

Atraumatic restorative treatment and minimal intervention dentistry

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In brief

To update the reader about the level of quality of ART sealants and ART restorations which is no different from that of comparable traditional treatments.

To inform the reader about the importance of Minimal Intervention Dentistry for managing the burden of dental caries in society. One should not forget that dental caries, in essence, is a preventable disease.

To inform the reader that atraumatic care procedures should be given preference over rotary-driven procedures as in doing so the chance for reducing anxiety and discomfort is reduced, access to care increased and oral health improved, particularly in children.

Too many people worldwide suffer from the consequences of untreated dentine carious lesions. This finding reflects the inability of the currently used traditional mode of treatments to manage such lesions. A change is needed. Dental training institutions should depart from the traditional 'drill and fill' treatments and embrace the holistic oral healthcare approach that is minimal intervention dentistry (MID) and includes within it minimally invasive operative skills. Dental caries is, after all, a preventable disease. The atraumatic restorative treatment (ART) concept is an example of MID. ART consists of a preventive (ART sealant) and a restorative (ART restoration) component. ART sealants using high-viscosity glass-ionomer (HVGIC) have a very high dentine carious lesion preventive effect. The survival rate of these sealants is not significantly different from that of sealants produced with resin. The survival rate of ART/HVGIC restorations matches those of amalgam and resin composite in single- and multiple-surface cavities in primary teeth and in single-surface cavities in permanent teeth. The principles of carious tissue removal within a cavity recommended by the International Caries Consensus Collaboration are in line with those of treating a cavity using ART. Owing to its good performance and the low levels of discomfort/pain and dental anxiety associated with it, ART and/or other evidence-based atraumatic care procedures should be the first treatment for a primary dentine carious lesion. Only if the use of ART is not indicated should other more invasive and less-traumatic care procedures be used in both primary and permanent dentitions.

Minimal intervention dentistry

MID is a philosophy or concept that attempts to ensure that teeth are kept functional for life. Its development was facilitated by the many studies conducted on a range of dental caries-related topics carried out from 1940 onwards that include fluoride, sugar, dental biofilm, adhesive dental materials and the repeat restoration cycle.¹ By early 1990, research had shown that managing dental carious lesions could be better achieved by moving away from the traditional surgical approach in favour of a 'biological' or 'medical' approach. The new

approach in the management of the carious lesion was named minimal intervention dentistry or MID.² This approach encompasses the following important strategies that aim to keep teeth free from carious lesions: (i) early caries detection and assessment of caries risk with validated instruments; (ii) remineralisation of demineralised enamel and dentine; (iii) optimal caries preventive measures; (iv) tailor-made recalls; (v) minimally invasive operative interventions; and (vi) repair rather than replacement of restorations.¹ It is evident from these strategies that MID does not exclusively equate to cutting smaller cavities than before, as many dentists had initially thought.^{3,4} The first three MID strategies should be employed throughout a person's life, and only when oral health maintenance has failed and a frank cavity has developed should a minimally invasive operative intervention be undertaken.

This publication presents the recommended contemporary cariologic principles for managing

dental caries, enamel carious lesions and dentine carious lesions. This is followed by a discussion of the atraumatic restorative treatment (ART) approach and the results of its use in oral health-care. The publication concludes with a comparison of the principles that guide the application of the preventive and restorative components of the ART approach and the principles underlying contemporary cariology.

Managing dental caries

'Dental caries' is the name of a disease and a carious lesion is the consequence of the caries process over time. A carious lesion appears in various forms, from a small demineralised area in enamel to a large cavity in dentine with or without pulpal involvement. The two major aetiological factors that govern the development and progression of a carious lesion are the supply of fermentable carbohydrates, particularly free sugars, and the inability to remove the cariogenic

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bacterial biofilm from a tooth surface adequately and regularly. These factors are behaviourally determined and, therefore, form the foundation for the understanding that dental caries is a behavioural and not an infectious disease as many dentists erroneously think and are being taught in dental schools around the world. One should realise that removing microorganisms cannot cure dental caries, neither is a dental carious lesion caused by specific microorganisms as was thought in the past.⁵

