *Cention N(Ivoclar,Vivadent.*

2.2 Learning objectives

1. The lecture will discuss/describe the range of available dental amalgam alternatives
2. Compare the limitations of dental amalgam alternative restoratives with those of dental amalgam.

3. Discuss the broad formulation, properties and clinical performance of newly developed resin composite materials
4. Present properties targeted in future dental resin composites

2.3 Learning outcomes;

	For Dental amalgam alternative restorative dental materials I: Dental resin compositethe participants will; 1.0 Give examples of the new types of resin composites that emanate from the modifications. 2.0 Understand contraindications of dental amalgam alternatives 3.0 Describes the new developments in resin composites that confer respectiveproperties and subsequent clinical performance 4.0 Anticipatesfor improved and novel resin composites

2.4 Overview of the available range of dental amalgam alternative restorative dental materials

In this section of the lecture, we will look at the most widely used group of direct alternative restoratives, the DRCs. But before we focus on these materials it is prudent that we familiarise with the range of dental amalgam alternatives currently available for dental use. Once again, we will endeavor to filter what is novel in recognition of the body of corporeal literacy that you have garnered in your training and practice.

Let us outline the alternative restoratives available for application firstly in high stress bearing areas in the permanent dentition (Figure 2.1), and those suitable for the 1^0 dentition, anterior restorations minimally invasive and preventive restorations (Table 2.1).

Ormocer-based composites

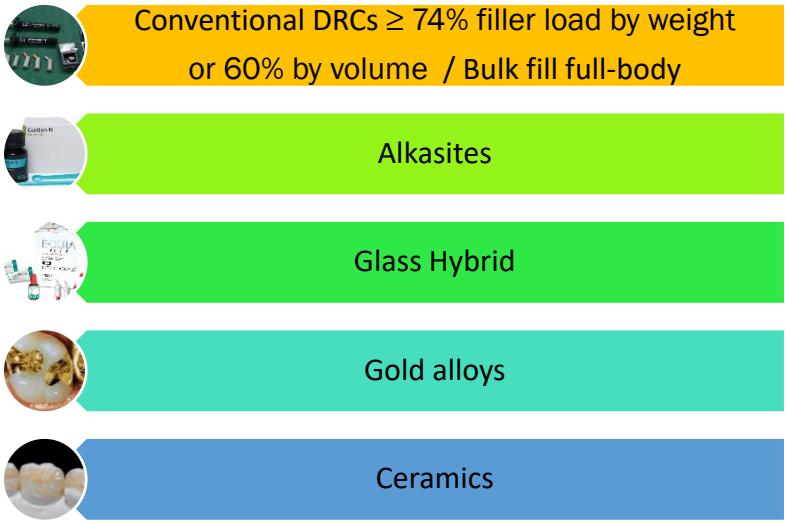


Figure 2. 1Direct and indirect dental amalgam alternatives applicable as definitive restorations for molars and premolars in the 2^0 dentition

Notethe considerable increase in modifications ofresin compositesand glass ionomer cements (GICs), all aiming to improve existing disadvantages and or add desirable new properties Table 2.1. So as a dentist the process of selection, appropriate manipulation for best clinical outcomes cannot be underestimated.

Table 2. 1 DAARs for use in the 1^0 dentition, anterior restorations minimally invasive and preventive procedure

Dental resin composites	Glass ionomer cements and related biomaterials	Biomaterials applied in Preventive procedures	Ceramics and metal alloys
Resin composites Flowable RCs Self-adhesive RCs Condensable DRCs Low shrinking DRCs Bulk fill DRCs Indirect DRCs Alkasites Compomers Giomers Self-healing RCs	Conventional glass ionomer cements Advanced GICs Glass Hybrids Resin modified GICs Nano ionomers Glass carbomers Zirconomers	Fissure sealants Unfilled resins High viscosity resin infiltrants Silver Diamine Fluoride Biodentine	Ceramics Stainless steel crowns

2.5 Contraindications of most of the dental amalgam alternative restorative dental materials.

Up to this point we have appreciated the diverse applications of DAARs, however it is correct to view them as alternatives not substitutes of dental amalgam.

	**In text question** In which clinical applications are DAARs limited in which DA may be an option when indirect restorations are not affordable?

There are clinical areas that werepreviously dominated by dental amalgam, and when correctly indicated and manipulated yielded durable long serving restoration, where today's direct DAARs have limitations Figure 2.2. The aforementioned include;

,

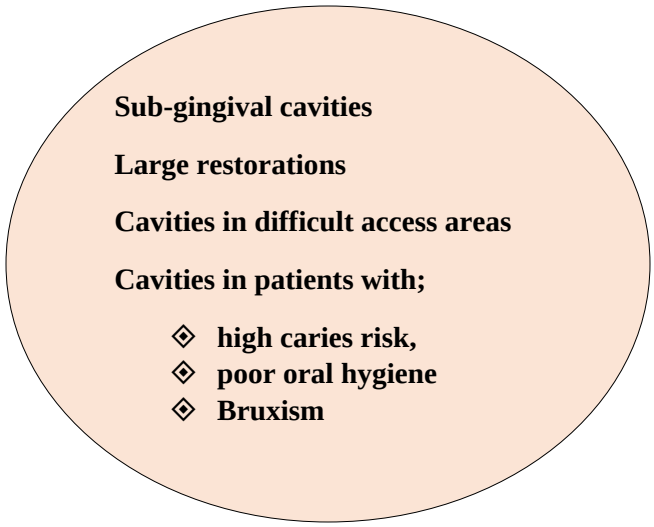


Figure 2. 2Contraindications of direct dental amalgam alternative restorative dental materials

In these areas indirect restorations using alternatives, ceramics, gold alloys and indirect composites whose use comes with infrastructural capacity and cost implications. You will agree with me that while a few patients have resources to have aforementioned restorations, this poses a phenomenal challenge to many patients in Kenya who end up losing their teeth opening the way for oral health inequality.

Developments in dental resin composites:The new biomaterials

You will notice that in each development a specific property or technique is being brought in the new material. In our discussion, we will endeavor to conclude if the particular property was indeed realized and whether or not as a result some property may have been lost or subdued in the process.

2.6 Conventional resin composites

Before we take the plunge to discuss the newly developed dental materials, let us briefly review conventional resin composites which have a history of 60 year now.

Following the advent of Bowens resin in 1962[29], phenomenal improvement has been done to yield conventional resin composites with strength and wear resistance amenable for performance in posterior restorations. In section 2.4 and figure 2.1 the filler loading highlighted 74% filler load by weight or 60% by volume isa key guide in selecting DRC to function inhigh stress bearing areas. Most of these are indicated as universal DRCs.

	**In text question** Are you able to explain what aspect of the conventional resin composites has led to their need of one modification after another?

First the limited depth of cure (2mm), the time-consuming incremental layering technique Figure 2.3. Which is aimed at reducing polymerisationshrinkage stress and the subsequent post-operative sensitivity. Secondly, the relatively high viscosity limiting wetting of the cavity walls and overall technique sensitivity among others. Nevertheless, posterior resin composite restorations show a good survival, with annual failure rates of 1.8% at5 years and 2.4% after 10 years of service. Opdam N.J *et al.*[30]We will demonstrate and discuss the manipulation technique later, in chapter three.

Note a list of products available in Kenya in appendix I.

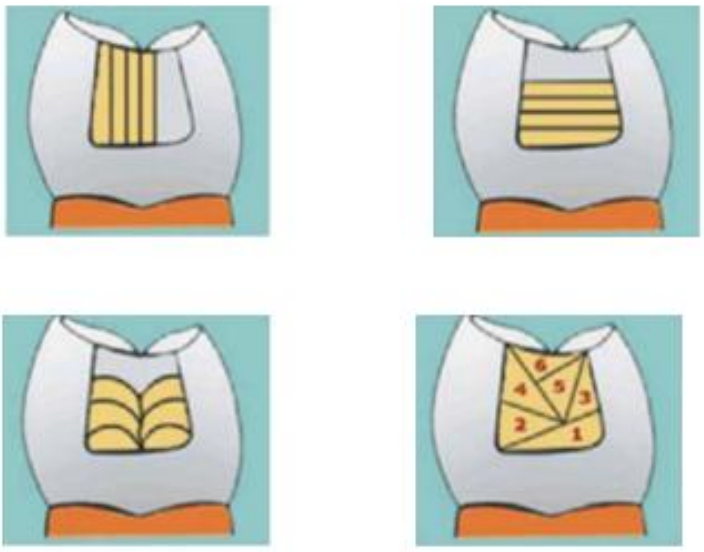


Figure 2. 3 Incremental layering techniques of conventional DRCs[31]

	**Take Note** The polymerisation shrinkage stress generated in the event that incremental layering is not executed is depended on the ratio of bonded verses unbonded cavity surface area. For instance a small class I will develop higher shrinkage stress than a class II and hence the patient is more likely to experience postoperative sensitivity.

2.7 Flowable resin composites

As we commence the modifications, we discuss the flowable resin composites(FRCs) which were developed to address special handling characteristics of resin composites rather than enhance physico-mechanical properties. A reduction in filler content of conventional DRCs to 37% - 53% by volume was done, resin quantity added to reduce viscosity the filler sizes maintained.[32]They were introduced in 1996 for application in class V cavities and have become a versatile materials that find application in various procedures.[33]

	In text question How did the modification affect polymerization shrinkage and where arethe FRCs applied?

They have high polymerization shrinkage 4.0–5.5% vol, reduces biocompatibility yet they find key application areas namely; bases under higher viscosity DRCs, restorations in low stress bearing area restorations with low C-factor, restoration repairs, preventive resin restorations, fissure sealants, bonding orthodontic brackets and restoration repairs.[32]Finally, there are coloured flowable resin composites that find applications as marking root canal orifices post obturation and restorations in deciduous teeth Figure 2.4.

Figure 2. 4 A coloured flowable resin composite material

2.7.1 Self-adhesive flowable resin composites

To further improve on handling characteristics of FRCs,compounds used in bonding agents have been added e.g Glycero Phosphate Dimethacrylate (GPDM) to make then self-adhesive. Thus eliminating separate etching bonding steps. A typical product *Constic*, DMG is presented in Figure 2.5.

Figure 2. 5A self-adhesive flowable resin composite material*DMG, America* *https://www.dmg-america.com/de/products/product/constic-1/*

The advantages include less time consuming application and comparable nanoleakage.[34]While disadvantages are lower bonding to enamel and dentine and compared to a nano-hybrid inferior marginal adaptation compared to a highly filled composite lower microhardness. Self-etch flowable resin composites that differs among different between products and studies are yet to provide long term performance in the oral environment.[32,34]these materials find similar indications with FRCs.

2.7.2 Bulk fill flow resin composite

This is yet another development within the flowable composites that targeted to improve the properties of FRCs. They find application as liners and bases in bulk fill full body restorative materials. Not as restorative materials.

	**In text question** What major advantage do the bulk fill flow composites have over the conventional flowable composites?

A welcome advantage is lower polymerization shrinkage and higher depth of cure which is an advantage in base applications. However their flexural strength and elastic modulus is inferior in some of these materials.[35]

2.8 Condensable resin composites

In modern dental practice where application of resin composite has continued to increase, you will probably attest to the comparable ease of building and achieving proximal contacts of restorations that dental amalgam provides. The packable/ condensable resin composite was developed in the 1990's to simulate the packability of dental amalgam and overcome the challenge of attaining proximal contacts. This was done by including Irregular, fibrous alumina silica fillers with viscosity modifiers to posterior composites.

What were the key successes?

- Less sticky
- Easier to pack
- Acceptable proximal contacts

Let us now proceed to appreciate the other properties Figure 2.6.[36,37]

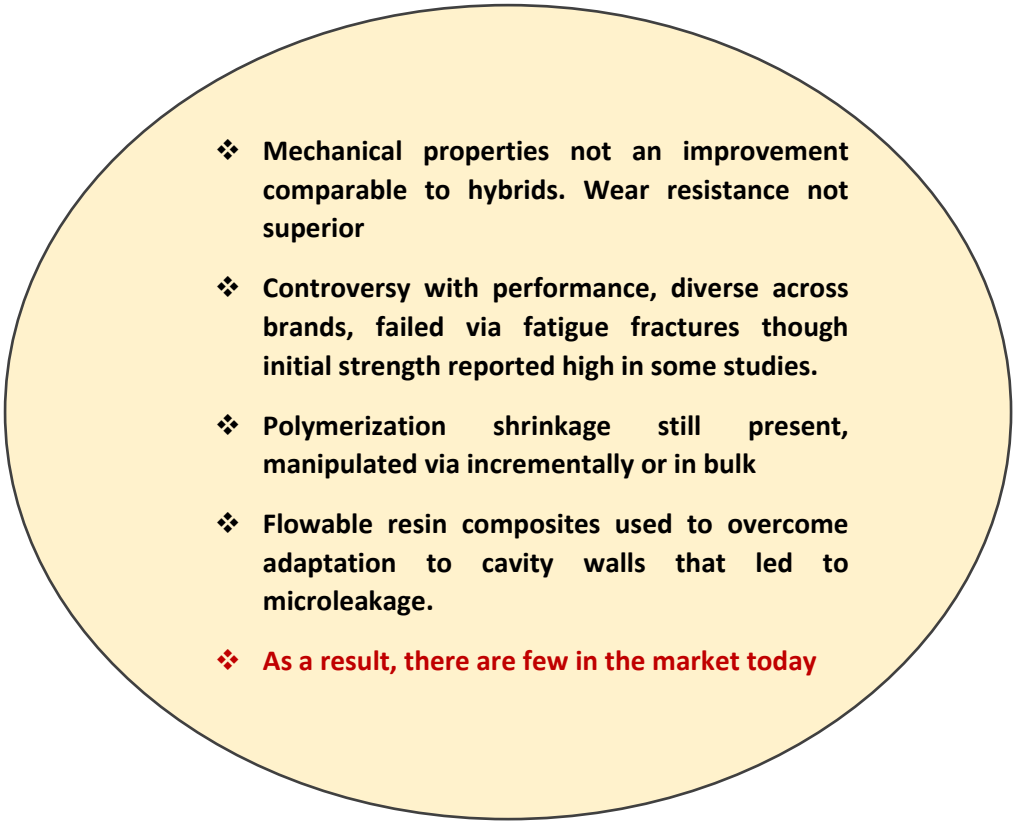


Figure 2. 6 Properties of condensable DRCs

Some of the available products in the market include *Filtek P60 3M ESPE, Surefill of DENTSPLY,* illustrated in Figure 2.7.

Figure 2. 7Packable DRC products

2.9 Low shrinking resin composites

In this section, we will discuss the Low shrinking resin composites (LSRCs) which were introduced in 2000's to overcome yet another major drawback of DRCs - polymerisation shrinkage. These materials utilized low shrinkage/low stress monomers for instance the silorane which have ring opening property, also utilized are monomers with rigid cores and flexible arms like the DuPond monomer.

The outcome was for the first-time a demonstration of lower shrinkage < 3% compared to conventional DRCs 3-5%Table 2.2. This also reduced shrinkage stress, and with no effect in physico-mechanical properties. [38]

Table 2. 2Properties of three practical low shrinking DRCs[39]

LS - Composite	Filler mode	Shrinkage %	Filler vol%	Filler wt%
GC Kalore	Nano-hybrid	1.84	69	82
Venus Diamond	Nano-hybrid	1 .71	64	81
Filtek P90	Nano-hybrid	<1	57	76

In text question

With such a success in overcoming polymerisation shrinkage and possession of high filler, are there drawbacks of DRCs that were not realized?

Two firstly performance on microleakage is conflicting,[40]the LSRCs required flowable composites for adaptation to cavity walls. The second drawback was in the manipulation **the time-consuming incremental layering technique of 2mm layering.**

Take Note

These materials are applicable in posterior restorations hence increasing the range of available DRCs. They were introduced in the 2000's together with the packable resin composites. At time when bonding agents were speedily developing hence pursuit of a restorative material with less shrinkage, ease of manipulation continued as we shall discuss in the next section

Some of the available LSRC's are illustrated in Figure 2.8.

Figure 2. 8 Typical low shrinking DRC materials

2.10 Ormocer-based composites

The term ormocer stands for organically modified ceramic, organic-inorganic co-polymers. The main components of the material are; organic methacrylate polymer and inorganic polysiloxane matrix (Si-O-Si) network into which inorganic ceramics particles of different shapes and sizes are dispersed. The advent of ormocer based composites targeted to overcome the disadvantages of polymerization shrinkage of resin conposites.

