Minimal intervention dentistry: part 5. Atraumatic restorative treatment (ART) – a minimum intervention and minimally invasive approach for the management of dental caries

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VERIFIABLE CPD PAPER

While originally developed in response to a need to provide effective restorative and preventive treatment in underserved communities where running water and electricity might not always be available, over the past two decades, the atraumatic restorative treatment (ART) approach has become a worldwide phenomenon; used not only in some of the poorest developing countries but also in some of the most wealthy. The ART approach involves the removal of infected dentine with hand-instruments followed by the placement of a restoration where the adjacent pits and fissures are sealed simultaneously using high viscosity glass-ionomer inserted under finger pressure. Reliable results can only be obtained if the treatment protocol, as described in this article, is closely followed. ART should be considered as a therapeutic option especially in children, anxious patients and those with special needs.

IN BRIEF

- Describes the clinical aspects of the atraumatic restorative treatment (ART) approach.
- Stresses the importance of following the treatment protocol to ensure reliable results and reviews the evidence base supporting its use.
- Suggests ART should be considered as a therapeutic option especially in children, anxious patients and those with special needs.

PRACTICE

MINIMAL INTERVENTION DENTISTRY

1. From 'compulsive' restorative dentistry to rational therapeutic strategies
2. Caries risk assessment in adults
3. Paediatric dental care – prevention and management protocols using caries risk assessment for infants and young children
4. Detection and diagnosis of initial caries lesions
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6. Caries inhibition by resin infiltration
7. Minimally invasive operative caries management – rationale and techniques

This paper is adapted from: Holmgren CJ, Roux D, Doméjean S. Traitement restaurateur atraumatique (ART). Une approche a minima de la prise en charge des lésions carieuses. *Réalités Cliniques* 2011; **22:** 245–256.

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Accepted 21 June 2012
DOI: 10.1038/sj.bdj.2012.1175

INTRODUCTION

Atraumatic restorative treatment (ART) was developed in the 1980s but embodies all the principles of an alternative philosophy of dental care that was ultimately to become known as minimal (or minimum) intervention dentistry.[1,2] Minimal intervention management of caries attaches importance to the diagnosis and evaluation of caries risk and includes prevention, stabilisation and healing (remineralisation) of early lesions and minimally invasive restorative treatment for cavitated dentine lesions with selective excavation of destroyed tissue combined with maximal preservation of healthy tissues. While developed originally in response to a need to provide effective restorative and preventive treatment in underserved communities, over the past two decades the ART approach has become a worldwide phenomenon. ART can be considered to be a cornerstone of minimal intervention caries management in combining prevention and minimal invasion.

The objectives of this paper are to:

1. Describe the philosophy of the ART approach within the overall concept of minimal intervention and minimal invasion for the management of dental caries
2. Describe the clinical aspects of ART
3. Review the evidence base for supporting the use of ART
4. Describe the indications for ART.

WHAT ARE ART SEALANTS AND RESTORATIONS?

Over the past 20 years some confusion has arisen as to what constitutes the atraumatic restorative treatment (ART) approach since a number of authors use the term to describe procedures that are not considered to be ART. To avoid confusion a recent definition by Frencken and van Amerongen should be adopted as follows: 'ART is a minimally invasive approach to both prevent dental caries and to stop its further progression. It consists of two components: sealing caries prone pits and fissures and restoring cavitated dentin lesions with sealant-restorations. The placement of an ART sealant involves the application of a high-viscosity glass-ionomer that is pushed into the pits and fissures under finger pressure. An ART restoration involves the removal of soft, completely demineralised carious tooth tissue with hand instruments. This is followed by restoration of the cavity with an adhesive dental material that simultaneously seals any remaining pits and fissures that remain at risk'.[3]

This definition implies that if any other method is used to prepare the cavity, for example, use of rotating instruments to open a cavity or the use of non-adhesive restorative material this cannot be considered as ART nor should the term 'modified ART' be used since this may lead to confusion.[4]

The philosophy and science behind the ART approach

The sealing of fissures with sealants has been shown to be an effective approach both for the prevention of fissure caries lesions *de novo* and for the prevention of the progression of early lesions in this site.[5-8] As such, sealants, including ART sealants that use a high-viscosity glass-ionomer cement (GIC), play an essential role in a minimal intervention and non-invasive approach.[9]