Managing enamel carious lesions

A variety of non-operative approaches, tailored to avoid the progression of enamel carious lesions into frank cavitation, have been developed and investigated. The most studied therapy for controlling enamel carious lesions concerns the use of fluoride in its different preparation forms such as gel, water, varnish and toothpaste. Studies have supported the efficacy and effectiveness of these agents.¹ The other evidence-based therapy for controlling enamel carious lesions is placing a sealant over vulnerable pits and fissures.¹ The evidence for the efficacy of other enamel carious lesion-controlling agents such as silver diamine fluoride (sdf), chlorhexidine, casein phosphopeptides amorphous calcium phosphate (cpp-acp) and natural antibiotics for use in clinical practice is currently not available.⁶

Managing dentine carious lesions

Activities aimed at managing a dentine carious lesion should be directed at: inactivation/control of the disease process, preservation of dental hard tissue, avoiding initiating the cycle of re-restorations, and preservation of the tooth for as long as possible.⁷

Inactivating the disease process is achieved by controlling the amount and frequency of free sugar intake daily and by removing the (cariogenic) biofilm from any tooth surface on a daily basis. Preservation of dental hard tissue is achieved by removing only soft carious tooth tissue from within a tooth cavity, which allows the remaining demineralised dentine to remineralise. The repeat restoration cycle can be avoided if the cleaned cavity is restored under optimal clinical conditions with an appropriate restorative material. An additional measure is the protection of the margins with a sealant material, which results in a so-called sealant-restoration.⁸

The MID philosophy seeks to preserve natural tooth tissue for as long as possible through not removing enamel and dentine (carious) tissue

unnecessarily and by supporting remineralisation of demineralised enamel and dentine. Hence, non-restorative treatments have a place in managing dentine carious lesions within MID. For permanent teeth, such a treatment is suggested for non-cavitated dentine carious lesions, while in primary teeth this treatment is advocated for both non- and cavitated dentine carious lesions. Examples of treating cavitated dentine carious lesions non-restoratively include the application of sdf,⁹ the ultra-conservative treatment (uct)¹⁰ and the Hall technique.¹¹

Managing cavitated dentine carious lesions restoratively

According to Kidd,¹² the aims of restorative management are to aid biofilm control at the restored surface of the tooth instead of removing it from within the cavity; protect the pulp-dentine complex and arrest the carious lesion by sealing it; and restore the function, form and aesthetic appearance of the tooth.

Principles for the removal of demineralised carious dentine

In February 2015, a group of 21 cariologists from 12 different countries met in Leuven, Belgium and formed the International Caries Consensus Collaboration (ICCC). The ICCC agreed on the following guidelines for the removal of carious tissue:⁷

- Preserve non-demineralised and remineralisable tissue
- Achieve an adequate seal by placing the peripheral restoration onto sound dentine and/or enamel, thus controlling the carious lesion and inactivating remaining bacteria
- Avoid discomfort/pain and dental anxiety as both impact significantly on treatment/care planning and outcomes. Methods that are less likely to lead to dental anxiety are preferable
- Maintain pulpal health by preserving residual dentine (avoiding unnecessary pulpal irritation/insult) and preventing pulp exposure, that is, leave soft dentine in proximity to the pulp if required
- Maximise longevity of the restoration by removing enough soft dentine to place a durable restoration of sufficient bulk and resilience.

Which carious tissue and how much of it needs to be removed?

Many studies have investigated the state of demineralised dentine under well-sealed restorations and the results demonstrate that not all demineralised dentine needs to be removed.¹

Removing all demineralised dentine prevents this tissue from remineralising and weakens the structure of the tooth unnecessarily. The amount of carious tissue that needs to be removed and how much is left behind will depend on the depth and size of the lesion and the risk of pulp exposure.