They were first marketed in 1998 and they are few products available in two companies VOCO (Admira product range) and DENTSPLY (Ceram·X). Compared to Bis-GMA resin composites ormocers contain less resin content and undergo less polymerization shrinkage[41], less shrinkage stress, excellent aesthetics and good wear resistance. First generation ormocers had no advantages over DRCs.[42]

New bulk ormocer versions have been developed *Admira Fusion x-tra* (Voco) *Ceram.X Duo*(DentsplySirona) that have acceptable degree of cure 4mm.[43] Ormocers clinical performance is similar to that of bulk fill composites, but show shorter longevity than nanofilled and nanohybrid resin composites.[44]One key advantage of ormocers is lower microleakage, they

however have lower compressive strength than DRCs. Indications of ormocer-based composites are the same as those of DRC's. Figure 2.9 presents two commercially available ormorcer based composites.

	**Take Note** ❖ Other that the lower compressive strength and conflicting outcomes on longevity, ormorcer-based composites are acceptable choice for direct aesthetic restorations.[45]

Figure 2. 9Available commercial products Admira Fusion and Admira Flow (VOCO), Ceram.X Duo (DentsplySirona)

2.11Bulk fill resin composites

These materials are the most widely used direct DAARS and we will proceed to discuss why? Let us proceed and discuss the bulk fill resin composites **(**BFRCs) that were introduced in 2010 to further overcome challenges with incremental layering technique,cavity wetting and polymerization shrinkage. As the name suggests BFRC's are inserted in bulk, larger increments 4 -6 mm is attained in most BFRCs. They are also flowable and able to wet the cavity walls therefore eradicating the need for a flowable resin composite. The first BFRC to be developed was Surefil SDR flow (Dentsply Caulk), the formulation of includes;

- a stress decreasing resin (SDR),
- Viscosity modulators.
- While some contain polymerization booster initiators e.g.Ivocerin (*Tetric-Ceram*).

For flowability a lower filler load with some having < 60 Vol% which is the minimum required for high stress bearing posterior restorations.[46,47]

Take Note

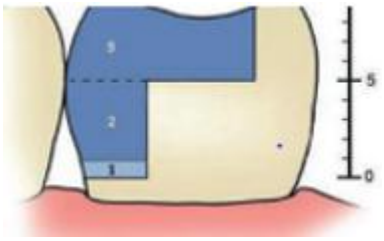
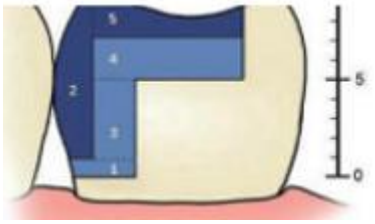
- In assuring light penetration to deeper layers most bulk fill resin composite pigments are semi tones. **All theseadvantages have resulted in widespread usage of BFRCs in posterior restorations as a dental amalgam alternative.ref**

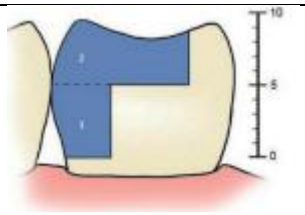
In the next sectionwe classify the BFRCs products and look into the respective applications.

2.11.1 Classification and selection of Bulk fill resin composites

First basing on filler loading and consistency, there are three types of BFRC's, with different properties and manipulationand applications as depicted in Table 2.3.

Table 2. 3Manipulation and application techniques of bulk fill DRCs

Filler load and consistency	**Manipulation**	**Applications**
High-viscosity (sculptable/full-body) higher; filler load, wear resistance	1-step bulk fill4mm increments	High stress bearing posterior restorations 
Low-viscosity (flowable/base), lower; filler volume, lower resistance and micro hardness,	2-step bulk. BFRCs applied in the inner layer of the restoration. Then capping with conventional DRC is done to restore occlusal surface, marginal ridges and proximal contacts!	On the inner layer of the restoration 
Sonic activated BFRC (sonic activator that	1-step bulk fill 5mm	High stress bearing posterior restorations

generates sonic vibration,materialsflows then reverts to viscous state.	increments	

Secondly, BFRCs can be classified as light and dual cured. Two products based on dual cure mode include Coltene's- Fill Up; Parkell's – HyperFil. These are applied as a single increment, managing the long-standing technique sensitivity of DRCsFigure xxx.

	**Take Note** ❖ A delay of 3 or 5 min prior to the light-activation of dual-cured cements can reduce shrinkage stress. ❖ Some of the dual cured bulk fills have inferior aesthetics and need conventional DRC capping, similar to the low viscosity BFRC but this time to manage aesthetics. ❖ From the discussion thus far, we can appreciate the role played by the universal resin composites, no wonder they've served for more than 3 decades the drawbacks notwithstanding.

The following question is paramount. To assure the properties of selected BFRC match the application, we should not rely on manufacturer's instructions solely.

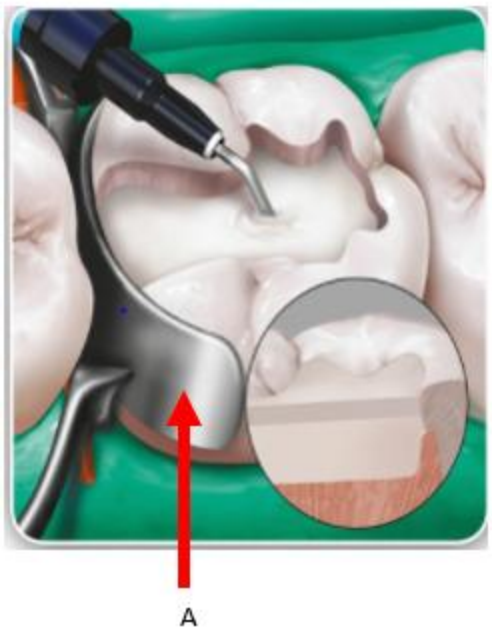
	**In text question** Are all BFRCs available applicable in posterior restorations? Does the type of BFRC you are using have optimal properties?

From the above discussion the low viscosity/base BFRC should not be utilized to replace the high stress bearing areas of the posterior teeth. Appendix I presents of available products the Kenyan market and delineates of the types.

2.11.2 Manipulation of BFRCs

As we continue to discuss this group of materials, you note thatsince they are not packable the issue of proximal contact attainment is still outstanding. This is tackled in its' manipulation via the use of thin matrices ≤ 0.038 in order to achieve proximal contact. Some are referred to as dead soft. Figure 2.10illustrates the isolation of all alternative restoratives for achievement of contact in posterior restorations.

Manipulation of BFRC's is demonstrated in Module III: Lecture IV. 4.3.1.



With your sectional matrix or circumferential band (<0.038mm) the following constitutes Step by step **manipulation;** of BFRC

- Complete cavity preparation
- Isolate with Rubber dam
- Execute pre-wedging (normal wooden wedge suffices).
- Place the sectional matrix
- Clamp the matrix with the ring
- Burnish
- **Extrude the BFRC and assure you do not exceed 4mm**
- **Light cure with light tip 90^0 and at most 3mm**
- **Light intensity should be at least $550mW/Cm^2$but for dual cure $960mW/cm^2$ is advocated.**
- **Finish the restoration**

Figure 2. 10Sectional matrix (A) in situ as flowable BFRC is syringed in the cavity

2.10.3 Properties of BFRCs

The modifications we discussed at the introduction of this section has come with desirable properties demonstrated by BFRC's. At the same time there are drawbacks that open direction for further research. Table 2.4.

Table 2. 4Advantages and disadvantages of bulk fill DRCs[48]

Advantages	Disadvantages
i. Lower post-gel shrinkage ii. Less shrinkage stress iii. Flowable	i. Less microhardness ii. Lower wear resistance iii. Cuspal deflection

iv. Higher reactivity to light v. Increased translucency. vi. Depth of cure 4-6mm	iv. Elastic modulus

Take Note

- Some manufacturers only increase the filler load and reduce pigments, as a result a variance of properties exits among the bulk fill products available today. It is therefore important to appropriately select these materials.

As we can see in Table2.5, even among the same class of BFRC's, the filler loads vary and hence, the mechanical properties, aesthetic result and placement technique varies significantly across the materials available.

Table 2. 5Distribution of properties of bulk fill DRCs depicting variations[49,50]

BFRC	Filler %wt	Filler % vol	Depth of cure (mm)	Microhardness (Knoop Hardness Number (80% of initial MH)
Filtek 350 (conventional)	82		2.63	89.37
Sonicfill 2 (Kerr)	83.5		6.6	101.58**(at 4mm)
Tetric Ceram Bulk Fill	79-81	60	4.88	50.89

Surefill SDR (Dentsply)	68	45	-	34.38 (4mm) VHN
Fill-up (Dual) Ivoclar)	65	49	-	34.5** (4mm) VHN
Filtek Bulk Fill Posterior (3M ESPE)	76.5	53.4	5.0	49.6
Extra fil (Voco)	86	-	5.38	74.34
Filtek Bulk fill Flowable	64.5	42.5	5.63	16.21
SDR	68	45	6.94	22.05

2.11.4 Applications of BFRCs

From our discussion the application of the high viscosity/full-body type is akin universal DRCs,[51] basically a good alternative to dental amalgam but should not used in large restorations to replace cusps. In such applications the ceramic inlays, gold inlays and indirect resin composites are indicated. Arguably, we can conclude by appreciating that flowable BFRC serve at a dentine replacement. In the next section we will discuss indirect DRS's as the next section of this lecture.

2.12 Indirect resin composites

In an endeavour to reduce polymerization shrinkage, increase extent of polymerization and reduce C-factor, the first-generation IRCs were introduced back in 1980's, and later the second generation materials emerged in 1990's. The first-generation indirect resin composite(IRCs) were microfilled conventional DRCs that were post-cured.[52]They however had shortcomings which were addressed in the second generation that are composed of microhybrid filler, polymerization done using heat at 120 -140°C in vacuum, under pressure, and oxygen free environment ± Light and some under water. The materials as stipulated below.[53]

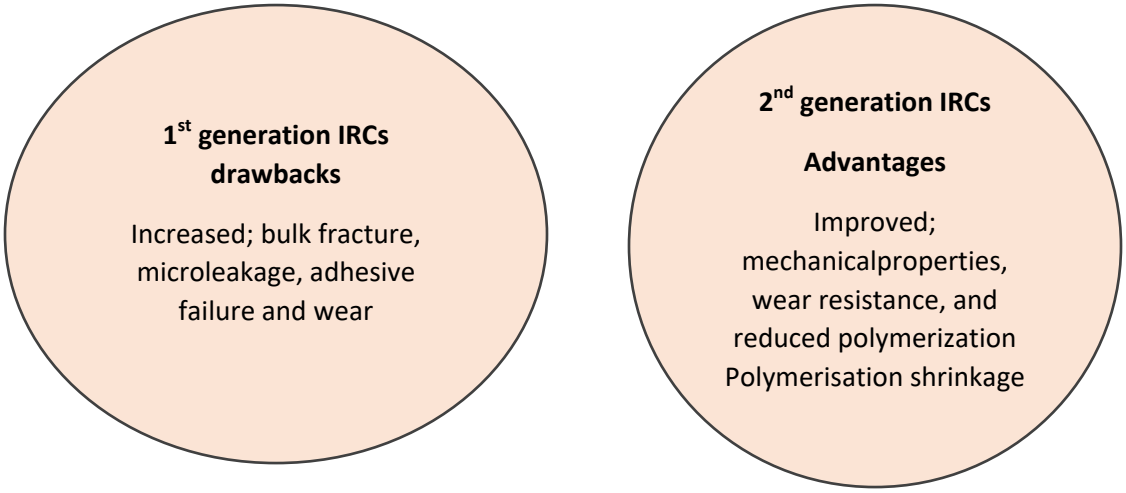


Figure 2. 11 Developments in indirect resin composites

IRcs have high filler 92% wt.82% Vol, their properties in btw highly filled conventional DRCs and ceramics.

	**In text question** Compared to direct DRCs what are the advantages of IRCs?

Due to the possibility of post curing, this results in high degree of conversion and subsequent in improved mechanical properties, diversifying the applications of DRCs to high stress bearing areas. The advantages include;

- Minimises the marginal gap and compensates for the unavoidable polymerization shrinkage
- Better functional stress distribution
- Aesthetics

- Colour stability
- Reduced post-operative sensitivity
- Easier to achieve proximal contacts and anatomic morphology
- Possibilities for repair;
- Greater longevity
- Adjustment and intra-buccal polishing.[4]

	**Take Note** Due to their applicability in large restorations, IRCs arethe scientifically based dental amalgam alternatives in socioeconomic considerations, where constraints exist in oral health policies and funding for oral health care. You will agree with me that the other alternatives; ceramics and gold alloys are accompanied by a high cost associated with the materials and manufacturing techniques.

Figure 2.12presents some available products

TESCERA ATL

AQUA THERMAL LIGHT POLYMERIZATION UNIT

Figure 2. 12Typical examples of indirect resin composites

2.12.1 Short fiber reinforced resin composites

As we progress with this discussion of DRCs it is clear that the ideal materials is yet to be invented. The short fiber reinforced resin composites **(**SFRRCs) were first reported in 1960's but the first product was marketed in 2013. They contain a Resin matrix, randomly-orientated E-glass fibers, and inorganic particulate fillers (some nanocluster fillers (SiO2 or ZrO or hybrid).

The new constituent E-glass fibres are silica-based glass and polyethelene fibres that areinsulative with dielectric strength (transmit electric force without conduction) with critical fiber length of 0.5-1.6mm conferring better performance. Contrastingly an SFRC flow versions are available has

micrometer scale fibres 200 µm -300 µm and Ø6 µm. The fibres increase the fracture toughness of the material higher than all other dental composites however they have major drawback Table 2.6.

Table 2. 6 Advantages of indirect resin composites over conventional DRCs and key drawback of IRCs[54,55]

Advantages	**Drawbacks**
Increased; • Flexural strength • Fracture toughness, fiber stop cracks depth of cure (4mm) as light is transmitted through the glass fibres and • Reduces polymerization shrinkage and shrinkage stress than particulate CDRCs.	Water sorption, leading to soluble inorganic oxides that aggravate reduction of mechanical properties in the oral environment.

	**In text question** i. How are SFRRCs manipulated? ii. Considering the highlighted drawback do they find place for restorations today?

The manipulation includes bi-layering with a conventional resin composite to prevent the water sorption, improve mechanical properties. A 1-2 mm thickness of conventional DRC, over the SFRRC. This is technically biomimetic as the restoration bio-emulates by structurally mimicking

dentine Figure 2.11.The bi-layering of SFRC with conventional layer has higher fatigue limit than the individual materials. Survival rate of 97.2% and success rate 88.9% reported by Tanner et al[56].

Figure 2. 13Short fibre reinforced resin composite and particulate filled resin composite (PFC) application bio-emulating the structure of dentine and enamel

Short fiber reinforced resin composites show a good clinical performance in the short term evaluation. However the properties differ between products due to filler load, E fibre length and adhesion between fillers and fibres that controls stress transfer.[57]

This technique is clinically applicable and might offer a cost-effective way to restore large posterior cavities in high stress bearing areas in vital and non-vital teeth as dental amalgam alternatives. Their applications are similar to IRCs and few brands are in the market, a typical products is presented in Figure 2.12.

GC, Tokyo, Japan

Nulite System International, Hornsby, Australia

Figure 2. 14Short fibre reinforced resin composite products

Table 2. 7Characteristics of the available SFRCs

Material	Fibre length	Fibre diameter	Aspect ratio	Filler type	Filler weight %	
Alert	60-80 µm	6-10 µm	6-13	Crushed and Chopped glass fibre	84	Pentron, Wallingford, CT, USA
Nulite F	150-200 µm	9 µm	16-22	Micro-rod glass	83	Nulite System International, Hornsby, Australia
Restolux	80-20 µm	10-15 µm	5-12	Chopped glass fibre	85	Lee Pharmaceutica, South El Monte, CA, USA
everX Posterior	1,300-2,000 µm	17 µm	76-118	E-glass fibre	74.2	GC, Tokyo, Japan
everX Flow	200-300 µm	6 µm	33-50	E-glass fibre	70	GC
NovaPro Universal	N/A	N/A	N/A	Hydroxyapatite fibre	77	Nanova, Columbia, MO, USA
Nova Flow	N/A	N/A	N/A	Hydroxyapatite fibre	77	Nanova

1.12.2 Resin composites for CAD/CAM systems

This is the final IRC that we are going to discuss. It presents a further development, formulation of polymer- infiltrated-ceramic-network, one product consists of porous pre-sintered ceramic (86% wt.) infiltrated with polymer (14% wt.).