The principle by which preventive and therapeutic sealants function is by providing a physical barrier that excludes bacteria and their nutrients from pits and fissures that cannot be cleaned and that have minimal access to saliva and fluoride. There is no reason why this principle shouldn't be extrapolated to situations where the caries process has extended into the dentine resulting in frank cavitation but without pulpal involvement. Here, the major constraint of a cavitated caries lesion is that in order to achieve a seal to the cavity and to render the external surface cleansable, there is a need to place a restoration, preferably with an adhesive material.[10,11]

If a restoration is required for caries control in cavitated lesions then the next question is how best to restore the cavity. Ideally the objectives should be to retain a maximum amount of sound tooth tissue for strength, make the restoration as small as possible so it is long lasting and to seal the adjacent pits and fissures that are of high caries risk (placement of a sealant restoration). Adhesive restorative materials, namely composites and GIC, have revolutionised cavity restoration since the need to destroy sound tooth tissue to achieve mechanical retention, as was the case for amalgam, has been greatly reduced. Furthermore, a better understanding of the histopathology of the dentine caries lesion means that a minimally invasive cavity preparation can safely be used. The term 'cavity preparation' is better named 'cavity cleaning' since it emphasises the more biological approach that ART and other minimal invasive approaches adopt over purely mechanistic approaches.

Over 50 years ago, Fusayama and Massler independently showed that the dentine caries lesion could be divided into two layers.[12-14] The layer closest to the opening into the cavity defined as 'outer carious dentine' or 'infected dentine' is a soft, infected biomass that has no sensation and is largely incapable of being remineralised. As such it is of no further structural use to the tooth and therefore should be removed (Fig. 1). The deeper part of the dentine caries lesion, that which is more distant from the opening of the cavity, is harder since the mineral content is higher. This is called 'inner carious dentine' or preferably 'affected dentine'. This often darker and stained layer is vital, minimally affected with bacteria and has the potential to remineralise. It is therefore logical to retain this layer. If rotary instrumentation is used to clean (prepare) the cavity, tactile feedback that enables the distinction between the softer infected dentine and the harder affective dentine is compromised. This often leads to excessive cavity preparation and unnecessary removal of sound tooth tissue or that which has the potential to remineralise.[15,16] While a number of alternatives to rotary instrumentation for cavity cleaning exist, the best compromise between effectiveness of caries removal and efficiency has been shown to be the use of hand-excavators.[15,16] These are used for cavity cleaning in the ART approach since they are readily available and, as they do not rely on electricity or running water, can be used both in the traditional dental clinic environment and for outreach situations where dental facilities do not exist.

It is important to emphasise that the ART approach to manage cavitated caries lesions does not intentionally leave soft, infected dentine behind in the cavity. The sole exception might be in deep caries lesions where there is a risk of pulpal exposure. As is now becoming common practice, in such cases soft dentine is retained deliberately and the cavity filled and sealed with a sealant restoration. The deliberate leaving of soft dentine caries in a cavity is contrary to traditional

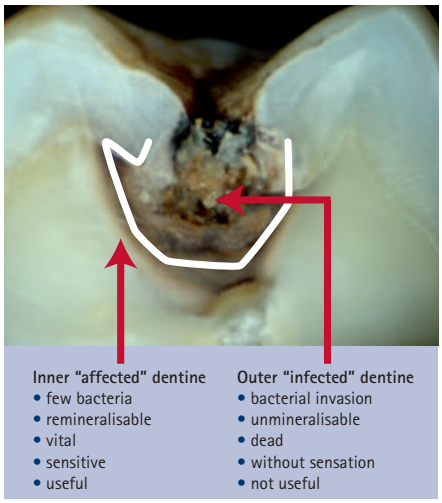

Fig. 1 Layers of a dentine caries lesion. The 'outer carious dentine' or 'infected dentine' is soft and infected and should be removed. The 'inner carious dentine' or 'affected dentine' can remineralise and should be retained

Fig. 2 A small enamel hatchet used to open access to underlying softened dentine

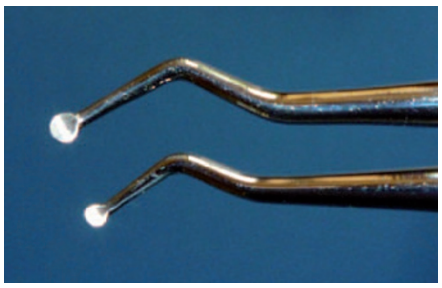

Fig. 3 Two spoon-shaped excavators, one small with a spoon approximately 1 mm across, another slightly larger are used to excavate soft dentine