According to the ICCC, the soft, decomposed dentine should be removed and the firm, demineralised dentine left behind. 'Soft' is defined as 'tissue that will deform when a hard instrument is pressed onto it and can easily be scooped up (hand excavator) with little force being required' and firm as 'tissue that is physically resistant to hand excavation and some pressure needs to be exerted through an instrument to lift it'.¹³ As recommended by the ICCC, in order to avoid pulpal exposure in deep cavities, it is better to leave some soft dentine over the floor of the cavity.^{14,15}

Which dentine carious tissue-removal method is preferable?

Most of the studies that have investigated the efficacy of the various carious tissue-removal methods have used different endpoints to delineate decomposed dentine. These endpoints cannot be related to the ICCC suggested strategies for the removal of dentine carious tissue. However, using results of available *in vitro* studies on this topic, it appears that rotating round-shape metal burs have the tendency to over-prepare cavities and that laser and oscillation techniques under-prepare cavities. Self-limiting burs made of polymer and ceramic material have also been found to under-prepare cavities. The most appropriate dentine carious tissue-removal methods in these studies used either a chemo-mechanically applied gel or a metal hand excavator.^{16,17}

Another principle that has become increasingly important concerns the avoidance of discomfort/pain and anxiety development. It is common knowledge that dental anxiety, developed at a young age, may lead to avoidance of self-care and seeking professional care and, eventually, to poor oral health. As hand instruments appear to cause less dental anxiety and discomfort/pain in children¹⁸ and have been shown to be selective in removing carious tissues, hand excavation should be preferred over rotary-driven excavation when removing carious tissues from dentine.

Restoring a cleaned cavity

The manner in which a cavity is restored contributes substantially to the life expectancy of the tooth. Avoiding or reducing micro-leakage at the

tooth-restoration interface is essential. Therefore, all minimally invasive operative restorative procedures should ensure the presence of a tight seal of the restorative material in the cavity to the enamel and dentine. This implies that the coronal part of the cavity should be as free from soft dentine as possible in order to obtain a secure bond of the adhesive material used to the available tooth structure. A further increase in tooth life expectancy is obtained by sealing the margins of the restoration and the adjacent pits and fissures when available and indicated. The restoration margin is the weakest part of the restoration. It is the most common reason for replacement of the restoration¹⁹ and is reinforced if sealed over. Sealing remaining pits and fissures may prevent the occurrence of dentine carious lesions.

A sealant-restoration using hand instruments and high-viscosity glass-ionomer (HVGIC) as the restorative and as the sealant material is called the atraumatic restorative treatment or ART.²⁰ This caries lesion management concept is presented later in this article.

Atraumatic restorative treatment

ART was introduced almost 30 years ago, when researchers were challenged to manage cavitated dentine lesions in an environment in which rotary-driven restorative care was not possible because of the lack of electricity and/or piped water. At that time, the dentists made use of what had been available in dentistry for many years: hand instruments for enlarging small cavity openings and for selective removal of carious dentine to soft (deep cavities) or to firm (medium cavities) stages in vital teeth. Today, in completing this process, local anaesthesia is seldom needed and used in children; the ART process causes less dental anxiety than the traditional approach of using the drill.²¹

The ART concept

ART is defined as a minimal intervention care approach with the aim of preventing the development of carious lesions and of stopping their progression into dentine. A second aim is to restore dentine carious lesions in a minimally invasive way. ART consists of two components: a preventive (ART sealant) and a restorative (ART restoration) component. ART sealants use an HVGIC, which is placed over carious lesion-prone pits and fissures under finger pressure. Hand instruments (such as an excavator and an applier-carver) are used for adjusting the bite and removing excess material (Fig. 1). In