The first commercial resin-composite for CAD/CAM applications was Paradigm MZ100 (3M ESPE, St. Paul, MN, USA), 2009

The process facilitates a higher volume fraction filler was achieved (~70%) and, consequently, superior mechanical properties were obtained[58]

The advantages over ceramics include; easier to machine, repairable intraorally and cost friendly.They serve as

Figure 2. 15Dental resin products for CAD/CAM technique

2.13 Ion-releasing resin composites: Compomers and Giomers

2.13.1 Compomers

The name compomer is drawn from composite (‘compo’) and glass ionomer (‘mer’), they are also termed as polyacid modified composites. They were introduced in the mid-1990’s as intermediary material between DRCs and GICs to combine the salient advantages of bot parent materials. Though not technically a new material, we will briefly discuss it since they find wide application as an alternative to dental amalgam particularly in the primary dentition. You will probably recall that compomers contain basic ionomer type glass of GICs, sialanised inert fillers and modified methacrylate monomers used in DRCs BUT NO WATER.[59] As a result they are akin DRCs in the setting reaction leaving the ionomer acid base reaction to occur when the restoration surface contacts water in the mouth. The latter reaction is an advantage with regard to fluoride release by compomers, but comes at a price of surface deterioration and reduction in strength in a couple of weeks to the level of 40% in some instances.[60] There are conventional compomers for restorations and flowable versions that find different applications as discussed later in this section.

	**Take Note** ❖ Compomers release less fluoride than traditional GICs. The have poor colour stability and poor wear resistance.[61] Additionally they lack the chemical adhesion property of GICs. Overall stronger than GIC's but inferior to DRCs.

Nevertheless they have superior aesthetics and flexural strength than GICs. The manipulation of compomers is akin that of DRCs, etching with 37% phosphoric acid and prime adhesive application. They should be incrementally build in the cavity.

	**In text questions** How do the properties of compomers compare with the intended objective? Where are compomers applied? What products are available in Kenya?

Compomers are closer to DRC's they lack the chemical bonding and fluoride release of GICs, at the same time they have lower flexural strength and fracture toughness compare to composites.

As a group of materials Compomers find wide application.[60]

- ❖ All cavity types in primary dentition.
- ❖ Restorations in areas with less occlusal forces in the secondary dentition -class V, III, base in open sandwich restorations in conjunction with DRCs, fissure sealants, bonding orthodontic brackets and root end fillings. They are also applied as luting cements and these as presented as powder and liquid.
- ❖ Shortcomings in colour match, surface texture and anatomical form and longevity.[62]
- ❖ Compomer restorations more successful than high viscosity GIC.

One of the products available in Kenya is Dyract Extra find other products in Figure 2.16

Figure 2. 16 Compomer dental materials

2.13.2 Giomers

In this section, we will look at giomers, like compomers giomers are intermediary between GICs and DRCs, they are essentially resin composites that consist of pre-reacted glass ionomer fillers. The fillers are either surface-pre reacted glass (S-PRG) or fully pre reacted glass (F-PRG). However,they differ with compomers as they consist of water bound in the reacted GIC component.[63] These material set via a light activated reaction andutilise bonding agents for adhesion so they are more like DRCs than GICs. With regard to presentation, giomers have both conventional and flowable consistencies. They are similar to resin composites, as they exude fluorescence and translucency giving aesthetical integration of new restorations.

	**In text question** What are the advantages and disadvantages of giomers?

Table presents a summary of the desirable and undesirable characteristics.

Advantages	Disadvantages
Excellent aesthetics	Higher micro-leakage than RMGICs and

Fluoride release lower than that of GICs, but they are capable of recharge and release of the ions.[64] Easy to handle and more flexible compared to DRCs Initial mechanical properties like DRCs	Zircomer (Zirconia filled DRCs) Require etch and bond to adhere to the tooth Bioactive glass on the surface dissolves upon contact with biological fluids releasing ions

The commercially available giomers are not many. They are ideal for restoring non-carious cervical lesions[63–65]. Representative materials are presented in Figure 2.17.

Figure 2. 17A conventional giomer and a flowable giomer

2.14 Smart resin composites

2.14.1 Bulk fill Alkasites

In this section we will discuss a group of DRCs that bring on board bioactivity,which is a departure from physico-mechanical properties that defines previous developments. The bulk fill alkasites (BFAs) are a bioactive sub-group of resin composite that sets via dual activation and consists of nano-size alkaline glass filler and exhibit caries-inhibiting capabilities.[66]Cention N (Ivoclar Vivadent, AG, Schaan, Lietschentein) is the first commercially available bioactive resin composite.

	**In text question** What bio-smart property do the alkasites demonstrate?

Alkasites releases Ca^{2+}, F^- and OH^- when intraoral pH values drop below the critical pH of 5.5 - 5.7, they are acid neutralizing to avert caries process. The hydroxyl ion act by neutralizing pH during acid attack favouring remineralisation. While the calcium and hydroxyl confer the alkaline property.[67,68]

Let us briefly appreciate the composition of BFAs, they contain an Organic matrix of four types of dimethacrylate monomers forming a highly cross-linked polymer urethane dimethacrylate (UDMA), dicalcium phosphate (DCP), polyethylene glycol-400 dimethacrylate (PEG-400 DMA), Aliphatic UDMA). They do not contain the monomers commonly used in other DRCs namely; Bisphenol A-glycidyl methacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA) and 2-hydroxy ethyl methacrylate (HEMA). The filler component has been modified by addition of calcium Fluorosilicate (alkaline filler). One product has a filler load (78.4%wt filler 57.6% Vol filler), out of which 24.6%wt is alkaline filler.[67]

There are few alkasite products in the market. Presentation is single paste light cure or self-cure powder and liquid Figure 2.18.

Ariston pHc (pH Control) **Cention N 30g powder 8ml liquid**

Figure 2. 18Bulk fill alkasites presentation modes; brands Cention and Ariston pHc

As we shift to discuss the manipulation of BFAs, it is akin that of powder/liquid and light cured versions of other dental materials.

Take Note

- The self-cure version release higher Fluoride, and longer sustainability than the light cure, and it also has a better alkanising effect.
- Alkasites releases fluoride in acidic pH like GICs, but decreases with increasing period unlike GICs. They show low incidence of secondary caries compared to resin composites.[69]
- They are a promising dental amalgam alternative posterior restorative material with their clinical efficiency comparable to that of resin composite.

We will proceed and outline the properties of this smart DRC.

i. Aesthetic, low shrinkage rate, and good biocompatibility compared to DA
ii. Better mechanical properties than GICs including Zirconomer
iii. Lower microleakage than Resin Modified Glass ionomer cements (RMGICs)
iv. Esthetics and μTBS of bulk fill resin composite with alkaline fillers "either self- or dual-cured" material is comparable to that of incremental nanohybrid resin composite.[70]
v. Compressive strength and diametral tensile strength is similar to a nanohybrid. [71]
vi. Flexural strength is 110 MPa which is greater than 80Mpa required by ISO 4049 for posterior restorations.
vii. Compressive strength of 302 Mpa[72]

However, they have inferior surface characteristics, and their post-operative sensitivity is higher than that of RMGICs and Activa a bioceramic restorative.

	**Take Note** ❖ They are a promising dental amalgam alternative posterior restorative material with their clinical efficiency comparable to that of resin composite. ❖ However clinical trial on longevity etc

2.14.2 Bioactive composite resin

Bioactive materials that combine advantages of GICsin a resin matrix. They consist of; Resin matrix - blend of diurethane and other methacrylates with modified poly acrylic acid (44.6 %), patented rubberized ionic resin (Embrace) with no bisphenol A, Bis-GMA and BPA derivatives.

Inorganic filler - reactive glass filler (21.8wt %), Inorganic filler %56wt% Filler is an Amorphous silica 6.7%), Sodium fluoride (0.75%).

	**In text question** What bio-smart property do the bioactive resin composites demonstrate?

They liberate Ca^{2+}, PO^{4-}, and F^{-} which is an additional bioactivity over conventional GICs and RMGICs.[73]

Presentation and Manipulation

Figure 2. 19Typical bioactive composite resin - Pulpdent, Corporation, Watertown, MA, USA

As reported by Rifai et al[74]unlike GICsthey are not self-adhesive. Etching with 37% Phosphoric acid, bonding agent, showed higher μtensile bond strength (μTBS). They are applied in increments.[73,75]

2.14.3 Amorphous calcium phosphate releasing resin composite

Amorphous calcium phosphate (ACP) converts into crystalline Hydroxyapatite (HAP), thus replacing the HAP crystal lost to the acid. An ideal biological property a desirable current advance. It was described in 1963 but ACP based resin composites' physico-chemical properties yet to be appropriated for clinical utility.[76,77]

	Take Note Amorphous calcium phosphate composites still need further enhancement of their physicochemical properties to extend their clinical utility. They are in the exciting future of alternative restorative materials.

2.15Self-healing micro capsule dental resin composites

Point to the trends in development of newer bioinspired or biomimetic mechanisms. They are aimed at improving fracture toughness. Composed of an epoxy system that contains resin filled microcapsules. Able to restore mechanical integrity after damage**. These materials have**

promising technology but yet to be evaluated for long-term tests on fatigue and wear behavior are needed to confirm the clinical efficacy.[78,79]Upon rest'fracture e.g. crack. **Rupture of PolymericMicrocapsules, release of catalyst (GRUBBS), polymer cross-linking occurs repairing the crack.**

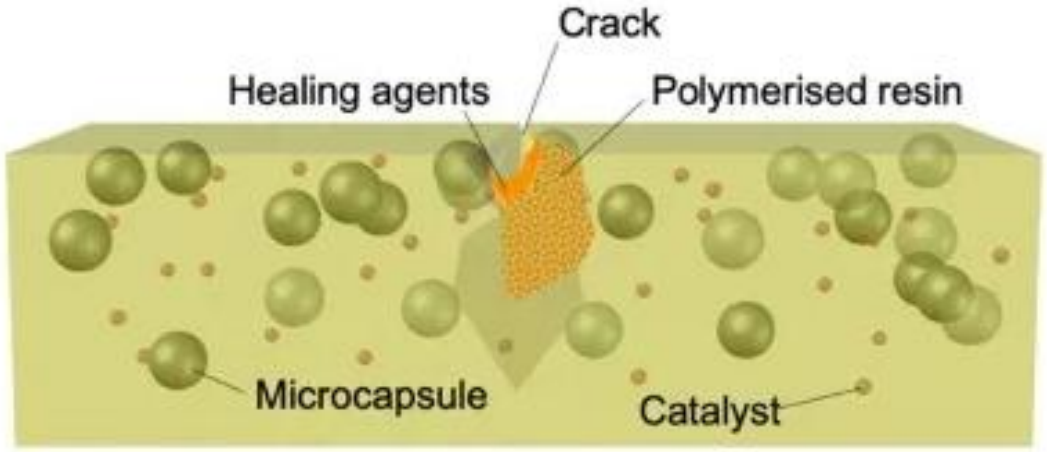


Figure 2. 20A graphical illustration of the mechanism of microcapsules response to a crack in a photo-cured resin composite model.*A space to be watched.*

3.0 LECTURE THREE

DENTAL AMALGAM ALTERNATIVE RESTORATIVE DENTAL MATERIALS II: GLASS IONOMER CEMENTS

3.1 Introduction

In the previous lecture, GICs and related biomaterials were outlined as a key group of dental amalgam alternatives. Welcome to the discussion of these smart dental materials. Developed over 40 years ago from a reaction between the polyacid of Zinc polycarboxylate cement and fluoroaluminosilcate component of silicate cements by Wilson and Kent GICs brought unique properties to dental cements and restorative that existed at the time. As you may recall early GICs had major drawbacks with regard to physic-mechanical properties. Moreover, since the first product ASPA I in 1976, phenomenal development has occurred introducing modifications of GICs with improved properties. Today's range of GICs include stronger versions like the hybrid ionomers that are applicable in some high stress bearing areas. Nevertheless, the performance GICsis yet to rival with dental resin composites. Let us now proceed to discuss GICs, we will lay emphasis on the current advances.

3.2 Learning objectives

1. Outline the new Glass ionomer cements
2. Illustrate the modes of presentation
3. Demonstrate the manipulation of GICs
4. Discuss the salient properties and performance of the GIC types
5. Demonstrate the applications of GICs

3.3 Learning outcomes

	For Dental amalgam alternative restorative dental materials I: Glass ionomer cements; 1.0 Give examples of the new types of glass ionomer cements that emanate from the modifications. 2.0 Manipulate and use GICs with ease 3.0 Describe the developments, respective properties and appropriate indications of GICs 4.0 Appreciate thefuture research direction in the GICs

3.4 Modifications of glass ionomer cements

In this section we will classify the available categories of GICs that have emanated from concerted research and development in this group of dental materials. You can attest to the fact that GICs have a unique place in dental practice and therefore they cannot be ignored in the dental amalgam phase down process. Before outlining the set of GICs think through the following question;

	**In text question** What should a material demonstrate to be regarded a GLASS IONOMER CEMENT per se? What are GIC related dental materials?

A glass ionomer cement is a dental material that undergoes a significant acid base reaction between a basic glass and acidic polymer. While a GIC related biomaterial has basic glass and acidic polymer but the setting reaction is a polymerization reaction with minimal acid base reaction after setting. GIC related biomaterial include the compomers and giomers as we shall discuss towards the end of this chapter.

In Figure 3.1 you find the classes of GICs, which we will discuss each type briefly in the subsequent sections.

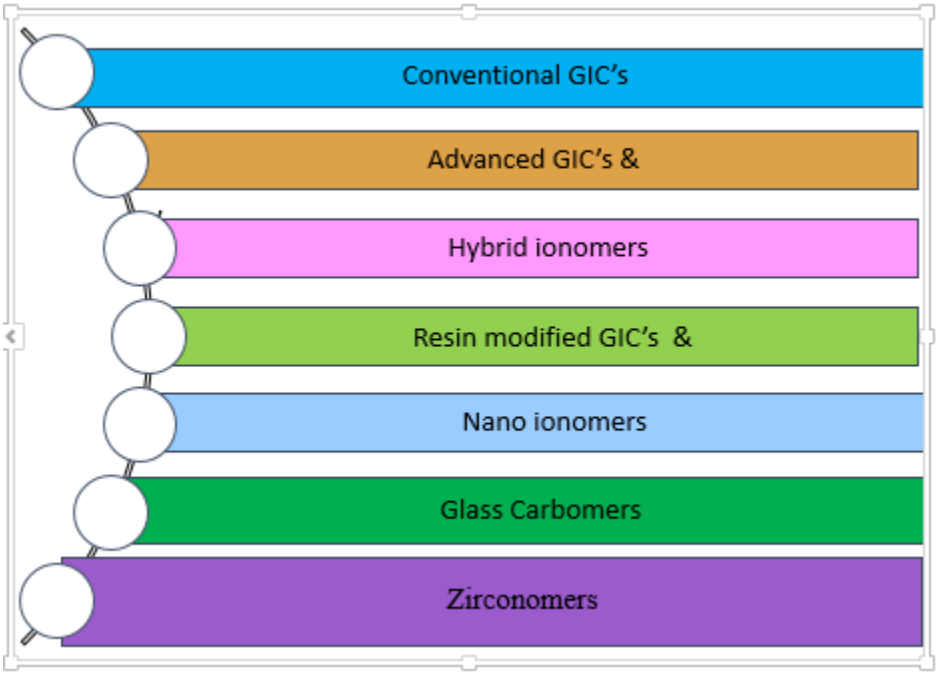


Figure 3. 1 Classification of Glass ionomer cement modifications

In this training we will discuss the novel categories types of GICs, but first we will briefly review the conventional GICs.

3.5 Conventional glass ionomer cements

These materials meet the specifications of a typical GIC. As presented in Table 3.**1**early properties were characterized bysome key advantages that could not be ignored. GIC was first described by Wilson and Kent in 1972.[80]

Table 3. 1 Salient advantages of GICs and disadvantages of early products

Advantages[80,81]	**Disadvantages** [82]
Chemically bond to tooth, Release recharge and re-lease fluoride Similar coefficient of thermal expansion to that of the tooth Biocompatibility	Poor strength, slow development of strength Low wear resistance, Opaque affecting hence poor aesthetics Sensitivity to moisture during setting

Their salient properties generated a lot of excitement. However, they could only find use in low-stress bearing areas of the mouth, class V and III restorations.Since the first GIC Aluminosilicate polyacrylic acid (*ASPA)*in 1976[83], a steady improvement has occurred introducing novel modifications.

Today's conventional GICs have seen improvement of the listed disadvantages, however their flexural strength, aesthetics and wear resistance is less than that of DRCshence contraindicated in large restorations.

	Take Note ❖ Glass ionomer cements presented in five modes; i. Powder & liquid bottles ii. Capsulated powder and liquid iii. Glass powder with freeze dried polyacid and distilled water iv. Paste v. One paste Figure 3.2.

Figure 3. 2 Presentation modes of GICs

In appendix I can view the available GICs in the Kenyan market, as a country we are privileged to have the entire range of products.