Fig. 4 A small flat plastic instrument is used for applying the GIC and for shaping the restoration. An 'Ash 6 special' is shown here

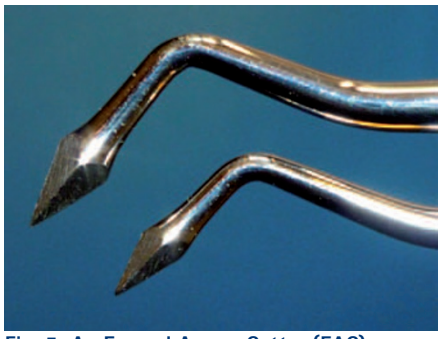

Fig. 5 An Enamel Access Cutter (EAC) can be used to access the cavity when the enamel hatchet is too large

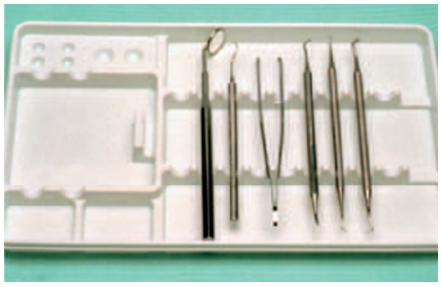

Fig. 6 The instruments are laid out in the sequence that they are going to be used

Fig. 7 The tooth surface is cleaned by rubbing with a damp cotton wool pellet and then dried with a dry pellet or a triple syringe

dictum but there is little evidence that infected dentine must be removed before sealing the tooth with a restoration.[17–19] Conversely, there is now a substantial evidence base from long-term studies that caries lesions that are sealed in place do not progress and might even regress.[11,20–22] This is consistent with the principles of therapeutic sealing since if cariogenic bacteria are isolated from their source of nutrition they either die or remain dormant and therefore cannot result in caries lesion progression.[23–27]

While the notion of intentionally leaving a limited amount of soft, infected dentine behind in a cavity to be restored might be totally contrary to what has been taught in dental schools over the years, the unsubstantiated dangers of such an approach must be balanced against the real dangers of complete removal of all soft infected dentine in deep lesions, which have been shown to lead to an increased number of pulpal exposures.[19,28] It is therefore not only logical but also good practice to retain some soft caries on the pulpal floor of deep caries lesions when there is a likelihood of causing a pulpal exposure in a vital and otherwise symptomless tooth, irrespective of the restoration method used.

PRACTICAL CONSIDERATIONS WHEN USING ART

Instruments required

Under normal situations no special instruments are needed to perform ART since most can be found in a normal dental clinic. The instruments required are as follows:

- Mirror, probe and tweezers
- A small enamel hatchet to open access to underlying softened dentine (Fig. 2)
- Two spoon-shaped excavators, one small with a spoon approximately 1 mm across, another slightly larger (Fig. 3). These are used for the removal of soft dentine. The larger excavator can also be used for packing filling material under enamel and for the removal of excess filling material
- A small flat plastic instrument for applying the GIC and for removing excess filling material and for shaping the restoration. An 'Ash 6 special' is ideally suited to this purpose (Fig. 4).

In addition to this basic set of instruments, a special instrument might be necessary. The 'Enamel Access Cutter' (EAC) has been developed to access smaller cavities where the blade of the enamel hatchet might be too large (Fig. 5). To reduce hand fatigue it is recommended that the instruments have a wide handle.

Materials required

In addition to the normal consumable materials that are found in a dental practice, for example, cotton wool rolls, petroleum jelly (Vaseline) etc, the only other requirement is a high-viscosity, high-strength GIC. Encapsulated GIC generally produce a more consistent mix but are usually more expensive than hand-mixed GIC. Furthermore, if an encapsulated GIC is to be used then a separate dentine conditioner will be required. Fuji IX™ (GC International), Ketac™ Molar (3M ESPE) and Chemflex™ (Dentsply) have been validated for use for ART. Other GIC that purport to be suitable for ART should only be used if there is evidence that they are effective.

ART RESTORATIONS STEP-BY-STEP

For experienced dentists the ART approach might at first appear simple and straightforward. However, reliable outcomes can only be achieved if the following steps are rigorously adhered to.

Step 1. Preparation of the ART instruments and materials before the clinical procedure

Before starting the clinical procedure ensure that all the instruments and consumable materials are laid out in a logical and ordered manner. They should be arranged in the sequence that they are going to be used (Fig. 6). Since cotton wool pellets are used for many steps in the ART approach, it saves time to separate an adequate number of these into individual pellets of suitable size beforehand.