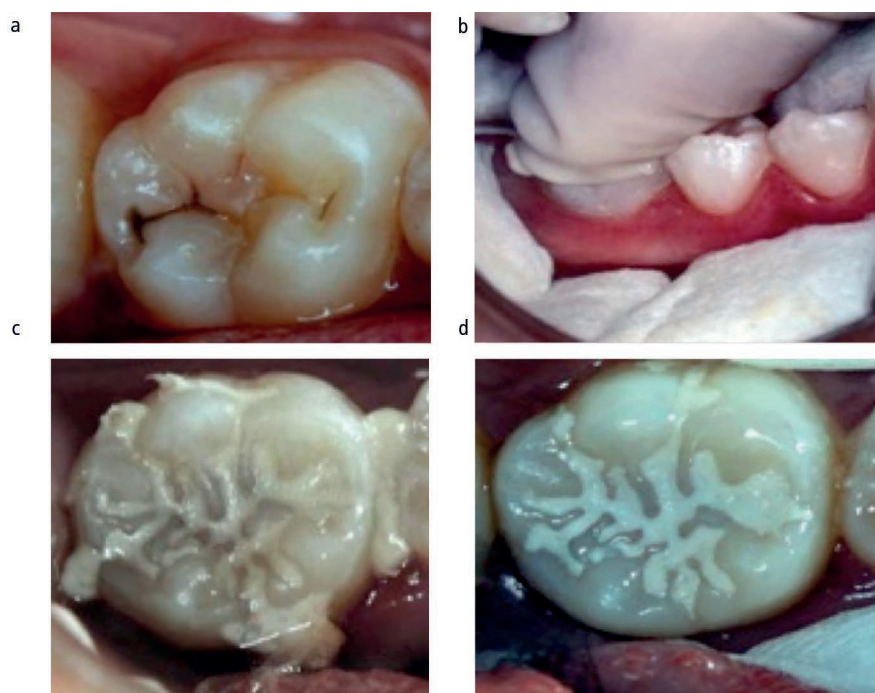


Fig. 1 ART sealant: a) vulnerable pit and fissure; b) HVGIC applied with 'press-finger' method; c) situation after removal of finger. Excess HVGIC is pushed to the sides and can be removed easily with an applier-carver instrument; d) final ART sealant after bite check (Courtesy of Professor F. de Lima Navarro)

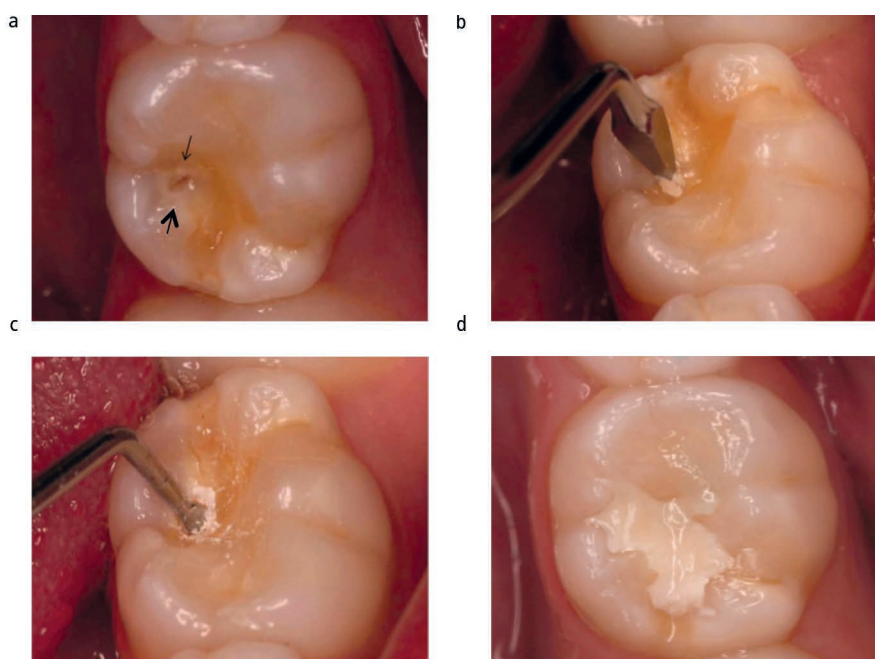


Figure 2. ART restoration method: a) small cavity in dentine; b) cavity opening is widened with the ART opener instrument. Weak enamel crumbles; c) cavity opening is now large enough for the small excavator to enter and to remove soft, decomposed tissue; d) finished ART sealant-restoration (© J. Frencken and S. Leal)

applying this approach, sealants can be placed in situations independent of the need for rotary instruments and thus electricity and running water. ART restorations involve the creation of sufficient access to the cavitated dentine carious

lesion for removal of soft, completely demineralised (decomposed) carious tissue with hand instruments. This action is only needed if the cavity is small. The cavity is then cleaned and restored with an adhesive dental material that