Before we conclude on this brief of conventional GICs let us look at tips in easy handling of these materials. Although with experience manipulation can be or is usually autopliloted whether by the dentist or the dental surgery assistant, it is a better option to use manufacturer's scoops to proportion the powder for best results. Apply a tooth surface conditioner (10% organic acid/constitute 25% strength of the liquid) see ***4.2.3.1.***

Take Note

- A well-mixed glass ionomer cement for restorative lump should have a glossy surface. While a mix for luting should string 3-4cm on lifting with a spatula. A well-mixed GIC is easier to handle.

We will proceed tooutline the myriad applications of GICs[84], due to the versatility of these materials it is wouldn't be surprising if over your practice time you have discovered additional uses.

Indications

i. Lining
ii. Luting
iii. Permanent restorations deciduous teeth
iv. Permanent restorations in class V, III, in permanent dentition
v. Temporary restorations
vi. Root filling
vii. Core build up
viii. Sandwich restorations
ix. Root Coronal seal and
x. Root end fillings

Contraindications

i. Class IV restorations
ii. Permanent restoration in high stress bearing areas.
iii. Large cavities that involve cusp replacements
iv. Direct veneers

Figure 3. 3 Indications and contraindications of conventional GICs

3.6 High viscosity/advanced glass ionomer cements – used in ART restorations

As the name suggests this type of GIC is an optimised conventional GICs developed after resin modified GICs. Its' development was driven by a WHO directive in 1990's, in quest for a dental material with properties that rival with those of RMGICsfor use in areas without electricity and running water[85]. Although their target application was ARTin resource constrained regions they are used worldwide. Advanced GICs are also termed as Condensable/packable or highly viscous GICs. One of the key differences between conventional and advanced GICs is the rapid setting reaction. Thanks to the modification of shorter polymer chains, reduced glass particle size and acid pre-treatment of the glass.

3.6.1 Examples of high viscosity GIC products

We can rightly appreciate that the objective of developing an optimised GIC for use in resource constraint areas was met with the addition of advanced GICs to the GIC dental biomaterials group. Though not a vast number of products these materials are used widely globally including non-resource constraint settings. Opportunely, they are available in the Kenyan market, see some typical examples Figure 3.5.

Figure 3. 4Advanced glass ionomer cement products

3.6.2 ART restorations and fissure sealants

Powder liquid versions can be used in areas without running water and electricity where a biological cavity is prepared with use of hand instruments.[86]The material is subsequently mixed and applied in bulkusing thumb pressure to pack the material in the cavity and fissures**Figure 3.5.**

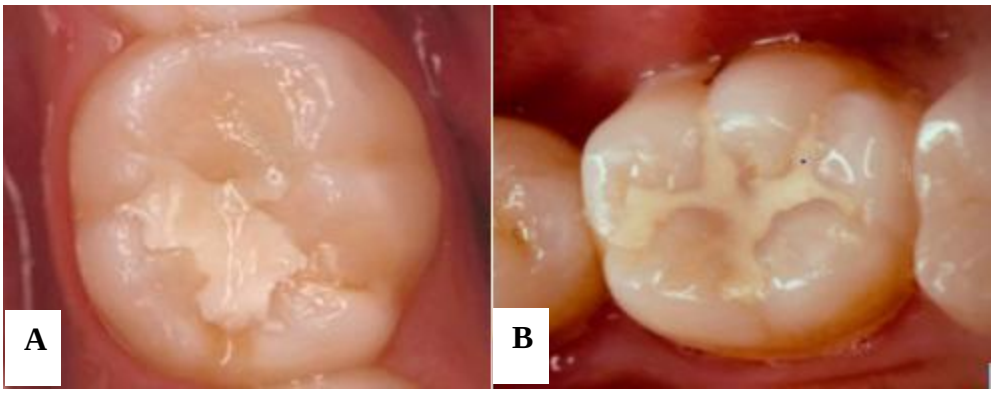


Figure 3. 5 An ART restoration A and an ART Pit and fissure sealant B

	**In text question** Are condensable GICs indicated for high stress bearing areas like marginal ridges and large restorations in posterior permanent teeth? How about in restoration of the deciduous dentition?

Due to the properties presented in Table 3.2 these materials should be applied insmall moderate to low stress posterior restorations in permanent teeth, the moderate to high failure rate after 3 and six years has been recently reported studies[87,88].Some studies however report equivocal performance of advanced GIC with DRC's and dental amalgam[89,90]. Comparatively, class one restorations have higher survival rates; 10.1% compared to multiple surface restorations 56.4% Hilgert LA *et al*[91]On the contrary they are suitable for restoration of all types of cavities in the deciduous dentition except anteriorly due to lack of optimal translucency. Newer versions have multiple shades, however these are few. e.g. Fuji 9 FAST Figure 3.7.

Figure 3. 6 Novel advanced GIC with multiple shades for aesthetics

Table 3. 2Advantages and disadvantages of Advanced GICs

Advantages	**Disadvantages**
i. Chemical bonding ii. Release recharge and re-lease fluoride iii. Condensable iv. Rapid hardening and can be finished v. Improved wear resistance vi. Low solubility vii. Decreased moisture sensitivity	i. Inadequate translucency (aesthetics) ii. Moderately polishable iii. Limited longevity iv. Depth cure akin conventional DRCs

	**Take Note** ◈ The use of advanced GIC's in ART brings on board, higher patients' comfort, low operator stress, low patient anxiety, no indication for local anaesthesia, cost effective and superior tooth conservation[89].

3.6.3 Glass hybrid – the nano-filled resin coated glass ionomer cements

In the previous section, advanced GICs emerged from research that endeavored to improve the setting reaction and maturation rates of the cement. Though successful the properties still fell short of the requirements for posterior applications in permanent teeth. We can say that the glass hybrids (GH) took the same research direction and goal to further improve the properties this time within the advanced GICs.

The glass hybrids are are essentially advanced GICs with a light cured nano-filled resin-based coating agent.[92]The GIC material sets by acid base reaction, while the resin coat is light cured. Some of the glass hybrids are presented in Figure 3.8.

Figure 3. 7Glass hybrid – a resin coat added to advanced GIC type

	**In text question** What is a typical composition of a resin coat? Is the resin coat effective in improving properties of the advanced GICs?

A resin coat consists of a resin matrix with 10-15% colloidal filler and filler dispersion technology preventing agglutination Table 3.3

Table 3. 3The GH resin coat constituents

Constituent	Percentage by weight
Methyl methacrylate	40-50%
Urethane dimethacrylate	30-40%
Colloidal silica	10-15%
Camporoquinone	0.09%
Phosphoric acid monomer	1-5%

Resin coats laminate and toughens the material by the following[93].

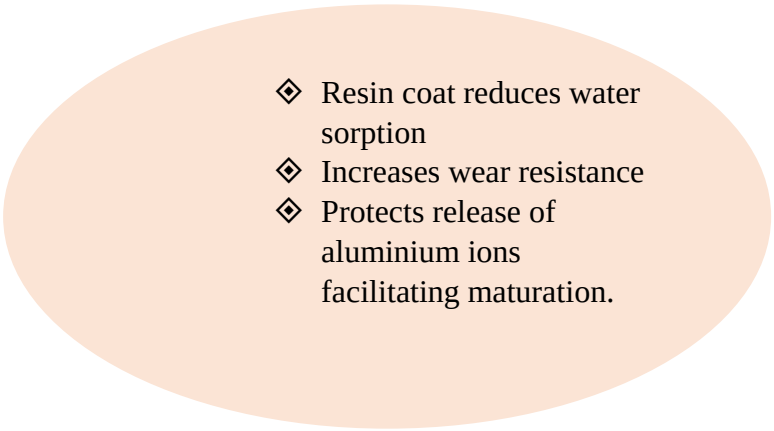


Figure 3. 8Properties brought on board by the resin coat

Glass hybrids are suitabledental amalgam alternatives in class one and average sized class II's, however clinical trials on these materials are under way. Some manufacturer's indications for both materials limited the cavity size to small occlusal cavities with an isthmus size of 50 % of the buccal-oral intercuspal distance. Whereas in-vitro studies report improved properties, clinical success is influenced by proper manipulation, cavity size and time factor.[93]

Selection of materials is key also in an evaluation of resin coats, Voco Varnish and Equia Coat are more successful than Riva Coat Clinical. performance of Equia Forte was better than Riva.[94,95]

3.7 Resin modified glass ionomer cements

This section ushers to discussion on a unique user friendly modification of glass ionomer cements also termed as light cured glass ionomer cements that you are familiar with. Since the light cured glass ionomer cements have been in use since 1980's, I will do a brief review. They were developed by addition of resins; UDMA, HEMABis-GMA added to PAA or pendant methacrylate groups that attached to PAA.[96]These materials provide a command setting process that commences on photocuring of the mixed cement, and can be finished immediately after insertion [97].The rapid attainment of strength, and the slower and continuous acid base reaction further strengths the cement and improves its aesthetics as well. However, although resin modified GICs exhibit the salient properties of conventional GICs namely; chemical adhesion and fluoride release, their mechanical properties still fall short of requisites for application in high stress bearing areas. Let us summarise the properties and applications before we proceed to discuss nanoglass ionomers a further modification of RMGIC.

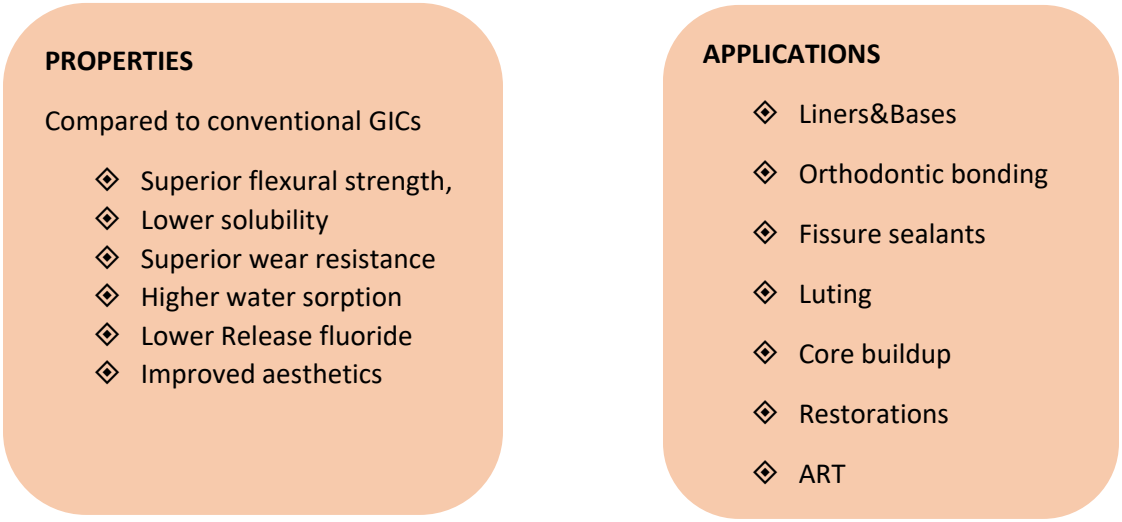


Figure 3. 9Properties and applications of resin modified glass GICs

	Take Note ◈ When we compare resin modified GICs to DRCs, they are more brittle, poses inferior flexural strength and aesthetics.

Some of the products include a chemically activated polymerization reaction and are termed as tri-cure. RMGIC's suitable for class II primary molar restorations. Figure 3.11A presents some practical products in use today

Figure 3. 10 A: Tri-cure RMGIC B: Dual cured RMGIC

3.7.1 Nano glass ionomers

Modification of conventional and RMGICs by reduction of filler size to 0.1-100 nanometers, and adding silane treated nano-sized bioceramic fillers generated this category of glass ionomer cements[98]. The modification brings on board increase in elastic modulus and compressive strength. However, they are technique sensitive, have higher creep which causes higher marginal failure than conventional GIC's and RMGIC's[99].

It is presented in an easy to manipulate paste system andprimer for dentine pre-treatment. Can even etch with 37% Phosphoric acid!

View the properties demonstrated by the current commercially available product resented in Figure 3.12

.

- Less occlusal wear than RMGIC but more mild marginal defects
- Chemical bond strength similar to that of conventional GICs
- Flexural strength and fatigue limit of Ketac nano lower than conventional GICs.
- Marginal discolouration> than RMGIC's
- Surface roughness and the hardness less than that of DRCs ref mechanically same as no –ves or +ve surface mechanical properties
- Less fluoride release than conventional GICs but comparable with conv' RMGIC

Figure 3. 11 Performance of nano glass ionomers[65,99,100]

It is commercialized as Ketac Nano Figure 3.13.

Figure 3. 12 The nano ionomer glass ionomer product

Less occlusal wear but more mild marginal defects than those with regular RMGIC, but these were of limited clinical significance. Nano-filled RMGI may not be better than conventional RMGI; its wear resistance deteriorates with time, and it has low bond strength to dentin[101].

Nano glass ionomers should be correctly indicated, proper isolation and properly manipulated to assure optimal properties.

They are clinically used for Class I temporary restoration and sandwich restoration, core build ups in permanent teeth and in the restoration of deciduous teeth.Nevertheless nano glass ionomers are in early stages of clinical use in dentistry.

As we can deduce from the properties of nano ionomers, there are the same as conventional GICs.

	**In text question** Which is the future trend in GICs' research? What innovative modifications are expected to be added to the range of existing GICs

Research continues to bring on board enhanced bio-smart properties, addition of nano-sized bioceramic glass under research, use nano-hydroxyapatite (nHA) and nano fluorohydroxyapatite (nFHA).

3.8 Zinc reinforced glass ionomer

Welcome to yet another modification of conventional GICs the Zinc reinforced glass ionomer (ZRGIs). In these materials, the glass filler is modified with zinc ions,a novel acrylic acid copolymer and decreased particle size.

It has higher flexural strength, fracture toughness and compressive strength compared to conventional GICs[102]. It is speculated that the formation of zinc polyacidcomplexes in the set cement, and the small particle size confers the strength. However

Therefore as alternatives to dental amalgam, ZRGI find application in class I, class III, and class V cavities, high stress bearing cases, cases requiring build-up, and in comprised clinical

situationswith better longevity than conventional GICs. The increased high flexural strength and the absence of visible surface defects like crazing and voids increases longevity of restorations.[103]

	Take Note ◈ Zinc reinforced GIC have no improvement in microhardness and has greater surface roughness when compared to other GIC's. ◈ While notable advantages are improved fracture toughness and abrasive wear resistance.[104]

Figure 3. 13 A Zinc reinforced GIC product

3.9 Zirconia reinforced Glass ionomer cement - White amalgam

In the quest to further strengthen GICs, zirconia oxide filler particles added to conventional GIC chemistry.

This modification improved compressive and diametral strength higher than conventional GICs and comparable to dental amalgam[105]. Higher fluoride releasethan conventional GIC, RMGI and Compomers hence anti cariogenic[106]. However, microleakage lower that dental amalgam and nevertheless it is a suitable dental amalgam alternative however they are opaque white colour.

Figure 3. 14 Zirconia reinforced GIC, Shofu Inc., Japan

3.10 Glass carbomer cements

So far we have appreciated that the modifications of GIC's target to improve the properties for improved performance. The glass carbomer cements (GCC) add to the nano-modified cements, they are composed of nanosized hydroxyapatite/fluoroapatite crystals.

The GCC cements have improved compressive strength and wear resistance, however the overall properties of glass carbomer appear to be slightly inferior to those of the best modern conventional glass-ionomers, they are more brittle and less strong.[107]

Flexural strength = to that of advanced Fuji IX (GIC)

Reduced moisture sensitivity, higher microleakage, reduced knop hardness and bond strength[108],

May have GCP gloss which is a modifiedpolysiloxane.

Durability of the material in clinical use is not yet known.

Figure 3. 15Carbomer cement a GIC modified by nano hydroxyapatite and seal for final coat on the cement restoration. (GCP Dental of the Netherlands).

Figure 3. 16Carbomer cement gloss and resin coat technology

MODULE III

4.0 LECTURE FOUR: PRACTICAL DEMONSTRATION MANIPULATION TECHNIQUES OF DENTAL AMALGAM ALTERNATIVES

4.1 Manipulation of DRC's

The application of direct DRC's is indicated in all cavity types except in cusp replacement and subgingival cavities. It is a universal restorative material, additionally applied core build up and preventive restorations.

4.1.1 Armamentarium

Most of the hand instruments' working ends are coated with titanium nitride, while others may be gold coated or simply highly polished stainless steel. The following instruments are required;

- Ball burnisher small/medium & medium/large
- Condenser and paddle
- Posterior contouring instrument small & large
- Blades
- Rubber dam kit
- Matrices; sectional, circumferential 0.038mm thickness
- Wedges –ordinary and ± fender wedge type
- Curved mosquito heamostat forceps
- Light curing unit - ≥ 600mW/cm^2 irradiance light.
- Radiometer
- Polishing stones, discs, paste etc.