Step 2. Isolation of the operating site

As for all restorations, isolation is important since contamination of the operating site with saliva or blood will affect bonding of the GIC to the tooth surface. For ART, a rubber dam is not necessary since isolation with cotton rolls is adequate. These must be changed as soon as they are saturated with saliva.

Step 3. Examining the cavitated tooth

Once the operating site has been correctly isolated, the tooth and the extent of caries lesion can be examined more easily. To assist in this task, carefully remove any plaque or food debris from the pits and fissures with a dental explorer, taking care not to create additional cavitation. The tooth surface is then cleaned by rubbing with a damp cotton wool pellet, followed by drying the surface with a dry pellet or gently with a triple syringe (Fig. 7). Discoloured or translucent enamel usually indicates demineralisation where the enamel might be weak and where the caries process might have

spread laterally along the enamel-dentine junction (EDJ).

Note: unlike for conventional restorations, a local anaesthetic is very rarely required since only necrotic tooth tissue is being removed during cavity cleaning. However, an anaesthetic can be given at the request of the patient.

Step 4. Gaining adequate access to the caries lesion

In small caries lesions, where the opening into the cavity is small, it is often necessary to widen the access. A dental hatchet is used ensuring that the instrument is correctly stabilised using an appropriate finger rest. The corner of the hatchet is placed in the entrance of the cavity, usually in the deepest part of the pit or fissure for the occlusal surface, and the instrument tip rotated backwards and forwards while maintaining slight pressure (Fig. 8). This fractures off the weak demineralised enamel surrounding the cavity entrance, permitting adequate access to the dentine caries for the smallest excavator. As mentioned above, an EAC can also be used to improve access to a caries lesion. This instrument is placed in the cavity opening and rotated in a similar way as the hatchet to fracture off weak demineralised enamel. The EAC has two pyramidal shaped working tips, one large and one small. The largest tip can be used when the cavity opening is relatively wide, but needs to be opened further; the smaller tip being used in small openings where there might be difficulty in using the hatchet.

Note: the EAC should not be used for creating cavities where they do not exist. If in doubt about the presence of a possible lesion it is better to place a therapeutic sealant without any mechanical preparation.

Step 5. Cavity cleaning

Hand excavators are used to remove soft, infected dentine. Cavity cleaning starts with the removal of soft dentine from the EDJ. Here the smallest excavator is used making circular scooping movements under the enamel (Fig. 9). This so called 'unsupported' enamel only needs to be removed if it is thin and weak or if additional access is required to complete removal of soft dentine at the EDJ. Here, some of the enamel can be gently fractured off with the blade of the hatchet along the line of the enamel prisms (Fig. 10).

Note: there is no danger in leaving sound, 'unsupported' enamel since it effectively becomes 'supported' when the cavity is restored with GIC.

Soft dentine from the rest of the cavity is now removed with the larger excavator as access permits. Care must be taken in deep cavities where there is danger of exposing the pulp. It is advisable not to exert excessive pressure on the pulpal floor with a small excavator since this increases the likelihood of exposure. For deep cavities close to the pulp it is better to leave some soft dentine on the pulpal floor than risk exposing the pulp. The resultant cavity is then washed and gently dried. In outreach situations a wet cotton wool pellet is used and the cavity dried with a dry pellet. Note, that since a local anaesthetic is not routinely used, luke-warm water for rinsing is preferable to reduce tooth sensitivity during this stage. The use of a triple syringe is not recommended. The cavity is then examined carefully and additional cavity cleaning is undertaken if necessary. It is important that stained or discoloured dentine that is hard should be retained.

There is normally no indication to use a lining material for an ART restoration except in the deepest of cavities. Here a setting calcium hydroxide liner can be used but only at the spot closest to the pulp. Excessive use of lining material will reduce the surface area available for bonding of the GIC.

Step 6. Conditioning the cavity and adjacent pits and fissures

The use of hand instruments on the dentine surface results in a smear layer. In order to improve the chemical and mechanical bonding of the GIC to the tooth tissues this smear layer must be removed by the use of a dentine conditioner. When using encapsulated GIC it will be necessary to use a separate dentine conditioner specially developed for this purpose. This differs from the liquid used for acid-etching for composites since a dentine conditioner usually contains a solution of between 10-40% polyacrylic, tartaric and/or maleic acid. Because of the difference in dentine conditioners available, it is important to carefully follow the manufacturer's instructions. If a hand-mixed powder-liquid GIC is used the liquid component of the GIC can be used as the conditioner. The concentration is often too high and needs to be reduced. This can be achieved easily by dipping a cotton wool pellet in water, removing excess on a paper towel and then dipping this moist cotton wool pellet in a drop of the liquid component of the hand-mixed GIC.