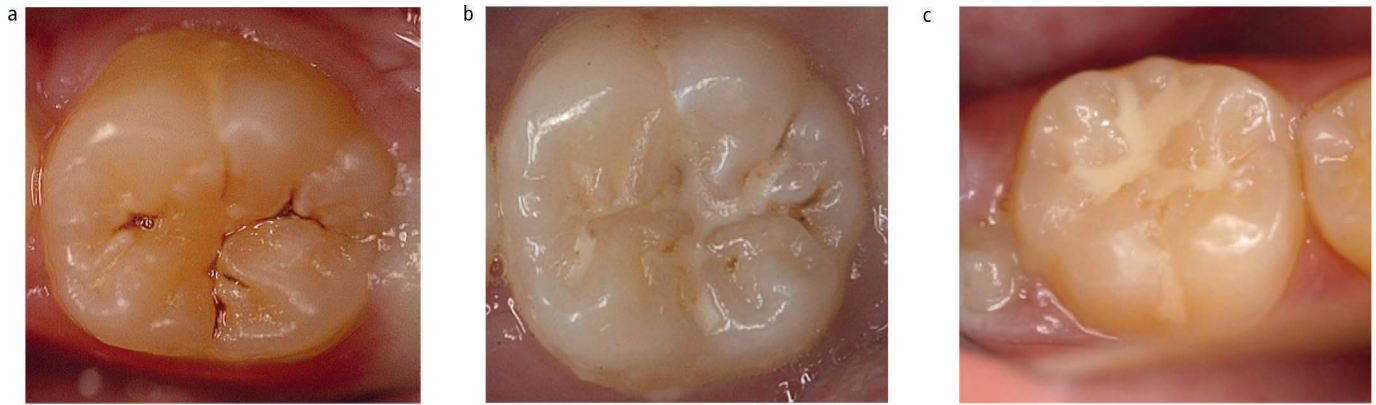


Fig. 3 (a) Sealant completely disappeared from the occlusal surface but not from the buccal surface, (b) partially, and (c) fully retained ART/HVGIC sealants after 4 years (Courtesy of Dr Hu Xuan)

simultaneously seals any remaining at risk pits and fissures (Fig. 2). The material mostly chosen for ART restorations is HVGIC.

A great advantage of using HVGIC over composite resin is that it allows the practitioner to use the press-finger technique to place the material into the cavity, which leads to what is called a sealant-restoration. This occurs because by using the finger to press down the HVGIC, it will penetrate the cavity and some excess will spread along the cavity margins and over the pits and fissures, sealing both areas. This action is considered to produce the extra-preventive effect provided by this approach.

Outcomes of ART-related studies

Effectiveness of ART sealants

The latest meta-analysis on ART sealants showed a weighted mean survival percentage of fully and partially retained ART/HVGIC sealants after 1, 2, 3, 4, 5 and 6 years of 79%, 69%, 68%, 62%, 63% and 59% respectively.²² These relatively high retention rates equate to a weighted mean annual failure rate (completely lost ART/HVGIC sealants) in permanent teeth of 7.5% over the first 5 years.

The cavitated dentine carious lesion-preventive effect of ART/HVGIC sealants appears to be very high. The weighted mean annual cavitated dentine carious lesion failure rate in previously sealed pits and fissures after 1, 2, 3, 4, 5 and 6 years was 0.4%, 2.4%, 2.8%, 4.1%, 9.6% and 15% respectively. The weighted mean annual cavitated dentine carious lesion-failure rate was 1.9% over the first 5 years.²² This finding shows a high effectiveness of ART/HVGIC sealants (Fig. 3) but how does this finding compares to resin sealants?