Figure 4. 1 Instruments utilised in placing resin composite restorations

	**In text question** Is it mandatory to have a radiometer and the curved mosquito heamostat forceps?

The light intensity level is crucial to frequently check the light output, if optimal degree of cure is to be accomplished. Nevertheless this can in-built in light curing units or co-owned

between practitioners. With regard to the curved mosquito heamostat forceps it is used to insert and remove wedges and remove the matrix after setting of the restoration. Any artery forceps can be utlilised.

4.1.2 Materials

a. Etching gel thirty seven percent phosphoric acid
b. Bonding agent
c. Conventional DRC
d. Bulk-fill resin composite

4.1.3 Steps by step restorative procedure and manipulation of conventional and bulk fill resin composites

In this section we will be skewed towards handling of the DAARS for quality fillings leaving the clinical procedures as you already know them. Also since a class I is surrounded by axial wall and presents an easy to isolate and fill up process, this section will delve into the proximal restoration procedure.

- Prepare the operatory field, DITTO
- Pre-wedging

The 0.038mm matrices are very thin and easily deform during placement, hence the need to establish adequate interdental space to allow their placement. This is best done before cavity preparation and following can be used to achieve this a wide wooden wedge can be placed with a curved mosquito haemostat forceps. In the absence of this any other artery forceps can be used, the latter works for me too. Additionally, afender wedge which is a protective wedge with a metal fin Figure 4.1 Can also be used. Prior separation can also be achieved with orthodontic separators.

- Cavity preparation DITTO/ uphold minimally invasive principles
- Placement of the matrix

You will agree with me that achieving a proximal contact is a key requirement in a class II restoration. It is mandatory that the matrix is placed without pressure, in case the space is not

enough a wider wedge should be placed to separate the teeth further. In the event the interference is located occlusally use of a plastic instrument can be used.

The matrix is placed and the wedge secured, subsequently the matrix is adapted; in the case of circumferential matrices it is tightened, whereas if it's a sectional band a ring is inserted see Video.

	**Take Note** A water tight compartment should been ensured with the matrix band isolation. Use of rubber dam is advocated. However some studies have shown that behaviour of restorations done under effective isolation with cotton rolls and aspiration did not significantly differ from those placed using rubber dam isolation in a ten year study. A Raskin et al[109], Cajazeira M R et al[110]

- Etching – Depending on your selected bonding agent system this may be a separate or combined with primer and adhesive. If separate remember to etch fluorosed teeth longer at least 60 seconds.
- Bonding – The wet bonding technique is efficacious, rub in your selected universal adhesive wait for the solvent to evaporate or lightly air dry and polymerise, see variations on curing timing in the following section.
- Manipulation of the resin composite

To build up the restoration to tooth morphology, find the various techniques that can be employed in the following in sections 4.1.3.1 and4.1.3.2.

4.1.3.1 Conventional DRCs

Incremental build up 2mm thick layers; Vertical, Horizontal, oblique or U-shaped layering. The method is also termed as Composite-Up layering technique. Light cure each layer for 20 seconds.

4.1.3.2 Bulk fill resin composites

Bulk fill resin composites have succeeded in overcoming the time-consuming composite layering technique. Find two options presented in Figure 4.3.

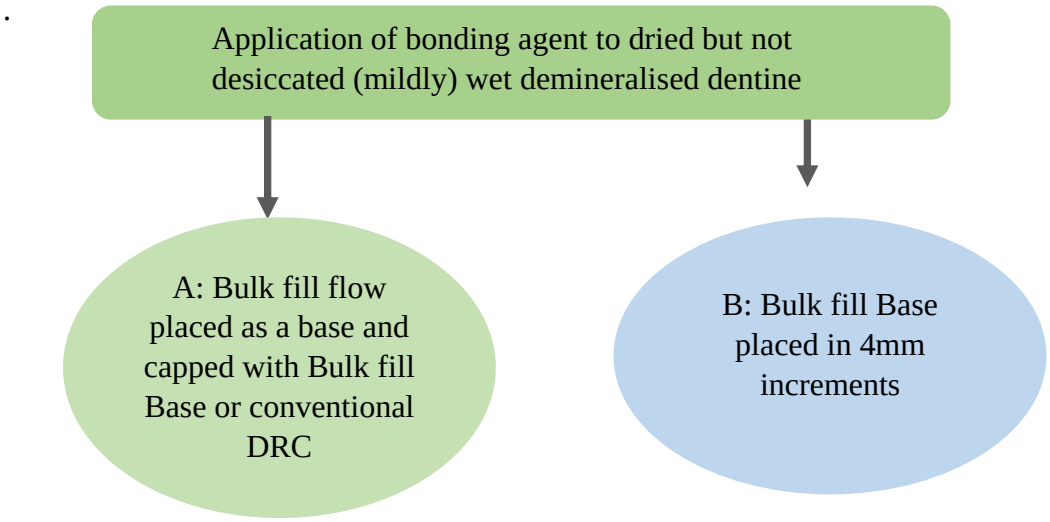


Figure 4. 2 Two manipulative options for bulk fill composites

As you adapt the BFRC in the cavity assure no more than 4mm thickness. You can measure the thickness of the layers with a periodontal probe.

	**Take Note** For ease of release of the resin composite from the plastic instrument into the cavity, have the material contact a small surface area of the instrument. This is particularly helpful when using the standard instruments.

Methods of building up the DRCs in a class II

- In one technique, the proximal is restored transforming the cavity into a class I. The residual cavity is filled via 2 mm for conventional DRCs and 4mm for BFRCs incremental layers and each light cured for 20 for seconds.

- In another technique for the BFRCs the cavity is filled with 4mm layers from cervical to occlusal in one go. All the walls build up simultaneously, also referred to as **Fast-modelling bulk technique**.

Both techniques are efficacious, however the latter is characterized by smaller size of defects at the margins.

Co-Blend application technique for bulk fill

This technique has been put forth where the DBA and the 4mm bulk fill is cured simultaneously.

	**Take Note** Since the depth of cavities can range from xx to yyy, execute additional light curing after removal of the matrix band for a further 10s, occlusal, **buccal and lingual/palatal.**

- Finishing and polishing

  Use of high speed fine diamond burs (red and yellow colour band diamond burs), sof-lex discs and yellow composite polishing rubbers to finish the restoration.

4.1.3.3 Bulk fill alkasite

One of the smart composites in the alkasite category that was launched and is available for clinical use is Cention N. We will describe the manipulation of bulk fill alkasites basing on it. Isolation technique employed for DRC in 4.3.1.

Manipulation of bulk alkasites – powder and liquid

The cavity geometry pre-determined by carious lesions

The materials can be applied to the tooth with a bonding agent adhesive or without an adhesive.

The powder and liquid is manipulated as follows;

i. P:L 1 scoop to 1 drop (wt. ratio 4.6:1)
ii. Mix for 45s – 60 s
iii. Working time 2 minutes 30 seconds
iv. Sets in 4 minutes
v. Bulk application for the light cured version while the self-cure has unlimited depth of cure.
vi. condense
vii. Remove excess material with a fine grit diamond
viii. Polish with soflex discs on the same sitting.
ix. The same self-cure material has a dual setting reaction when light. Hence the bonding and light curing is a variation for the operator.

Figure 4. 3 Manipulation of bulk alkasite (*Cention N*)

4.2 Manipulation of glass ionomer cements

The indications of GICs include definitive restoration of all paediatric cavity types, class III and V in the permanent dentition, temporary restorations in class I and II, core build ups, endodontic coronal seal, deep cavity margin elevation among many others.

The armamentarium described in Figure 4.1 find application in the GIC group of materials.

4.2.1 Materials

Glass ionomer cements are both available as and manually mixed powder/liquid and encapsulated powder/liquid containers. Select radiopaque products for permanent restoration, lining and basing not all GICs are radiopaque.

a. Glass ionomer cement
b. Organic acid conditioner 10-25% polyacrylic acid
c. GIC Surface coat for the freshly inserted restoration
   i. Emollients – e.g. petroleum jelly
   ii. Solvent-based waterproof
   iii. Light-cured resin-based coatings

4.2.3 Steps by step restorative procedure and manipulation of glass ionomer cements

The glass ionomer cements are versatile materials. Unlike DRCs they are moisture tolerant and do not require rubber dam isolation. Due to their inherent property of chemical bonding to the enamel and dentine neither etching with 37% nor adhesive bonding agent are required.

When restoring a definitive class II restoration, the matrix placement procedure described in 4.1.3 is executed.

4.2.3.1 Manipulation of advanced glass ionomer cement

Cavity is conditioned with GIC conditioner for 10-25 seconds, surface is washed and dried. The conditioner modifies the smear layer and improves adhesion to enamel and dentine. Find the sequential steps in handling of GIC are presented.

a. Condition the tooth to increase surface energy and wettability
b. Shake powder bottle and tap liquid bottle
c. Dispense level spoon full powder measure(s) and divide into two halves.
d. Hold the liquid bottle at 90^0 todispense NEAT drop(s)

e. If water settable ensure that the drop is NEAT too.

f. Use agate spatula, rapidly fold in half of the powder for 15 seconds, and add the other half – MIX OVER A SMALL SURFACE AREA finish in 30 seconds.

g. Mix should be glossy!! apply Wait for the surface to be dull then to condense

h. Once set in 6 minutes cut off gross excess material using a sharp instrument.

i. Polish with soflex discs, tungsten carbide burs or Arkansas white stones

j. Apply varnish or emollient

Lowest roughness of GIC surfaces was found after treatment with the Mylar strip, which as you would agree with me is not always practical![111]

4.2.3.2 Resin modified glass ionomer cement

The manipulation of RMGIC is more user friendly than that of Conventional GIC's, due to control of working time by the operator.

The cavity is conditioned as described in 4.2.3.1 while some RMGICs have primer components like Vitremer. The mix is placed in bulk in the cavity and light cured. Capsulated, auto-mix and ready-to-use resin modified GIC versions are also available for use.

4.2.3.3 Manipulating of glass hybrid – the resin coated Glass ionomer cement

As you may have realized Equia Fill/Forte has become a household name among alternatives to dental amalgam. It is the most used and researched glass hybrid material – an advanced GIC with a resin coat.

In manipulating the glass hybrid in which case we will use Equia for the demonstration, we have to appreciate the short setting time of 2.30 minutes. Let us look at the manipulation technique.

- +- condition the cavity with weak organic acid
- Dry prepared tooth surface
- Shake the capsule or tap on a hard surface to loosen the powder inside

- Push the plugger in and activate the capsule for 2 seconds.

e. Triturate immediately for 10 seconds

f. Light pressure packing after 45 seconds, the working time is 1.15 minutes

g. Timings of condensation are key video.

h. Allow to set 2. minutes 30 seconds

i. To remove the matrix band slide it out horizontally

j. Finish restoration with water cooled extra fine (yellow band) diamond high speed bur

k. Apply resin coat

l. Photo cure for 20seconds

m. Soft food for 48 hours

Figure 4. 4 Glass hybrid *(Equia Forte*) restorative procedure

4.3.1 Pit and fissure sealants

The indications of PFSs are well known, we will however allude to a few variations that are executed in manipulation of the most commonly used material, resin based fissure sealant types. To effectively prevent the initiation and progression of dental caries correct manipulation and follow up review is key.

4.3.1.1 Self-etch fissure sealants

As the name suggests, after tooth cleaning with pumice, the PFS is dispensed agitated to remove any air bubbles and photo cured.

4.3.1.2 Manipulation of resin based pit and fissure sealants

Standard application of PFS involves etching and its' application. As a variation bonding agents have been used on etched enamel before application of PFS. However, studies show conflicting results with regard to advantage of applying a bonding agent.

4.3.1.3 Manipulation of ART pit and fissure sealant

Manipulated the advanced GIC as outlined in 4.2.3.1, with restorative mix characteristics. The material is then applied a cleaned tooth and adapted using thumb pressure. Upon setting adjust the occlusion.

MODULE IV

5.0 LECTURE FIVE

DENTAL CARIES PREVENTION AND USE OF ALTERNATIVES IN DENTAL AMALGAM PHASE DOWN

5.1Introduction

In the first lecture of this training programme we unpacked dental caries prevention as one of the key measures that constitute the dental amalgam phase down process. It is listed as the first measure and it calls for "setting national objectives aiming at dental caries prevention and health promotion thereby minimizing the need for dental restoration".In the long run as countries phase down the use of dental amalgam and embrace oral health promotion and prevention of dental caries, the goal is to reduce the number of restorations altogether, which has culminated to a decline in prevalence of dental caries.[112]

In this lecture we will take a departure from discussing restorative function of dental amalgam alternative restorative dental materials to focus on disease preventionproperties; inhibition of biofilm adhesion, promotion of remineralisation of hydroxyapatiteand sealing of early enamel carious lesions. In lectures two and three, we discussed resin composites and GIC' respectively, we will proceed to discuss modifications of these materials, and their subsequent manipulation in dental caries prevention and arrest processes. With the utilization of this special group of alternative materials, micro-conservative restorations have been added to the range of modern restorative procedures, enjoining DAPD to the minimally invasive dentistry. Therefore, DAPD has translated to abandoningthe largely surgical approach in the treatment of dental caries using the traditional dental amalgam restorative model, andtaken a paradigm shift towards use of adhesive dental amalgam alternatives.

5.2 Learning objectives

1. Outline the position of dental caries prevention in dental amalgam phase down
2. Discuss the use of dental amalgam alternative restoratives in new philosophy of caries management for the modern age.
3. Discuss the formulation, properties and manipulation and performance of biomaterials use in caries prevention.
4. Discuss the formulation, properties and manipulation and performance of biomaterials used dental caries arrest and micro conservative restorations.

5.3 Learning outcome

	For dental caries prevention and use of alternatives in dental amalgam phase down; 1. Anchor dental caries prevention moment in use of DAARs in DAPD. 2. Routinely include management and follow up early carious lesions. 3. Manipulate novel fissure and use DAARs in dental caries prevention. 4. Indicate and use of DAARs in non-surgical ultra conservative approaches

5.4 Dental caries prevention and DAPD in modern dental practice

Welcome to this section in which we recast the position of dental caries prevention in dental practice today. Before that, it is worthwhile to remind ourselves of the eclipsing dentistry dominated by largely restorative treatment (surgical approach) where dental amalgam took a centre stage and saving billions of posterior teeth. Let me pose a question to those who may not have made the shift, are you ready to shift to non-operative dental caries management?[113]It is not surprising that in modern dental caries management the "drill and fill" approach may still remain predominant in some settings; private, public and dental schools. Thus, neglecting to fully address the underlying disease process and thus negating the benefits of the range of biomaterials available for caries prevention and early caries arrest.[114]

We can rightly appreciate that the demineralization-remineralisation process of caries development concept is the crux of modern-day caries management[115]. As we shall discuss in the successive sections of this lecture, newly developed bio-smart pit and fissure sealants release release Ca^{2+} and PO4- that supersaturate promote hydroxyapatite crystals at the remineralisation

phase of the dental caries cycle. The ability to for the materials to sense decent in pH, takes intelligence of these biomaterials above the properties of glass ionomer cements.

The world faces a disproportionate global dental caries burden that is decreasing in developed countries and increasing in low and middle income countries[116,117]. As at 2017 the prevalence of dental caries in 2^0 Dentition is 2, 301,999, 1^0 Dentition 530, 801 spelling the future need of restorative materials. Dental amalgam phase down process with its' measures of dental caries prevention and increased use of dental amalgam alternatives has catalyzed reduction of dental caries incidence, a welcome step towards a holy grail of a caries free world.

5.5 Dental materials and agents used in dental caries prevention –

As usual we will focus the discussion on novel materials and techniques. In the foregoing section we cited the availability of bio-smart preventive dental materials. Let's proceed and discuss the type and properties of this unique material in the following sub-section.

5.5.1 New Bio-smart pit and fissure sealants: Amorphous Calcium Phosphate based

Prior to commencing on the discussion this bio-intelligent fissure sealant, let us briefly review the performance of this significant group of materials. Most of the dental amalgam alternative restorative dental materials are utilized as pit and fissure sealants (PFSs) with resin composites and GIC being mostly employed to inhibit biofilms from teeth surfaces. There is evidence to support substantial effectiveness of resin based fissure sealants in preventing or controlling occlusal decay compared with no intervention.

Amorphous calcium phosphate based PFSs are resin based sealants that have been modified by adding amorphous calcium phosphate which is a precursor of hydroxyapatite (HAP). These bio-smart material effectively remineralise demineralized human enamel,[118]the mechanism of action is illustrated in Figure 5.2.