Note: the liquid component of GIC can only be used for conditioning if it contains the acid component of the GIC. There are some brands of GIC where the liquid component consists of demineralised water only, the acid being in the powder in a freeze-dried form. Under such circumstances a

Fig. 8 The corner of the hatchet is placed in the entrance of cavity, usually in the deepest part of the pit or fissure for the occlusal surface and the instrument tip rotated backwards and forwards while maintaining slight pressure

Fig. 9 The smallest excavator is used to remove soft dentine from the enamel dentine junction by making circular scooping movements under the enamel

Fig. 10 Where more access is required, some of the enamel can be gently fractured off with the blade of the hatchet along the line of the enamel prisms

Fig. 11 The GIC is inserted into the cavity in small increments using the rounded end of the applier/carver instrument. Where possible, pack the GIC under any overhanging enamel first, before filling the central portion of the cavity

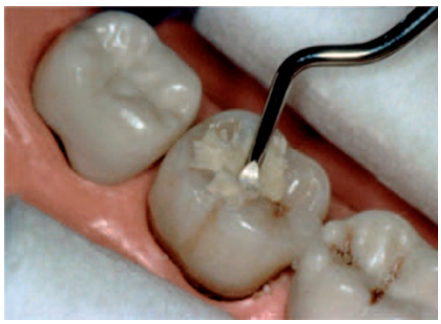

Fig. 12 Slightly overfill the cavity and then place additional GIC in any pits and fissures adjoining the cavity

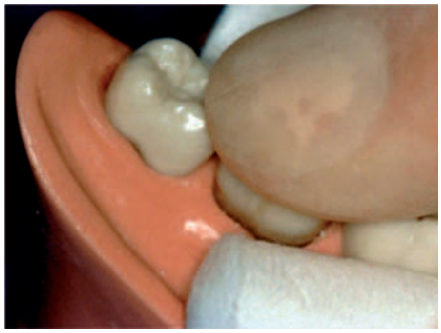

Fig. 13 The tip of the index finger is then placed onto the central part of the restorations to enable the GIC to be pressed firmly into the cavity, pit and fissures

separate dentine conditioner must be used.

The conditioner is applied to the cavity and pits and fissures using a cotton wool pellet for 15-20 seconds or for the period of time specified by the manufacturer. Bond strength is affected if insufficient or too long a time is allowed for conditioning. Wash the cavity and pits and fissures with pellets dipped in clean, luke-warm water and then dry carefully. If a triple-syringe is used, take care not to over-dry the cavity since this will tend to reduce the chemical bonding of the GIC to the dentine.

Note: At this stage proper isolation is essential. Contamination of the conditioned tooth surface with saliva or blood will have a negative effect on the bonding of the GIC to dentine and enamel. Therefore, if the conditioned tooth surface becomes contaminated it is essential to wash and dry it, recondition, wash and dry it again.

Fig. 14 The excess GIC is displaced to the outer margins of the occlusal surface and will need to be removed as soon as possible with the carver or large excavator taking care not to dislodge the restoration

Fig. 15 The finished restoration is then covered with petroleum jelly or varnish and the patient advised not to eat for at least one hour

Step 7. Mixing GIC

A consistent and correct mix of GIC is essential for reliable results. Always follow the manufacturers' instructions. This involves following recommendations for mixing time and finishing the restoration within the specified working time. For hand-mix GIC, the correct powder to liquid ratio must be maintained since too much powder or too much liquid can result in a weaker restoration.[29] If a hand-mix GIC is used, those for ART have a high powder-to-liquid ratio and are usually more difficult to mix than other GICs, thus special care needs to be taken. The consistency of the final mix does, however, vary between different manufacturers.

Step 8. Restoring the cavity and filling the pits and fissures

The mixed GIC must be used promptly since any delay will compromise bonding to the tooth surface. The GIC is inserted into the cavity in small increments using the rounded end of the applier/carver instrument. Where possible, pack the GIC around the margins of the cavity, particularly under any overhanging enamel, before filling the central portion of the cavity (Fig. 11). This helps to prevent air bubbles from being incorporated into the restoration. Overfill the cavity slightly and then place additional GIC in any pits and fissures adjoining the cavity (Fig. 12).