Comparison between ART sealants and resin sealants

As most long-term comparisons between the effectiveness of glass-ionomer-based materials and resin-composite sealants over the last decade have used HVGIC applied according to the ART approach, it is of interest to analyse the outcomes of these comparisons. An analysis was conducted on the basis of five research articles that reported on studies of 2- to 5-year-long periods carried out between 2006 and 2015 in Brazil, China and Syria, using the hand-mixed high-viscosity glass-ionomers Fuji IX (GC, Tokyo, Japan), Ketac Molar (3MESPE, Seefeld,

Germany) and Ketac Molar Easymix (3MESPE, Seefeld, Germany) and the light-cured resin sealants Clinpro (3MESPE, Seefeld, Germany), Delton (3M, St Pauls, USA), Fluoroshield (Dentsply, York, USA) and Helioseal (Ivoclar, Schaan, Liechtenstein).

Of the five studies analysed, one showed a significantly higher cavitated dentine carious lesion-preventing effect in occlusal surfaces for ART/HVGIC than for resin-composite sealants²³ while no difference was obtained in the four remaining studies. Three studies used the same ART carious lesion assessment criteria²³⁻²⁵ while four studies sealed only high-caries-risk occlusal surfaces in first permanent molars²³⁻²⁶ (Table 1). Given that, in addition to the methodological differences, different brands of materials and different operators were used, it is remarkable that sealants produced through the ART method using high-viscosity glass-ionomers showed a performance that is similar to or significantly higher than resin-composite sealants, which were considered to be the reference sealant material.²⁷

On the basis of extensive evidence, the use of dental sealants is strongly recommended for all surfaces at risk of developing dental

Table 1 Comparison of survival rates (%) of ART/HVGIC and resin-composite sealants in preventing cavitated dentine carious lesion development in occlusal surfaces by year of study (Year). N = number of occlusal sealants; ART/HVGIC = atraumatic restorative treatment/high-viscosity glass-ionomer cement

Author	Year	ART/HVGIC		Resin composite		
		N	%	N	%	P-value
Beirut <i>et al.</i> ²³	5	139	94.1	115	78.8	0.003
Barja-Fidalgo <i>et al.</i> ³⁸	5	21	87	28	80	0.27
Zhang <i>et al.</i> ²⁴	4	239	97.3	297	96.4	0.31
Hilgert <i>et al.</i> ²⁵	3	69	90.2	169	91.4	0.59
Liu <i>et al.</i> ²⁶	2	179	92.7	178	96.1	0.17

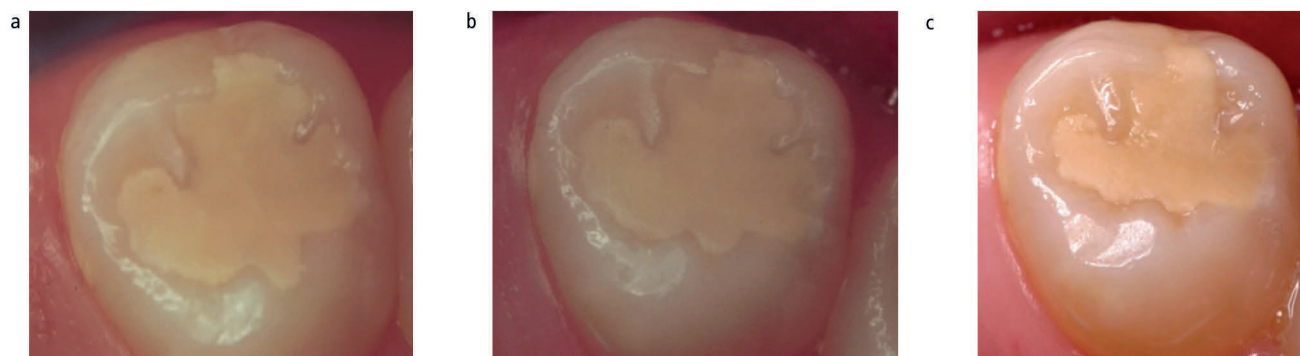


Fig. 4 ART restoration: (a) baseline; (b) after 2 years; and (c) after 10 years (Courtesy of Prof. F. de Lima Navarro)

caries. Both resin composite material and high-viscosity glass-ionomers performed using the ART approach showed good results.