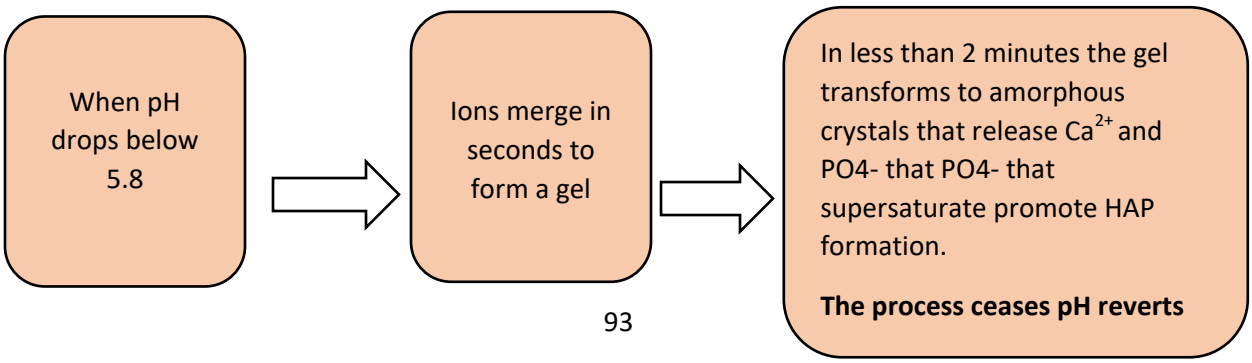


Figure 5. 1Mechanism of inhibiting enamel and dentine demineralizationby bio-smart ACP fissure sealant

There are few brands of the available smart materials with ACP in the market. Figure 5.2 illustration of some.

Figure 5. 2 Two products of bio-smart fissure sealants

Prevest PF is available Kenya (appendix I)

We will now proceed and recap on manipulation of this material. It is manipulated via the conventional PFSs application technique of pumice, etch, application and photocuring. One of the ACP sealants has been evaluated in several studies, as purported, Delivers minerals deeper into the lesion and efficacious than fluoride releasing fissure sealants.

- Inhibit enamel demineralization.[119]
- Aegis – higher surface hardness values.
- Deposits more mineral overall compared to F- releasing materials.[120,121]
- More efficacious than Fluoride containing Fissure sealants[122]

Efficacy of one of the few ACP based PFS *Aegis*™ with regard to retention and inhibition of caries was superior to moisture tolerant type *Embrace Wetbond*™[123]. We will discuss the latter type in a subsequent section.

5.5.2 ART pit fissure sealants

In the previous chapter in section 3.6.1 we discussed advanced glass ionomer cements, theGICs developed for ART most brands are available in the Kenyan market Fuji IX, Ketac Molar. The material finds application like all GICs as we outlined in chapter three, and additionally as a fissure sealant Figure 5.3.

The PFS application is handy in situations where there are constraints of running water and electricity. The attachment of an ART fissure sealant depends on thumb pressure on the pits and fissures, executed while packing a restoration or when indicated on a tooth. ART pit and fissure sealants should be a component of restorations executed in community outreaches and where the first choice resin composite sealant is not applicable. The usage of ART sealants was deemed to be less cumbersome in an outreach setting as observed in this trial. Efficacy? Liu study + other and do a in text question or note

Figure 5. 3 ART Fissure sealant

	In text question How does the efficacy of ART fissure sealant compare with that of fluoride- releasing resin sealant?

Their effectiveness in preventing fissure caries in permanent molars did not differ significantly over 24 month, as observed in a randomized clinical trial study. The ART fissure sealant is a suitable option to be resources for resin sealant placement are not readily available.[124]For instance in the school environment it is simple and straightforward to place ART sealants, there are no equipment or high applicator skills are required. A novel fissure sealant GIC Triage is available in white and pink colour for easy to place sealants

Figure 5. 4 Triage GIC for Pit and fissure sealing

5.5.3Novel Wet bond and self-etching pit fissure sealants

Welcome to this short section about two types of PFSs' modifications that simplify the clinical manipulation technique, serving as suitable alternatives in unique clinical conditions as we will outline.

First, wet bond as the name suggests, are PFSs that easily wet and spread on tooth enamel. They are resin based PFSs with hydrophilic monomers that render them moisture-tolerant resin sealants, however they could not replicate the physical properties usually associated with conventional resin sealants[125]**.** Nevertheless they are applicable in patients where isolation is a challenge. There are few products in the market Figure 5.3.

Figure 5. 5Pulpdent Cooperation, Watertown, USA

Secondly, as the name suggests, self-etching PFShave inherent etching ability, thus simplifying the application of sealants, the etch and rinse stage is eliminated. The first such sealant is *Enamel Loc*which is a resin based sealant with bonding agent moiety 4-methacryloxyethyltrimellitic acid, UDMA, TEGMA, methacrylated phosphoric acid esters, photo initiators, titanium dioxide and fumed silica. It contains no Bisphenol A, Bis-GMA, or BPA derivatives. Similar to the wet bond PFS they are suitable alternatives to the conventional resin based that require etching, in clinically challenging clinical situations like dental phobia, disability and behavioural problems among children and geriatric patients. A current commercial product are presented in Fig 5.6.

Figure 5. 6Premier Dental Products Co. Plymouth meeting, USA

	Take Note ◈ Conventional resin composite sealants have higher bond strength than self-etching sealants. However the microleakage rates were similar in the two types of sealants, which is crucial in preventing

	secondary caries.[126]

5.3.4 Fluoride releasing PFSs

The superior retention of resin based sealants over glass ionomer cements contributes to their efficacy as it seals off micro-organisms. Fluoride-releasingresin based PFSs were developed to bring on board the advantages of fluoride in these materials. Nevertheless their effectiveness was found to be similar to that of glass ionomer cements in a two year study.[124,127]

Burst into school age children dc prevention and PFS SEALING

Colour changing sealants what causes colour to change?Performance opaque added titanium oxide. Helioseal white changes to green

Figure 5. 7 A fluoride releasing smart (colour change)

	**In text question** How can Kenya take advantage of PFSs to prevent the most affected part of the tooth by dental caries? Your thoughts?

Let me share my thoughts, the message should be shared to the general public and the process implemented, making use of PFSs that are applicable in all parts of the country.

Firstly, MOH can integrate fissure sealants in the school programme. Glass ionomer cements based and autopolymerising resin sealants can be targeted for use. Thenengagement and train the clinical oral health officers. A short training course particularly with the autopolymerising type for swift application to assure optimal penetration and prevent failure due to limited working time usually 1-2 minutes. [128]Secondly all dentists to adopt it as a standard of care to prevent pit and fissure caries where indicated, patient education is key to take us to that level. Obviously this should be accompanied by overall dental caries prevention message.

5.6 Minimally invasive approaches for dental caries arrest

This section ushers us to discuss dental materials that aid in attainment of the **dental caries arrest** and **prevention** a step towards minimizing the need for restorations as targeted by the dental amalgam phase down measure number 1. You will recall that in the forgoing two lectures, the available direct dental amalgam alternatives we covered adhere to the tooth tissue; GICschemically and DRCs micromechanically. A unique property that makes them applicable in ultra-conservative restorations; dental caries preventive, early dental caries arrest and restoration repairs. Additionally, the cyclic insidious dental carious disease process gives room for intervention at different levels of the process with a goal to stop the process, thus conserving sound tooth structure.

Delayed intervention in caries processes that can be monitored and smaller-sized preparations restricted to removal of carious tissue are the other of MID which are possibilities with DAARs. Understandably, since the MID replaces the engraved GV black cavity preparation principles, countries are at different levels in making this shift. With regard to use of dental amalgam, DRCs is replacing dental amalgam for restoring primary caries lesion at a very high rate and in some countries amalgam becoming almost extinct.[129]

5.6.1 Silver Diamine Fluoride

Let us start with a brief discussion of silver diamine fluoride (SDF) which has increasingly become appreciated in dental practice today. It is a colourless topical alkaline solution with a pH of 10-12, containing silver and fluoride, which forms a complex with ammonia.

Although SDF is available in low and high concentrations;10%, 12%, 30%, or38% w/v $Ag(NH_3)_2F$, research findings reveal (38% w/v Ag $(NH3)_2F$, 30% w/w) to more efficacious in arrest and prevention of dental caries.[130]The silver is antibacterial, while silver and fluoride interact synergistically to form fluoro-hydroxyapatite, thus hardening the teeth preventing further demineralization[131].

Silver diamine fluoride topical though non-technique sensitive should black staining due to formation of silver compounds in a major adverse effect that should be limited to the area of application strictly. SDF is contraindicated in patients allergic to silver and in cases of break of the stratified squamous epithelium like in desquamative gingivitis or mucositis. It is effective the following clinical conditions.

- Incipient carious lesions on permanent teeth
- Carious deciduous teeth in patients BUT NOT INVLOVING THE PULP
- Proximal lesions outer half of enamel (E1) and inner enamel (E2), remineralisation occurs and the radiolucency disappears!
- Interim Rx for secondary caries on geriatrics or debilitated patient

Figure 5. 8 Indications of SDF

The black staining of untargeted tissues has to be avoided.

	**Take Note** In case of accidental staining with SDF, a salt slurry or H_2O_2can be used to clean although total eradication of the stain in not always achievable. For enamel staining 20% glutathione has been shown to be efficacious. An additional agent is a saturated solution of potassium iodide immediate to the staining.However it is contraindicated in pregnant women and in the first six months of breastfeeding due to risk of overloading the developing thyroid

	gland with iodine.

Figure 5. 9 SDF brand available in Kenya

SMART

5.6.2 Resin infiltrant materials

Resin infiltrants fit in the category of dental amalgam alternatives that intervenein the dental carious process via a micro-invasive infiltration technology. The material is essentially a resin with high penetration coefficient (273 cm/s compared to normal adhesive 31cm/sec. The most efficacious types are based on TEGMA and currently one commercial product *Icon*, (DMG, Hamburg, Germany) is available Fig 1.

Figure 5. 10 Resin infiltrant product

	In text question What is the mechanism of action of resin infiltrant materials?

The principle of resin infiltration for caries arrest is to occlude the porosity formed during the caries process and prevent pathways for acid to further dissolve the tooth structure.[132]Enamel lesions undergo remineralisation in non cavitated lesions Additionally, it gives a colourless optical o illusion for instance to white spot lesions in enamel thus improving aesthetics[133]. The RI are efficacious if hypoplasia is <800µm deep.

Before we describe the manipulation of RIs let us outline the indications. They find application in management of smooth surface non cavitated incipient caries in permanent teeth;

i. Applicable in posterior proximal and anterior demineralized (white spot) lesion[134]
ii. Demineralisation confined to outer half enamel (E1), inner half enamel (E2) to the outer third of dentine D1emanating from different etiologies. Caries, fluorosis, developmental hypoplasia, post orthodontics etc.

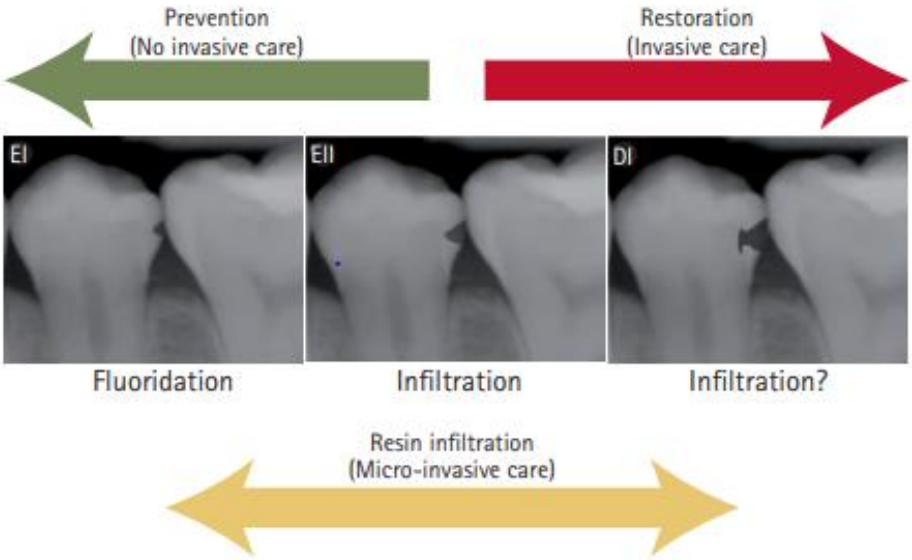


Figure 5. 11Effect of managing E1 and E2

To manipulation resin infiltrantsthe following instruments and materials are required[134,135]

- Separator – to temporarily open up the interproximal space.
- Pumice free prophylaxis
- Topical anaethesia – to alleviate pain from the gingiva
- Wedge - to maintain open interdental space
- Applicator tips – to apply the *Icon* etch, dry and resin.
- 15% Hydrochloric acid etch (*Icon* etch, DMG) for 120 s – to elimination of a 58 µm (37 µm) surface layer of enamel. Multiple etching cycles can done as needed.
- Pure ethanol 99% *Icon*-Dry, DMG) 30s – to dry the etched enamel
- Apply resin infiltrant leave for 3 minutes, floss and then photocure for 40 seconds

https://youtu.be/wvOA_x6wBNI

Efficacy of RI in enamel is high lesions 93% success. D1Rate reported Richard C.

5.6.3 Use of dental amalgam alternative restoratives in preventive resin restorations (PRRs)

This third minimally invasive procedure is applied for small occlusal cavities in posterior teeth, mostly2^0 dentition. The technique was first introduced as early as 1905 by Willoughby D. Miller. We can rightly describe a PRR as an extension of fissure sealant that allows for caries arrest with minimal tooth loss. It is a restoration executed when a small discrete cavity exists in a patient in whom delayed intervention is not a consideration, and certainly a not a class I amalgam.[136]PRR can also be applied where dental amalgam/resin composites exist in posterior teeth.[137]Further it is executed without local anaesthesia. Let us proceed to outline the steps;

- Removal of caries via excavation or use of a small high speed bur
- Etching with phosphoric acid or air abrasion and etching
- Bonding agent application
- Restoration of the cavity with resin composite
- Application of sealant in and pits fissures

5.6.4 Dental amalgam alternative restoratives in repair verses replacement of old restorations

In this section we will discuss repair of existing defective restorations a conservative approach,[138]an alternative tototal restoration replacement. The procedure takes advantage of the adhesive property of dental amalgam alternative restoratives to preserve tooth structure thus influence the rate of descent down the 'restorative death spiral'.

As we discussed in lecture one section 1.7, techniques that preserve tooth structure build up towards the overall goal of phasing down the use of dental amalgam to reduce the need of restorations and use of restorative materials. Further, consensus on evaluation of restorations and subsequent management exits.[138,139]

Table 5. 1 Application of DAARs in restoration repairs for tooth conservation where possible[138]

Status	**RECOMMENDED INTERVENTION**
Very minor defects/staining – no disadvantages if untreated	NO TREATMENT
Overhangs, discolouration, roughness, small gaps/pores manageable without adding restorative material except bonding	REFURBISH

Minor defects localized clinically unacceptable	REPAIR WITH ALTERNATIVE RESTORATIVE MATERIALS A MI APPROACH. ± TOOTH PREPARATION
Severe defects where repair is not feasible	REPLACEMENT

5.7 Use of DAARs and shift to Saucer shaped proximal cavities

Before we conclude this chapter let us look at the impact of phasing down the use of dental amalgam to decision making by dentist with regard to cavity preparations in proximal cavities.

	**In text question** Has the shift towards use of dental amalgam alternatives been accompanied by departurefrom traditional retentive amalgam proximal cavity preparation?

Some dentists have progressively abandoned the retentive amalgam proximal cavity design and embraced the "**Caries-removal-only"** technique, aka saucer shaped class II. As reported in a recent study2019, most dentists in Netherlands favoured saucers shaped technique for proximal lesions by 59.1 %.[140]Contrastingly, reported that most commonly used DAAR being DRC though use may not be accompanied by minimally invasive concept uptake.[11,115,141]

5.7 Innovative dental caries prevention at the dental practice and in the community

What innovative dental caries preventive ways can you devise for individual patient and the community?

6.0 References

1. Unep. Minamata Convention on Mercury - Text and Annexes. UNEP, 2013a. 2013;69.
2. Kenya National Oral health Survey report [Internet]. 2015. Available from: http://www.health.go.ke/?wpdmpro=national-oral-health-survey-report-2015
3. Petersen PE. Future Use of Materials for Dental Restoration. [Internet]. Geneva, Switzerland, WHO; 2009. 30 p. Available from: https://www.who.int/oral_health/publications/dental_material_2011.pdf
4. David A.E. Shephard. Methyl mercury poisoning in Canada. C J [Internet]. 1976;114:463–72. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1956835/pdf/canmedaj01553-0071.pdf
5. Hancocks S. A sense of place. BDJ. 2013;
6. Damluji SF, Tikriti S. Mercury Poisoning from Wheat. Br Med J. 1972;1(5803):804.
7. Louis Mackenzie, F J Trevor Burke ACCS. Posterior Composites: A Practical Guide Revisited. Dent Updat 2012 Apr;39(3)211-2, 215-6. 2012;39(3):211-2,215-6.

