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Original article

Survival of occlusal ART restorations using high-viscosity glass-ionomer with and without chlorhexidine: A 2-year split-mouth quadruple-blind randomized controlled clinical trial



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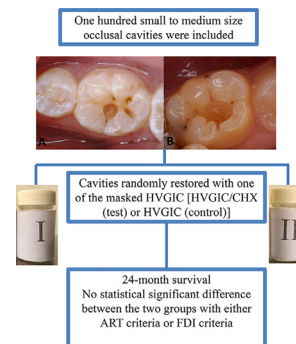
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HIGHLIGHTS

- Comparing the survival of HVGICs (with and without CHX) using ART criteria.
- Comparing the survival of HVGICs (with and without CHX) using FDI criteria.
- Compare the effect of the two restorations on caries development.
- No significant difference in the survival percentages between the two types of HVGICs.
- The addition of CHX to the HVGIC is not recommended.

GRAPHICAL ABSTRACT



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ABSTRACT

The study question was whether the use of high-viscosity glass-ionomer with chlorhexidine (HVGIC/CHX) for the Atraumatic Restorative Treatment (ART) prepared cavities could achieve a higher restoration survival percentage and be more effective for preventing dentine carious lesions adjacent to the restoration than the use of HVGIC without CHX. The study followed a split-mouth, quadruple-blind, randomized controlled clinical design and lasted 2 years. Patients with at least two small- to medium-sized occlusal cavities were included. The occlusal cavities were prepared according to the ART method and restored with HVGIC/CHX (test) and HVGIC (control). A replica of all restorations available and digital photographs were fabricated at baseline and after 0.5, 1, 1.5 and 2 years and evaluated by two examiners using the ART and Federation Dentaire Internationale (FDI) restoration assessment criteria. Survival curves were constructed using the Kaplan-Meier method, and the log-rank test was used to test for significance between the survival percentages. A total of 100 subjects with an average age of 14.4 years participated. According to the ART restoration assessment criteria, the 2-year survival percentages of ART/HVGIC/CHX (96.8%) and ART/HVGIC (94.8%) did not differ significantly and no significant difference was found between the test (97.9%) and control (96.9%) groups according to the FDI restoration assessment criteria. Eight and five occlusal restorations failed according to the ART and FDI restoration criteria, respectively. No dentine carious lesions along the restoration margin were observed. The 2-year survival of ART restorations in both groups was high. The development of carious dentine lesions adjacent to the restoration was

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not observed in either treatment group. There is no evidence for modifying HVGIC by incorporating chlorhexidine in order to prevent dentine carious lesion development or to improve the survival of ART restorations in occlusal surfaces in permanent teeth. HVGIC without chlorhexidine can be used successfully to restore occlusal 'ART-prepared' cavities in permanent teeth.

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Introduction

One of the minimal intervention dentistry (MID) concepts that emerged in the dental literature in the mid-1990s is the Atraumatic Restorative Treatment (ART) approach, which is considered a viable option for providing preventive and restorative care in private practice and in the field [1,2]. In contrast to the conventional stepwise excavation of carious lesions, the ART approach is performed in one session [3]. ART consists of removing soft, demineralized tooth tissue using hand instruments and restoring the treated cavity and adjacent pits and fissures with an adhesive restorative material that is usually a high-viscosity glass-ionomer cement (HVGIC) [2,4]. Because ART does not require electricity or running water, it is a very suitable treatment for use in community oral health programs in developed and developing countries that face difficulties in meeting the demand of care by relying solely on the traditional rotary treatment approach [1,5,6].

Several clinically tested HVGIC restorative materials possess unique biological, physical and chemical properties that make them useful as a preventive and restorative material with the ART approach. Their important properties include chemical adhesion to tooth structures, thermal compatibility with enamel and dentine, a good level of biocompatibility and the ability to remineralize demineralized dental tissue [7]. The removal of only soft, decomposed dentine while leaving firm, demineralized dentine behind means that the cavity still contains microorganisms. In shallow and medium 'ART-treated' cavities, it is unlikely that this situation will cause pathological problems. For deep cavities, the International Caries Consensus Collaboration (ICCC) recommends that soft, demineralized dentine tissue on the floor of the cavity be left behind; however, this recommendation has a low strength grading [3]. Additionally, according to the ICCC, lining may not be necessary as no significant difference was found in the survival of teeth with deep cavities (between 1/4 and 1/3 into dentine) that had been lined or not; however, this recommendation also has a low strength grading.

Evidence has revealed that demineralization-causing microorganisms left in prepared cavities become ineffective under properly sealed restorations. Nevertheless, clinicians are trained to remove microorganisms by cutting away partly demineralized dentine [8]. Others have applied disinfecting agents to ensure the absence of microorganisms before cavity restoration. According to the ICCC, there is no clinical evidence to support the use of cavity disinfection [3]. Alternatively, the use of an antimicrobial-containing restorative material might be a means of inhibiting microorganisms in cavities.