Rub a small amount of petroleum jelly on the gloved index finger. Spread the petroleum jelly thinly over the tip of the gloved index finger with the thumb. Then, place the index finger on the occlusal surface and press the GIC firmly into the cavity, pit and fissures (Fig. 13). Roll the ball of the finger slightly bucco-lingually and then mesio-distally so that material is spread over the whole occlusal surface. This is called 'the press-finger technique'. After at least ten seconds, slide the finger sideways to prevent the restorative material from lifting out of the cavity or pits and fissures. The press-finger technique results in excess GIC being displaced to the outer margins of the occlusal surface. Remove this excess as soon as possible with either the carver instrument or the large excavator, taking care not to dislodge the restoration (Fig. 14). Ensure that the proximal areas are clear of excess GIC.

Note: in the event that insufficient GIC has been mixed to ensure the cavity and fissures are completely filled, pack this first mix into the cavity with the applier but DO NOT use the press-finger technique at this stage. While maintaining good moisture control, a second batch of GIC is mixed that can then be used to completely fill the cavity and pits and fissures.

Step 9. Finishing the ART restoration

Before the GIC becomes too hard, the occlusion is checked with articulating paper. Any parts of the restoration that are too high can be adjusted using the carver instrument or the large excavator. The finished restoration is then covered with petroleum jelly or varnish (Fig. 15). Ask the patient to avoid eating for at least an hour.

Note: the dentist can adapt the clinical procedures according to the equipment available and his normal working practice. For example, a local anaesthetic can be used, a rubber dam can be placed, and a

rotary instrument instead of a hatchet can be used to gain minimal access to the body of the lesion. The use of rotary instruments is, however, specifically not part of the classic ART approach. Since the ART approach, as has been described above, provides satisfactory clinical results (see our section on the evidence base), there is no need to overload the clinical procedures with methods or equipment that may raise anxiety in patients (eg rotary instruments are often not accepted by children and dental phobics).

ART SEALANTS STEP-BY-STEP

The only difference between placing an ART restoration and an ART sealant is that with the latter there is no cavity to clean and restore. Otherwise all the other steps and materials remain identical.

The same high-viscosity GIC is used but cavity preparation is not undertaken. Thus, techniques of isolation, cleaning, conditioning and filling of the pits and fissures remain identical. The steps are therefore summarised as:

- Step 1. Preparation of the ART instruments and materials before the clinical procedure
- Step 2. Isolation of the operating site
- Step 3. Cleaning the pits and fissures and examination of the tooth
- Step 4. Conditioning the pits and fissures
- Step 5. Mixing the GIC
- Step 6. Filling the pits and fissure
- Step 7. Press-Finger
- Step 8. Finishing the ART sealant (Fig. 16).

THE EFFECTIVENESS OF ART – WHAT IS THE EVIDENCE BASE?

Ideally all dental care decisions and treatments should be based on a sound research evidence base, this being the basis of evidence-based dentistry. This helps to ensure that dental care is both safe and effective. Unfortunately, the evidence base to support the effectiveness of many of the commonly performed treatments in dentistry is limited both in quantity and quality.[30,31] Gradually, properly conducted systemic reviews of dental treatment approaches are appearing in the literature and there are attempts by a number of organisations to sensitise and educate the dental profession (Cochrane, NICE, American Dental Association, etc). Despite initiatives by organisations such as the Centre Français d'Evidence Based Dentistry, which has started to make some Cochrane reviews available in French, there remains a dearth of information in the French language.

Since its early development, ART has constantly been subject to research evaluation and remains one of the most researched minimal intervention approaches with currently over 200 publications on the subject. With respect to the effectiveness of the approach a number of systematic reviews and meta-analyses have been undertaken. The first meta-analysis of the effectiveness of single-surface ART restorations in the permanent dentition was published by Frencken *et al.* in 2004.[32] This study, based on an analysis of five studies reported no difference in survival results over three years between single-surface ART restorations and amalgam restorations. It also indicated that results were better from the then more recent studies as the ART approach evolved and better restorative materials became available.