Effectiveness of ART restorations

ART restorations have been assessed using the ART restoration criteria. On the basis of studies that compared the results of ART/HVGIC restoration survival assessed according to the ART restoration criteria and the United States Public Health Services (USPHS) and Federation Dentaire Internationale (FDI) criteria, it can be concluded that the ART restoration criteria fail restorations earlier. It is therefore safe to state that, had these ART/HVGIC restorations been assessed using only the USPHS or FDI assessment criteria, the survival results would have been slightly higher than reported in the literature.

The mean annual failure rate of single-surface and multiple-surface ART/HVGIC restorations in primary molars over 3 years was 5% and 17% respectively. The mean annual failure rate of single-surface ART/HVGIC restorations in permanent posterior teeth using high-viscosity glass-ionomers over the first 5 years was 4%.²² Very few studies have investigated the survival of ART restorations in multiple-surface cavities in permanent teeth, which means that no conclusion could be drawn regarding this issue. The meta-analysis revealed that secondary dentine carious lesion development in single-surface ART/HVGIC restorations in permanent pre- and molars occurred in 0.5% over the first five years (Fig. 4). In conclusion, it is appropriate to state that:

- ART using HVGIC can be used safely in single-surface cavities in both primary and permanent posterior teeth
- ART using HVGIC cannot be used routinely in multiple-surface cavities in primary posterior teeth
- Insufficient information is available for

conclusions to be drawn about ART restorations in multiple surfaces in permanent posterior teeth and in anterior teeth in both dentitions

- Secondary carious lesion development is rarely observed at the tooth-restoration interface of single-surface ART/HVGIC restorations in permanent teeth.

How do ART restorations compare with traditional restorations?

Systematic reviews and meta-analyses show that the longevity of ART/HVGIC restorations in primary teeth is no different from that produced using traditional methods with either amalgam^{28,29} or resin composite.^{30,31} In comparing ART and conventional restorations there appears to be no difference in the longevity of single-surfaces restorations in the permanent dentition.^{28,32,33}

Contemporary cariologic principles

The recommendations that emerged from the ICCC meeting are considered to have laid the foundations for understanding aspects of contemporary cariology. Managing to keep tooth surfaces free of carious lesions is, generally speaking, achieved by limiting consumption of predominantly free sugars and by removing biofilm from tooth surfaces daily, supported by a fluoride toothpaste. A sealant, whether resin- or glass-ionomer-based, is considered to be the treatment that gives the best results in managing enamel carious lesions in the long term.³⁴ A sealant is also under investigation for managing micro-cavities and non-cavitated dentine carious lesions. As explained in the section 'Managing enamel carious lesions' earlier in the present paper, there are other agents that have been shown to prevent the occurrence of carious lesions in enamel.

According to the recommendations of the

ICCC, cavitated dentine carious lesions are managed through removing soft, completely demineralised dentine and leaving demineralised dentine that is remineralisable behind. The ICCC guidelines for the removal of carious tissue can be summarised as:⁷ 1) preserve non-demineralised and remineralisable tissue; 2) achieve an adequate seal; 3) avoid discomfort/pain and dental anxiety; 4) maintain pulpal health; and 5) maximise longevity of restoration.

ICCC recommendations

How does the ART concept relate to the recommendations on carious tissue removal formulated by the ICCC?