8. Osborne JW, Summitt JB. Extension for prevention: Is it relevant today? Am J Dent. 1998;11(4):189–96.

9. Krisztina M, Mercedes L, Emoke T, Barbara K, Katalin N, Pál F, et al. Paradigm shift in conservative dentistry: The end of the amalgam era. Orv Hetil. 2018;159(42):1700–9.

10. Giacaman RA, Muñoz-Sandoval C, Neuhaus KW, Fontana M, Chałas R. Evidence-based strategies for the minimally invasive treatment of carious lesions: Review of the literature. Adv Clin Exp Med. 2018;27(7):1009–16.

11. Schwendicke F, Frencken JE, Bjørndal L, Maltz M, Manton DJ, Ricketts D, et al. Managing Carious Lesions: Consensus Recommendations on Carious Tissue Removal. Adv Dent Res. 2016;28(2):58–67.

12. Fisher J, Varenne B, Narvaez D, Vickers C. The Minamata Convention and the phase down of dental amalgam. Bull World Health Organ. 2018;96(6):436–8.

13. Agency OC and pollution. Vista analysis on behalf of Norwegian climate and pollution agency. Review of Norwegian experiences with the phase-out of dental amalgam use. [Internet]. 2012. Available from: www.klif.no/publikasjoner/2946/ta2946.pdf

14. United Nations Environment Programme. Lessons from Countries Phasing Down Dental Amalgam Use. DTI/1945/GE. 2016;(March):1–28. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/11624/Dental.Amalgam.10mar2016.pages.WEB.pdf?sequence=1&isAllowed=y

15. BIO Intelligence Service. Study on different options for communicating environmental information for products, Final report prepared for the European Commission – DG Environment. 2012.

16. Lynch CD, Wilson NHF. Managing the phase-down of amalgam: Part I. Educational and training issues. Br Dent J. 2013;215(3):109–13.

17. Regulation EUM, State M. Developing National Plans to Phase Down Dental Amalgam Use in the EU Member States. In 2019.

18. Helena Forss EW. From amalgam to composite: selection of restorative materials and restoration longevity in Finland. Acta Odontol Scand. 2001;59(2):57–62.

19. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 Diseases and Injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392(10159):1789–858.

20. Carolina Loch, Yuwen Liaw, Atikah Pg Metussin, Christopher D Lynch, Nairn Wilson, Igor R Blum PAB. The Teaching of Posterior Composites: A Survey of Dental Schools in Oceania. J Dent May;84. 2019;(84):36–43.

21. Al-Asmar AA, Al-Khatib KM, Al-Amad TZ, Sawair FA. Has the implementation of the Minamata convention had an impact on the practice of operative dentistry in Jordan? J Int Med Res. 2019;47(1):361–9.

22. Arotiba GT, Loto AO, Ijarogbe O, Ajayi Y, Menakaya I, Adogame L, et al. Lessons from mercury dental amalgam phase down for developing economies. African J Oral Heal. 2019;8(2):29–39.

23. Karthik Krishna Ramesh1, Maya Ramesh2 RK. Management and Disposal of Mercury and Amalgam in the Dental Clinics of South India: A Cross-Sectional Study. J Pharm Bioallied Sci [Internet]. 2019;11(6):151–5. Available from: http://www.jpbsonline.org/article.asp?issn=0975-7406;year=2019;volume=11;issue=6;spage=151;epage=155;aulast=Ramesh

24. Faraj BM, Mohammad HM, Mohammad KM. The Changes in Dentists' Perception and Patient's Acceptance on Amalgam Restoration in Kurdistan-Iraq: A Questionnaire-based Cross-Sectional Study. J Clin Diagnostic Res. 2015;9(4):ZC22-5.

25. Mumtaz R, Ali Khan A, Noor N, Humayun S. Amalgam use and waste management by Pakistani dentists: An environmental perspective. East Mediterr Heal J. 2010;

26. Osiro O.A, Kisumbi B.K SH. Selection of direct restorative and root filling materials

Kenyan dentists by Kenyan dentists in 2014. East Africa Med J. 2016;93(10):27–32.

27. Ganatra FA, Kisumbi B.K GL. Selection of posterior dental restoratives by dentists. 2009;1(2):59–64.

28. Kisumbi B.K, Gathece L.W., Koyio L.N, Wamai J. Dental amalgam waste management by dentists in East Africa. Int Dent J. 2013;63(Suppl 1):P 684.

29. BOWEN RL. Properties of a silica-reinforced polymer for dental restorations. J Am Dent Assoc. 1963;66(1):57–64.

30. Opdam NJM, Van De Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, et al. Longevity of posterior composite restorations: A systematic review and meta-analysis. J Dent Res. 2014;93(10):943–9.

31. Narene AVK, Veniashok B, Subbiya A, Vivekanandhan P, Sukumaran VG. Polymerisation shrinkage in resin composites-A review. Middle - East J Sci Res. 2014;21(1):107–12.

32. Baroudi K, Rodrigues JC. Flowable Resin Composites : A Systematic Review and Clinical Considerations. J Clin Diagnostic Res. 2015;9(6):ZE18–24.

33. Bayne SC, Thompson JY, Swift EJ, Stamatiades P, Wilkerson M. A characterization of first-generation flowable composites. J Am Dent Assoc. 1998;129(5):567–77.

34. Sachdeva P, Goswami M, Singh D. Comparative evaluation of shear bond strength and nanoleakage of conventional and self - adhering flowable composites to primary teeth dentin. Contemp Clin Dent. 2016;7(326):331.

35. Nitta K, Nomoto R, Tsubota Y, Tsuchikawa M, Hayakawa T. Characteristics of low polymerization shrinkage flowable resin composites in newly-developed cavity base materials for bulk filling technique. 2017;36(6):740–6.

36. Brandão L, Abado GL, Vaz LG, Saad JRC. Compressive strength and compressive fatigue limit of conventional and high viscosity posterior resin composites Resistência a compressão e limite de fadiga compressiva de resinas compostas convencional e de alta viscosidade para dentes posteriores. Dent Mater. 2005;19(4):272–7.

37. Wang L, Cristina F, Garcia P, Araújo PA De, Batista E, Francisco R, et al. Wear resistance

of packable resin composites after simulated toothbrushing test. J Esthet Restor Dent [Internet]. 2004;16(5):303–14. Available from: https://pubmed.ncbi.nlm.nih.gov/15726799/

38. Carvalho D, Salles R, Rovaris K, Hass V. Effect of Low Shrinkage Monomers on Physicochemical Properties of Dental Resin Composites. Braz Dent J. 2015;26(3):272–6.

39. Fernandes RAML, De Oliveira Lima JT, Da Silva BH, Sales MJT, De Orange FA. Development, implementation and evaluation of a management specialization course in oncology using blended learning. BMC Med Educ. 2020;20(1):1–10.

40. Tavangar M, TayefehDavalloo R, Kazemi R. A Comparative Evaluation of Microleakage of Two Low-Shrinkage Composites with a Conventional Resin Composite: an In Vitro Assessment. J Dent Shiraz Univ Med Sci J Dent Shiraz Univ Med Sci. 2016;17(171):55–61.

41. Yap AUJ, Soh MS. Post-gel polymerization contraction of "low shrinkage" composite restoratives. Oper Dent. 2004;29(2):182–7.

42. Monsarrat P, Garnier S, Vergnes JN, Nasr K, Grosgogeat B, Joniot S. Survival of directly placed ormocer-based restorative materials: A systematic review and meta-analysis of clinical trials. Dent Mater. 2017;33(5):e212–20.

43. Oltramare RS, Odermatt R, Burrer P, Attin T, Tauböck TT. Depth-related curing potential of ormocer-and dimethacrylate-based bulk-fill composites. Materials (Basel). 2021;14(22):1–8.

44. Abreu NMr, Sousa FB, Dantas RV, Leite PKbS, Batista AU, Montenegro R V. Longevity of bulk fill and ormocer composites in permanent posterior teeth: Systematic review and meta-analysis. Am J Dent. 2022;35(2):89–96.

45. Kalra S, Singh A, Gupta M, Chadha V. Ormocer: An aesthetic direct restorative material; An in vitro study comparing the marginal sealing ability of organically modified ceramics and a hybrid composite using an ormocer-based bonding agent and a conventional fifth-generation bonding agent. Contemp Clin Dent. 2012;3(1):48–53.

46. NASCIMENTO AS, RODRIGUES JFB, TORRES RHN, SANTOS KO, FOOK MVL, ALBUQUERQUE MS de, et al. Physicomechanical and thermal analysis of bulk-fill and conventional composites. Braz Oral Res. 2019;33(0):1–13.

47. Ilie N, Bucuta S, Draenert M. Bulk-fill Resin-based Composites: An In Vitro Assessment of Their Mechanical Performance . Oper Dent. 2013;38(6):618–25.

48. Haugen HJ, Marovic D, Par M, Khai M, Thieu L. Bulk Fill Composites Have Similar Performance to Conventional Dental Composites. 2020;21(14). Available from: https://pubmed.ncbi.nlm.nih.gov/32698509/

49. Rizzante FAP, Duque JA, Duarte MAH, Mondelli RFL, Mendonça G, Ishikiriama SK. Polymerization shrinkage, microhardness and depth of cure of bulk fill resin composites. Dent Mater J. 2019;38(3):403–10.

50. Penha K janilee de S, Souza A ferreira, Santos M jansen, San L josé. Could sonic delivery of bulk-fill resins improve the bond strength and cure depth in extended size class I cavities ? Oper Dent Endod [Internet]. 2020;12(12):1131–8. Available from: https://pubmed.ncbi.nlm.nih.gov/33282133/

51. Cidreira Boaro LC, Pereira Lopes D, de Souza ASC, Lie Nakano E, Ayala Perez MD, Pfeifer CS, et al. Clinical performance and chemical-physical properties of bulk fill composites resin —a systematic review and meta-analysis. Dent Mater. 2019;35(10):e249–64.

52. Ferracane JL, Condon JR. Post-cure heat treatments for composites: properties and fractography. Dent Mater. 1992;8(5):290–5.

53. Bona A Della, Corazza PH, Zhang Y, Fundo P. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater. [Internet]. 2015;30(5):564–9. Available from: https://pubmed.ncbi.nlm.nih.gov/24656471/

54. Khan AS, Azam MT, Khan M, Mian SA, Rehman IU. An update on glass fiber dental restorative composites: A systematic review. Mater Sci Eng C [Internet]. 2015;47:26–39. Available from: https://pubmed.ncbi.nlm.nih.gov/25492169/

55. Raju R, Rajan G, Farrar P, Prusty BG. Dimensional stability of short fibre reinforced

flowable dental composites. Sci Rep [Internet]. 2021;11(1):1–11. Available from: https://doi.org/10.1038/s41598-021-83947-x

56. Tanner J, Tolvanen M, Garoushi S, Säilynoja E. Clinical Evaluation of Fiber-Reinforced Composite Restorations in Posterior Teeth - Results of 2.5 Year Follow-up. Open Dent J [Internet]. 2018;12(1):476–85. Available from: https://pubmed.ncbi.nlm.nih.gov/30069257/

57. Lassila L, Keulemans F, Vallittu PK, Garoushi S. Characterization of restorative short-fiber reinforced dental composites. Dent Mater J. 2020;39(6):992–9.

58. Coldea A, Swain M V, Thiel N. In-vitro strength degradation of dental ceramics and novel PICN material by sharp indentation. J Mech Behav Biomed Mater [Internet]. 2013;26:42–42. Available from: https://pubmed.ncbi.nlm.nih.gov/23807311/

59. Nicholson JW. Polyacid-modified composite resins ("compomers") and their use in clinical dentistry. Dent Mater. 2007;23(5):615–22.

60. Gupta2* NM and S. Compomers: A Review of Literature. Acta Sci Dent Sci. 2021;5(6):53–6.

61. Nicholson J, Czarnecka B. Polyacid-modified composite resins (compomers). Mater Direct Restor Teeth. 2016;(December):69–85.

62. Heintze SD, Loguercio AD, Hanzen TA, Reis A, Rousson V. Clinical efficacy of resin-based direct posterior restorations and glass-ionomer restorations – An updated meta-analysis of clinical outcome parameters. Dent Mater. 2022;38(5):e109–35.

63. Rusnac ME, Gasparik C, Irimie AI, Grecu AG, Mesaroş AŞ, Dudea D. Giomers in dentistry - at the boundary between dental composites and glass-ionomers. Med Pharm Reports. 2019;92(2):1–6.

64. Francois P, Fouquet V, Attal JP, Dursun E. Commercially available fluoride-releasing restorative materials: A review and a proposal for classification. Materials (Basel). 2020;13(10).

65. Priyadarshini BI, Jayaprakash T, Nagesh B, Sunil CR, Sujana V, Deepa VL. One-year

comparative evaluation of Ketac Nano with resin-modified glass ionomer cement and Giomer in noncarious cervical lesions: A randomized clinical trial. J Conserv Dent. 2017;20(3):204–9.

66. Xu* HHK, , M.D. Weir, L. Sun, S. Takagi and LCC. Effects of Calcium Phosphate Nanoparticles on Ca-PO4 Composite. J Dent Res [Internet]. 2007;86(4):378–83. Available from: https://pubmed.ncbi.nlm.nih.gov/17384036/

67. Gupta N, Jaiswal S, Nikhil V, Gupta S, Jha P, Bansal P. Comparison of fluoride ion release and alkalizing potential of a new bulk-fill alkasite. 2019;22(3):296–9.

68. Wiriyasatiankun P, Sakoolnamarka R, Thanyasrisung P. The impact of an alkasite restorative material on the pH of Streptococcus mutans biofilm and dentin remineralization : an in vitro study. BMC Oral Health [Internet]. 2022;22:334 (2022). Available from: https://doi.org/10.1186/s12903-022-02354-4

69. Melissa Tiskaya , N A Al-Eesa , F S L Wong RGH. Characterization of the bioactivity of two commercial composites. Dent Mater [Internet]. 2019;35(12):1757–68. Available from: https://pubmed.ncbi.nlm.nih.gov/31699444/

70. Mohamed NI, Safy RK, Fawzy A, Elezz A. Microtensile Bond Strength , Marginal Leakage , and Antibacterial Effect of Bulk Fill Resin Composite with Alkaline Fillers versus Incremental Nanohybrid Composite Resin. Eur J Dent [Internet]. 2021;15(3):0–7. Available from: https://pubmed.ncbi.nlm.nih.gov/33368067/

71. Iftikhar N. A Comparative Evaluation of Mechanical Properties of Four Different Restorative Materials : An In Vitro Study. Int J Clin Pediatr Dent [Internet]. 2019;12(1):47–9. Available from: https://pubmed.ncbi.nlm.nih.gov/31496572/

72. Bahari M, Kahnamoui MA, Esmaeel M, Chaharom E, Kimyai S, Sattari Z. Effect of curing method and thermocycling on flexural strength and microhardness of a new composite resin with alkaline filler. Dent Res J [Internet]. 2021;22(18):96. Available from: https://pubmed.ncbi.nlm.nih.gov/35003561/

73. Benetti AR, Michou S, Larsen L, Peutzfeldt A, Pallesen U, van Dijken JWV. Adhesion and

marginal adaptation of a claimed bioactive, restorative material. Biomater Investig Dent [Internet]. 2019;6(1):90–8. Available from: https://doi.org/10.1080/26415275.2019.1696202

74. Rifai H, Qasim S, Mahdi S, Lambert M jacky, Zarazir R, Amenta F. In-vitro evaluation of the shear bond strength and fluoride release of a new bioactive dental composite material. J Clin Exp Dent [Internet]. 2022;14(1):e55–63. Available from: https://pubmed.ncbi.nlm.nih.gov/35070125/

75. Tohidkhah S, Kermanshah H, Omrani LR. Marginal microleakage and modified microtensile bond strength of Activa Bioactive , in comparison with conventional restorative materials. Clin Exp Dent Res [Internet]. 2022;8(October 2020):329–35. Available from: https://pubmed.ncbi.nlm.nih.gov/35037730/

76. Danijela Marović 1, Kristina Šariri, Nazif Demoli, Mira Ristić, Karl-Anton Hiller, Drago Škrtić, Martin Rosentritt, Gottfried Schmalz, Zrinka TarleDanijela Marović 1, Kristina Šariri, Nazif Demoli, Mira Ristić, Karl-Anton Hiller, Drago Škrtić, Martin Rose ZT. Remineralizing amorphous calcium phosphate based composite resins : the influence of inert fillers on monomer conversion , polymerization shrinkage , and microhardness. Croat Med J [Internet]. 2016;57(5):465–73. Available from: https://pubmed.ncbi.nlm.nih.gov/27815937/

77. Khan AS, Syed MR. A review of bioceramics-based dental restorative materials. Dent Mater J [Internet]. 2019;38(2):163–76. Available from: https://pubmed.ncbi.nlm.nih.gov/30381635/

78. Wu J, Weir MD, Melo MAS, Xu HHK, Division TE, Greenebaum S, et al. Development of novel self-healing and antibacterial dental composite containing calcium phosphate

nanoparticles. J Dent [Internet]. 2015;43(3):317–26. Available from: https://pubmed.ncbi.nlm.nih.gov/25625674/

79. Ning K, Loomans B, Yeung C, Li J, Yang F, Leeuwenburgh S. Influence of microcapsule parameters and initiator concentration on the self-healing capacity of resin-based dental composites. Dent Mater [Internet]. 2021;37(3):403–12. Available from: https://pubmed.ncbi.nlm.nih.gov/33353737/

80. Wilson AD, Kent BE. A new translucent cement for dentistry. The glass ionomer cement. Br Dent J [Internet]. 1972;132(4):133–5. Available from: https://pubmed.ncbi.nlm.nih.gov/4501690/

81. Minimal Intervention Dentistry II : Part 7 . Minimal Intervention in Cariology : The Role of Glass- Ionomer Cements in the Preservation of Tooth Structures Against Caries. 2014;216(10):2014.