The interest in the ART approach led to a substantial number of research publications on the subject during this time that permitted a second more comprehensive meta-analysis to be undertaken in 2006.[33] Here, 28 studies were included in the analysis. The high mean survival rates for single-surface ART restorations using high-viscosity GIC in permanent dentitions found in the previous meta-analysis was confirmed and a survival rate of 72% over a period of six years was reported.[32] Similarly, in primary teeth single-surface ART restorations using high-viscosity GIC had a high mean survival rate of 95% after one year and 86% after three years. The survival rates of multiple-surface ART restorations in the primary dentition were low with a mean annual failure rate of 17%.

The most recent meta-analysis of ART survival based on 29 publications reported that for single-surface ART restorations in permanent teeth over the first three and five years the mean survival rates were 85% and 80% respectively and 86% for multiple-surface ART restorations in permanent teeth over one year.[34] The survival rates of single and multiple-surface ART restorations in primary teeth over two years were 93% and 62% respectively. A systematic review comparing the longevity of ART and amalgam restorations concluded that,

Fig. 16 A completed ART sealant

in the permanent dentition, the survival of ART restorations is equal to or greater than that of equivalent amalgam restorations for up to 6.3 years and is site-dependent.[35] In primary teeth no difference in survival outcomes between the two types of restoration was observed.

ART has also been used in institutionalised elderly populations for treating root surface caries where short-term results suggest that ART restorations compare favourably with traditional approaches to treat such lesions.[36] In this context, an earlier study where ART restorations were provided for housebound Finnish elderly also showed high success rates.[37]

With respect to the evidence base for ART sealants, the meta-analysis of van't Hoff *et al.* in 2006 found that the number of studies reporting on the retention and caries preventive effect of ART sealants was low but based on available evidence the mean survival rate for partially and fully retained ART sealants in permanent dentitions using a high-viscosity GIC was of the order of 72% after three years.[33] In terms of effectiveness in preventing caries over this time period, 97% of sealed teeth remained sound. The more recent meta-analysis by de Amorim *et al.*[34] showed that the caries prevention effect of ART sealants was high.

A summary of the evidence base for ART is that:

- Single-surface ART restorations using high-viscosity GIC in both primary and permanent teeth show high survival rates and can therefore be safely used
- The survival rate for multiple surface ART restorations in primary teeth is rather low
- ART restorations have the ability to

outperform amalgam restorations in terms of survival
- ART sealants have a high caries preventive effect.

INDICATIONS FOR THE ART APPROACH

As with all preventive and restorative approaches ART must not be considered a panacea and therefore careful case selection is essential. The indications for ART are based on the strengths of the approach for certain situations combined with the evidence base for its effectiveness. Thus, the indications can largely be divided into two levels, the patient and the tooth.

Indications at the patient level

At the patient level, one of the major strengths of the ART approach is that it is well accepted by patients. The high acceptance is because, unlike most traditional restorative treatment of vital teeth, ART rarely requires a local anaesthetic. This is largely because of the minimally invasive nature of the approach where only necrotic tissue is removed and where remaining sound tissue is retained. Moreover, since rotary instrumentation is not used with ART, the threatening sound from this and the necessary high-volume suction is absent. In this respect, a recent review on dental anxiety and pain relating to the ART approach concluded that the ART approach has been shown to cause less discomfort than other conventional approaches and is, therefore, considered a very promising 'atraumatic' management approach for use in carious lesions in children, anxious adults and possibly dental-phobic patients.[38]

The other major strength of the ART approach is that it can be used equally well in a dental practice setting as in an outreach environment such as in schools or in old people's homes. The concept of delivering care outside the dental practice setting is largely alien to the dental profession. In France, as in many developed countries, little dental care is delivered outside the traditional dental clinic environment. This does, however, limit the coverage of dental care to those persons who can easily access a dental clinic or are adequately motivated to do so. As an example, in France for children at age six, two thirds of dental cavities in primary teeth are not treated. Similarly, in 12-years olds, only half the decayed teeth are restored.[39] The reasons for this lack of care is obviously multifactorial but demands the question whether other models of delivery of oral care using approaches such as ART could be explored in France, for instance providing prevention and caries management within the schools as is done in other countries.[40]

Likewise, non-mobile elderly or physically and mentally handicapped people might not easily be able to access the dental clinic. Although oral health data for the elderly in France is limited, a report by the Haute Autorité de Santé (HAS) showed that elderly people have little access to dental care and that between 30-60% require restorative treatment.[41,42] Here some extractions and restorative care using the ART approach could be delivered in their homes without resort to expensive portable dental equipment.[36,37]