With respect to the prevention of dentine carious lesion development, the meta-analysis by De Amorim *et al.*²² has shown that ART/HVGIC sealants are very reliable in keeping vulnerable tooth surfaces free from the presence of dentine carious lesions. The preventive effect of ART/HVGIC sealants is no different from that of resin-composite sealants as shown in the section comparing ART sealants and resin-composite sealants in the present paper. In erupting permanent molars, the ART/HVGIC sealant appears to be an even better choice than a resin-composite sealant because of the hydrophilic nature of the glass-ionomer as compared to the hydrophobic nature of the resin composite, which requires a high level of moisture control that is often difficult to achieve.³⁵

A comparison of the ICCC recommended principles regarding carious tissue removal and dentine cavity treatment according to the ART method is presented in Table 2. The ART treatment approach is in line with all five ICCC principles. In particular, the principle of avoiding discomfort/pain and dental anxiety features more prominently in ART than in the traditional drill and fill treatments. As many

Table 2 Comparison of ART cavity treatment principles with the ICCC recommended principles regarding carious tissue removal

Principles ICCC	Principles ART	Agreement
Preserve non-demineralised and remineralisable tissue	Only soft 'infected' dentine is removed and 'affected' dentine remains ^{3,20}	Yes
Achieve an adequate seal	HVGIC bonds well to enamel and dentine. ^{39,40} Secondary dentine carious lesion development over 5-years is rare. ²² ART restorations are sealant-restorations, which provide extra protection	Yes
Avoid discomfort/pain and dental anxiety	Pain and discomfort are low. ⁴¹⁻⁴³ Dental anxiety is low and less than with traditional restorative treatment ²¹	Yes
Maintain pulpal health	Using ART, soft, decomposed dentine is left on the floor of a deep cavity as recommended by ICCC. ⁷ Abscess/fistulae occurrence with ART restorations in primary teeth no different from comparable amalgam restorations ¹⁰	Yes
Maximise longevity of the restoration	Survival percentages of single-surface ART/HVGIC restorations in primary and permanent teeth are no different from comparable restorations with amalgam and resin composite (primary dentition) ^{29,31}	Yes

people report dental anxiety after the traditional treatment – in The Netherlands 24% in an age group of 18-93, with the highest proportion among 21- to 25-year olds³⁶ – it is suggested here that the restorative treatment of a primary dentine carious lesion is first approached through the ART method. If ART is not indicated, only then should the dental practitioner resort to the traditional treatment, preferably through opening the cavity with a bur and removing carious tissue from within the cavity with an excavator hand instrument. Pain, discomfort and dental anxiety should be controlled as much as possible, as people who suffer from dental anxiety often develop poor oral health.

Currently, a number of so-called atraumatic treatments exist that are applicable for use in primary teeth. These include, besides ART, application of sdf, the Hall-technique and the removal of biofilm from open cavities. In paediatric dental care, therefore, these atraumatic treatments have gained an important place alongside (traditional) restorative care.

Concluding remarks

The way the dental profession manages dental caries ought to be changed. Dental caries is preventable and it is, therefore, unacceptable that untreated cavitated dentine carious lesions in permanent and primary teeth are numbers one and ten respectively on the list of most prevalent medical conditions investigated during the period 1990–2010.³⁷ This outcome calls for a greater emphasis on keeping healthy teeth healthy, right from birth into old age.

People need to be convinced that a diet that is low in sugar consumption and twice daily tooth brushing with a fluoridated toothpaste are an absolute necessity. The major task of the dental profession is to guide the public in creating an environment at home, at school, in the workplace and in institutions in which these two carious lesion-preventive actions can be exercised. This requires, among other things, that many dental training institutions shift the emphasis in the curriculum from teaching young students predominantly cavity-curing topics to teaching them also cavity-preventive topics. The MID concept is the way forward and is being implemented in a number of countries.¹

ART is a well-researched example of a treatment concept that has a place within MID. It concurs with the principles of carious lesion management and carious tissue removal as recommended by the ICCC. Because of the patient-friendly nature and quality performance of ART, dental practitioners should seal vulnerable pits and fissures in (erupting) molars with an HVGIC according to the ART method and they should consider attempting the treatment of a primary dentine carious lesion first through ART.

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