82. Maldonado A, Swartz ML, Phillips RW. An in vitro study of certain properties of a glass ionomer cement. J Am Dent Assoc. 1978;96(5):785–91.

83. Crisp S, Wilson AD. Reactions in Glass Ionomer Cements: V. Effect of Incorporating Tartaric Acid in the Cement Liquid. J Dent Res [Internet]. 1976;55(6):1023–31. Available from: https://pubmed.ncbi.nlm.nih.gov/187629/

84. Fabio Antonio Piola Rizzante, Rafael Schlögel Cunali, Juliana Fraga Soares Bombonatti, Gisele Maria Correr, Carla Castiglia Gonzaga, Adilson Yoshio Furuse. Indications and restorative techniques for glass ionomer cement. Rsbo. 2016;12(1):79–87.

85. Van Duinen RNB, Kleverlaan CJ, De Gee AJ, Werner A, Feilzer AJ. Early and long-term wear of “Fast-set” conventional glass-ionomer cements. Dent Mater . 2005;21(8):716–20.

86. Frencken JE. Atraumatic restorative treatment and minimal intervention dentistry. Br Dent J. 2017;223(3):183–9.

87. Fotiadou C, Frasheri I, Reymus M, Diegritz C, Kessler A, Manhart J, et al. A 3-year controlled randomized clinical study on the performance of two glass-ionomer cements in Class II cavities of permanent teeth. Quintessence Int. 2019;51(1):e1–11.

88. Heck K, Frasheri I, Diegritz C, Manhart J, Hickel R, Fotiadou C. Six-year results of a

randomized controlled clinical trial of two glass ionomer cements in class II cavities. J Dent. 2020;97:5–6.

89. Mickenautsch S. Are high-viscosity glass-ionomer cements inferior to silver amalgam as restorative materials for permanent posterior teeth? A Bayesian analysis. BMC Oral Health. 2015;15(1):1–8.

90. Molina GF, Faulks D, Mulder J, Frencken JE. High-viscosity glass-ionomer vs. composite resin restorations in persons with disability: Five-year follow-up of clinical trial. Braz Oral Res. 2019;33:1–9.

91. Hilgert LA, De Amorim RG, Leal SC, Mulder J, Creugers NHJ, Frencken JE. Is high-viscosity glass-ionomer-cement a successor to amalgam for treating primary molars? Dent Mater. 2014;30(10):1172–8.

92. Lohbauer U, Krämer N, Siedschlag G, Schubert EW, Lauerer B, Müller FA, et al. Strength and wear resistance of a dental glass-ionomer cement with a novel nanofilled resin coating. Am J Dent. 2011;24(2):124–8.

93. Klinke T, Daboul A, Turek A, Frankenberger R, Hickel R, Biffar R. Clinical performance during 48 months of two current glass ionomer restorative systems with coatings: A randomized clinical trial in the field. Trials [Internet]. 2016;17(1). Available from: http://dx.doi.org/10.1186/s13063-016-1339-8

94. Aydin N, Karaoğlanoğlu S, Aybala-Oktay E, Çetinkaya S, Erdem O. Investigation of water sorption and aluminum releases from high viscosity and resin modified glass ionomer. J Clin Exp Dent. 2020;12(9):e844–51.

95. Türkün LS, Kanik O. A prospective six-year clinical study evaluating reinforced glass ionomer cements with resin coating on posterior teeth: Quo vadis? Oper Dent. 2016;41(6):587–98.

96. Antonucci, J. M.; McKinney, J. E.; Stansbury JW. Resin-Modified Glass-Ionomer Dental Cements Field of the Invention. [Internet]. Government Patent Health Education and

Welfare; 198814, 1988. Available from: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB88185665.xhtml

97. S.K. S, T.F. W. Resin-modified glass ionomer materials. A status report for the American Journal of Dentistry. Am J Dent [Internet]. 1995;8(1):59–67. Available from: http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L125121205

98. Najeeb S, Khurshid Z, Zafar MS, Khan AS, Zohaib S, Martí JMN, et al. Modifications in glass ionomer cements: Nano-sized fillers and bioactive nanoceramics. Int J Mol Sci. 2016;17(7).

99. Padmaja S, Somasundaram J, Sivaswamy V. Nano glass ionomers-a review. Indian J Forensic Med Toxicol. 2020;14(4):4560–6.

100. Dermata A, Papageorgiou SN, Kotsanos N. Three-year performance of a nano-filled resin-modified glass ionomer cement in class II primary molar restorations. Eur Arch Paediatr Dent. 2021;22(3):425–32.

101. Abo-Hamar SE, El-Desouky SS, Abu Hamila NA. Two-year clinical performance in primary teeth of nano-filled versus conventional resin-modified glass-ionomer restorations. Quintessence Int. 2015;46(5):381–8.

102. Patil K, Patel A, Kunte S, Shah P, Kaur B, Paranna S. Comparative evaluation of the mechanical properties of zinc-reinforced glass ionomer cement and glass ionomer type IX cement: An in vitro study. Int J Clin Pediatr Dent. 2020;13(4):381–9.

103. Zoergiebel J, Ilie N. Evaluation of a conventional glass ionomer cement with new zinc formulation: Effect of coating, aging and storage agents. Clin Oral Investig. 2013;17(2):619–26.

104. Poojar B, Ommurugan B, Adiga S, Thomas H, Sori RK, Poojar B, et al. A New Zinc Reinforced Glass Ionomer Cement: A Boon in Dentistry. Asian J Pharm Clin Res. 2017;7(10):1–5.

105. Chalissery VP, Marwah N, Almuhaiza M, AlZailai AM, Chalisserry EP, Bhandi SH, et al. Study of the mechanical properties of the novel zirconia-reinforced glass ionomer cement. J

Contemp Dent Pract. 2016;17(5):394–8.

106. Tiwari S, Kenchappa M, Bhayya D, Gupta S, Saxena S, Satyarth S, et al. Antibacterial activity and fluoride release of glass-ionomer cement, compomer and zirconia reinforced glass-ionomer cement. J Clin Diagnostic Res. 2016;10(4):ZC90–3.

107. Sidhu S, Nicholson J. A Review of Glass-Ionomer Cements for Clinical Dentistry. J Funct Biomater. 2016;7(3):16.

108. Olegário IC, Malagrana APVFP, Kim SSH, Hesse D, Tedesco TK, Calvo AFB, et al. Mechanical properties of high-viscosity glass ionomer cement and nanoparticle glass carbomer. J Nanomater. 2015;2015.

109. Raskin A, Setcos JC, Vreven J, Wilson NH. Influence of the isolation method on the 10-year clinical behaviour of posterior resin composite restorations. Clin Oral Investig. 2000;4(3):148–52.

110. Cajazeira MRR, De Sabóia TM, Maia LC. Influence of the operatory field isolation technique on tooth-colored direct dental restorations. Am J Dent. 2014;27(3):155–9.

111. Miličević A, Goršeta K, Van Duinen RNV, Glavina D. Surface roughness of glass ionomer cements after application of different polishing techniques. Acta Stomatol Croat. 2018;52(4):314–21.

112. Krisztina Mikulás, Mercedes Linninger, Emőke Takács, Barbara Kispélyi, Katalin Nagy , Pál Fejérdy PH. Paradigm Shift in Conservative Dentistry: The End of the Amalgam Era. Orv Hetil. 2018;159(42):1700–9.

113. Pitts NB. Are we ready to move from operative to non-operative/preventive treatment of dental caries in clinical practice? Caries Res. 2004;38(3):294–304.

114. Fontana M, Guzmán-armstrong S, Andrew B, Allen KL, Featherstone J, Kanjirath P, et al. Development of a Core Curriculum Framework in Cariology for U.S. Dental Schools. 2016;705–20.

115. Fontana M, Pilcher L, Tampi MP, Urquhart O, Slayton RL, Araujo MWB, et al. Caries management for the modern age: Improving practice one guideline at a time. J Am Dent Assoc [Internet]. 2018;149(11):935–7. Available from:

https://doi.org/10.1016/j.adaj.2018.09.004

116. Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: a global public health challenge. Lancet. 2019;394(10194):249–60.

117. Osiro OA, Kariuki DK, Gathece LW. The Minamata Convention on Mercury and its implications for management of dental caries in low- and middle-income countries. Int Dent J. 2019;1–5.

118. Weir MD, Chow LC, Xu HHK. Remineralization of demineralized enamel via calcium phosphate nanocomposite. J Dent Res. 2012;91(10):979–84.

119. Zawaideh FI, Owais AI, Kawaja W. Ability of Pit and Fissure Sealant-containing Amorphous Calcium Phosphate to inhibit Enamel Demineralization. Int J Clin Pediatr Dent. 2016;9(1):10–4.

120. Langhorst SE, O'Donnell JNR, Skrtic D. In vitro remineralization of enamel by polymeric amorphous calcium phosphate composite: Quantitative microradiographic study. Dent Mater. 2009;25(7):884–91.

121. Skrtic D, Antonucci JM, Eanes ED, Eichmiller FC, Schumacher GE. Physicochemical evaluation of bioactive polymeric composites based on hybrid amorphous calcium phosphates. J Biomed Mater Res. 2000;53(4):381–91.

122. Ünal M, Oznurhan F, Kapdan A, Dürer S. A comparative clinical study of three fissure sealants on primary teeth: 24-month results. J Clin Pediatr Dent. 2015;39(2):113–9.

123. Sachin Gowardhan Khatri 1, Kavita Ashok Madan 2, Samuel Raj Srinivasan 3 SA. Retention of moisture-tolerant fluoride-releasing sealant and amorphous calcium phosphate-containing sealant in 6-9-year-old children: A randomized controlled trial. J Indian Soc Pedod Prev Dent [Internet]. 2019;37(September):92–8. Available from: https://pubmed.ncbi.nlm.nih.gov/30804314/

124. Liu BY, Xiao Y, Chu CH, Lo ECM. Glass ionomer ART sealant and fluoride-releasing resin sealant in fissure caries prevention - results from a randomized clinical trial. BMC Oral Health. 2014;14(1):1–9.

125. Haricharan PB, Barad N, Patil CR, Voruganti S, Mudrakola DP, Turagam N. Dawn of a

New Age Fissure Sealant? A Study Evaluating the Clinical Performance of Embrace WetBond and ART Sealants: Results from a Randomized Controlled Clinical Trial. Eur J Dent. 2019;13(4):503–9.

126. Babaji P, Vaid S, Deep S, Mishra S, Srivastava M, Manjooran T. In vitro evaluation of shear bond strength and microleakage of different pit and fissure sealants. J Int Soc Prev Community Dent. 2016;6(8):S111–5.

127. Colombo S, Beretta M. Dental Sealants Part 3: Which material? Efficiency and effectiveness. Eur J Paediatr Dent. 2018;19(3):247–9.

128. Veiga NJ, Ferreira PC, Correia IJ, Pereira CM. Fissure Sealants : A Review of their Importance in Preventive Dentistry. Ohdm. 2014;13:989.

129. Laske M, Opdam NJM, Bronkhorst EM, Braspenning JCC, Van Der Sanden WJM, Huysmans MCDNJM, et al. Minimally Invasive Intervention for Primary Caries Lesions: Are Dentists Implementing This Concept? Caries Res. 2019;53(2):204–16.

130. Jeremy A Horst, Hellene Ellenikiotis PMMJAHH. USCF Protocol for Silver Diamine Fluoride: Rationale, Indications, and Consent. J Calif Dent Assoc. 2016;44(1):16–28.

131. Hamama HH, Yiu CK, Burrow MF. Effect of silver diamine fluoride and potassium iodide on residual bacteria in dentinal tubules. Aust Dent J. 2015;60(1):80–7.

132. Meyer-Lueckel H, Paris S. Improved resin infiltration of natural caries lesions. J Dent Res. 2008;87(12):1112–6.

133. Senestraro S V., Crowe JJ, Wang M, Vo A, Huang G, Ferracane J, et al. Minimally invasive resin infiltration of arrested white-spot lesions: A randomized clinical trial. J Am Dent Assoc. 2013;144(9):997–1005.

134. Anand V, Arumugam SB, Manoharan V, Kumar SA, Methippara JJ. Is Resin Infiltration a Microinvasive Approach to White Lesions of Calcified Tooth Structures?: A Systemic Review. Int J Clin Pediatr Dent. 2019;12(1):53–8.

135. Lasfargues JJ, Bonte E, Guerrieri A, Fezzani L. Minimal intervention dentistry: Part 6. Caries inhibition by resin infiltration. Br Dent J. 2013;214(2):53–9.

136. Simonsen RJ. Preventive resin restorations and sealants in light of current evidence. Dent Clin North Am. 2005;49(4):815–23.

137. Afshar H, Jafari A, Khami MR, Razeghi S. Evaluation of Microleakage in Composite-Composite and Amalgam-Composite Interfaces in Tooth with Preventive Resin Restoration (Ex-viva). J Dent (Tehran). 2012;9(2):128–12834.

138. Setcos JC, Khosravi R, Wilson NHF, Shen C, Yang M, Mjör IA. Repair or replacement of amalgam restorations: Decisions at a USA and a UK dental school. Oper Dent. 2004;29(4):392–7.

139. Hickel R, Peschke A, Tyas M, Mjör I, Bayne S, Peters M, et al. FDI World Dental Federation: Clinical criteria for the evaluation of direct and indirect restorations-update and clinical examples. Clin Oral Investig. 2010;14(4):349–66.

140. Kopperud SE, Staxrud F, Espelid I, Tveit AB. The post-amalgam era: Norwegian dentists' experiences with composite resins and repair of defective amalgam restorations. Int J Environ Res Public Health. 2016;13(4).

141. Aggarwal VR, Pavitt S, Wu J, Nattress B, Franklin P, Owen J, et al. Assessing the perceived impact of post Minamata amalgam phase down on oral health inequalities: A mixed-methods investigation. BMC Health Serv Res. 2019;19(1):1–12.

Appendix I: Dental amalgam alternatives in the Kenya market

Material	Brand/Manufacturer	Manufacturer	Category
GIC	Chemfil Superior	Dentsply, Sirona	Traditional GIC
	Fuji II	GC, America	Traditional GIC
	Fuji VIII	GC, Europe	Self-cured resin modified GIC
	Fuji IX capsules	GC, AMERICA	Highly viscous GIC for ART
	Fuii IX	GC, America	
	Ketac universal	3M, USA	Self-cured GIC
	Equia forte HT	GC, America	Glass hybrid GIC

Compomer	Dyract Extra	DentsplySirona, Germany	
COMPOSITES			
Nano ceramic	Ceram X	DentsplySirona, Germany	Universal
Pure nano	Filtek Z250 XT	3M, USA	Universal
	Filtek Z350 XT universal	3M, USA	Universal
Nano hybrid	Tetric N Ceram	Ivoclar, Germany	Universal
	Filtek Z250 XT	3M, USA	Universal
	ICE	Ivoclar, Germany	Universal
	Diafil	DiaDent	Universal
Micro hybrid	Spectrum	DentsplySirona, Germany	Universal
	Amelogen	Ultradent, USA	Universal
	Value plus	3M, USA	Universal
	P60 posterior syringe	3M, USA	Packable DRC
Bulkfill	SDR flow plus	DentsplySirona, Germany	Universal
	Bulkfill flowable	DentsplySirona, Germany	Universal
	Filtek Bulk filtek	3M, USA	Universal
Flowable	X flow	DentsplySirona, Germany	Universal
	TG	UK	Universal
	Filtek Z350 XT	3M, USA	Universal
Hybrid	TR- Econom	Ivoclar, Germany	Universal
Alkasite	Cention N	Ivoclar, Germany	Smart composite