Indications at the tooth level

The indications at the tooth level are based on the best evidence from clinical studies. There is now evidence to show that ART single-surface restorations using high-viscosity GIC have a high survival rate in both primary and permanent teeth that is comparable to, if not better than, traditional amalgam restorations.[34,35] Taken that ART restorations are both minimally invasive and caries protective when compared to other traditional restorative methods, ART restorations might therefore be considered a treatment of choice for single-surface caries lesions. The evidence suggests that ART restorations can be used for multiple surface caries lesions in primary teeth but that, as for other multiple-surface restorations in primary teeth, the survival rates are lower than those for single-surface restorations. There are limited data on the use of ART restorations for multiple-surface lesions in permanent teeth and therefore additional research is required on this aspect.

With respect to the use of sealants generally, their use should be targeted to individuals and teeth that are at high risk of developing caries and to teeth that are already exhibiting early caries lesions. This means that instead of adopting an invasive approach for initial or incipient caries lesions, the placement of sealant can effectively halt the progression of these lesions. Such an approach can potentially preserve tooth structure and lower the likelihood of future complex restorations.[8,43] ART sealants made using a high-strength high-viscosity GIC have the advantage over resin-based sealants in that they can be used where moisture control is less than optimal, for instance, in erupting teeth in high caries risk individuals or in younger children.

Irrespective of the type of sealant used, be it ART or resin-based, its placement is non-invasive. Therapeutic sealants can effectively halt the progression of initial or incipient caries lesions. Conversely, even if a minimal invasive approach is used to treat such a lesion, the tooth is condemned for life to the repeat restoration cycle.[43] Thus, therapeutic sealants using resins or ART can preserve tooth structure and lower the likelihood of future complex restorations.[8]

REPAIR OF ART RESTORATIONS

An important element of the minimal intervention approach is the repair of defective restorations rather than their total replacement.[9] Replacement of defective restorations is accompanied by a risk of increasing the size of the cavity thereby weakening the tooth if the defective restoration is removed in its entirety. Tyas *et al.*[9] discuss at length the decision-making process as to whether to leave, repair or replace what is deemed to be a defective restoration. Alternative treatments to replacement of both defective amalgam and resin-based composite restorations using refinishing, sealing of defective margins or repair, show the viability of this approach in the long term.[44,45] These principles can also be applied to ART restorations and sealants made with GIC. Indeed Christensen positively encourages the use of GIC for the repair of defective restorations.[46]

CONCLUSIONS

Over the past two decades ART, as a minimal intervention and minimal invasion approach for the management of dental caries, has proven to be a success in both developed and developing countries. There is now a strong evidence base to show that ART is a quality approach to control caries that is reliable and effective. As with many developments in oral health, but especially minimal intervention and minimal invasion approaches, the dental profession and the dental education system has been very slow to take these on board even though there is a strong

evidence base for these approaches. Thus the concepts that are described in this article might be alien and hard to accept by many dental practitioners who have had a traditional, rhetorical-based dental education. This is consistent with what is known as the research-application gap. In France, it appears that very few practicing dentists or dental academics are aware of the ART approach or other minimal intervention and minimal invasion approaches and the opportunities they can afford. Failure of the dental profession and the dental education system to embrace these approaches results in the oral health of our patients being placed at a disadvantage.

ADDITIONAL NOTE

The indications for ART at the patient level mentioned in this article relate to the situation in France with country-specific examples given. For example, while in France for children at age six, two-thirds of primary teeth with cavities are not restored, this figure is even worse in the United Kingdom where, according to the 2003 survey of children's dental health in the United Kingdom, for children age five, only one eighth of decayed teeth are restored on average. This does not imply that the authors advocate that all decayed primary teeth be restored.[47,48] With respect to 12-year-old children the situation appears better in the United Kingdom than in France since over half the decayed permanent teeth are filled.[47,48] In common with France, access to oral dental care in the United Kingdom is difficult for the elderly or handicapped.[49] For example, in one survey of nursing home residents in Avon, 63% were found to have root caries.[50] The commonality of untreated dental caries in both France and the United Kingdom points to the need to explore new approaches to the delivery of oral care. Atraumatic restorative treatment might be one of a number of approaches that could lead to an improvement of oral health in our populations.

The authors would like to thank Dr Jo Frencken for reviewing the manuscript and for kindly providing Figures 6 to 15 and Claudie Damour-Terrasson, publishing director of the Groupe Information Dentaire, Paris, France, for authorising the translation and publication of the series in the BDJ.

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