HVGIC materials have been shown to have an antimicrobial effect in laboratory studies [9,10]. This antimicrobial effect was significantly enhanced *in vitro* [11,12] and *in vivo* [13] when chlorhexidine (CHX) was added to HVGIC. A 7-day study showed a reduction in the total microorganism count in the area under restorations of HVGIC and HVGIC with chlorhexidine (HVGIC/CHX). However, the reduction in the number of microorganisms in the dentine was significantly greater in HVGIC/CHX-treated teeth than in HVGIC-treated teeth [13]. Unfortunately, no clinical studies using HVGIC/CHX as a restorative material could be found. A clinical study investigating the effect of CHX is relevant as laboratory studies have shown that adding CHX to HVGIC achieved a

positive antibacterial effect while not weakening the HVGIC [11,12], and such a study may provide evidence of whether HVGIC/CHX restoratives should be produced.

Therefore, this study investigated whether ART restorations with HVGIC/CHX would achieve a higher survival percentage and be more effective in preventing the occurrence of dentine carious lesions than ART restorations with HVGIC in occlusal cavities in permanent teeth. The null hypotheses were (1) there is no difference between the survival percentages of HVGIC and HVGIC/CHX restorations in occlusal cavities in permanent teeth treated according to ART; and (2) there is no difference in the occurrence of dentine carious lesions adjacent to HVGIC and HVGIC/CHX restorations.

Material and methods

Study setup and ethical aspects

A 2-year clinical study was conducted following a prospective, randomized, controlled, split-mouth, quadruple-blind (operator, patients, evaluators and statistician) design. The ethical committee of the Ministry of Health and Population, Government Health Insurance, Egypt, provided permission for the study to be performed (RHD-IRB0000687-13Oct2014-EM01). The trial was registered at International Standard Randomized Controlled Trials (Number: ISRCTN 16774328). The school authorities, the students and their parents were informed in writing about the content of the study. The parents were requested to complete a consent form. Only students whose parents had completed the form were allowed to enter the study.

The study population comprised students from 4 (2 for boys and 2 for girls) local governmental preparatory schools in Giza governorate, Cairo, Egypt, who had a comparable low to moderate socioeconomic status. These schools were selected as there was a dental clinic nearby that belonged to the government health insurance system where the study students were allowed to be treated. All students in the second and third preparatory years were screened at the school compound by the first (EM) and second (MS) authors. Students who met the inclusion criteria, which are presented in Table 1, were invited to participate. For each participant, the age, gender,

Table 1
Inclusion and exclusion criteria for students enrolment in the present study.

Inclusion criteria
<ul style="list-style-type: none"> • Healthy patients without a history of any medical disease or condition that could interfere with the study protocol or affect the clinical results. • Patients without oral habits that could affect the study results. • Presence of a natural antagonist. • Presence of at least two cavitated dentine carious lesions in an occlusal surface in first or second permanent molars situated on different sides of the jaw. • Site/Stage 1.2 or 1.3 occlusal cavities. • Absence of apparent enamel crack or fracture. • No pulp involvement or symptoms of pulpitis or apical periodontitis.
Exclusion criteria
<ul style="list-style-type: none"> • Poor oral hygiene. • Deciduous teeth. • Patients declaring daily consumption of substantial volume of citric juices.

grade, school name, phone number of both parents, complete home address, tooth type/location (according to the Federation Dentaire International [FDI] two-digit system), D3MFS and Simplified Oral Hygiene Index (S-OHI) [14] were recorded. The size of the cavitated dentine carious lesions was determined according to the Si/Sta classification [15]. Teeth with either a 1.2 or 1.3 score were included (Fig. 1). Non-study students who required treatment were referred to the regular school dental clinic.

Sample size calculation

On the basis of a significance level of 0.05, a power of 80%, the extrapolation of findings from an ART meta-analysis [16] that showed a 3-year survival percentage of 85 for single-surface ART restorations in permanent posterior teeth using hand-mixed HVGIC, and the expected 12% increase in survival percentage (97%) obtained from using HVGIC/CHX, the required sample size was determined to be 88 single-surface cavities per treatment group. Accounting for a student dropout rate of 10%, 97 samples per group were required for the 3-year period (PS Power and Sample Size Calculations Software, version 3.0.11 for MS Windows).

Restorative blinding and randomization

The restorative materials were available in two identical containers; one contained 1% HVGIC/CHX (GC Corporation Tokyo, Japan), and the other contained Fuji IX GP (GC Corporation Tokyo, Japan). Both materials were shade A3. The containers were masked by a non-study dentist who labelled the containers as “I” or “II” and kept the identity key secured. Two well-trained assistants helped with the mixing and handling procedures. They were also blinded to the identification of the restoratives.

Randomization of the two restoratives for the prepared cavities was performed as follows: 100 identical opaque sealed envelopes numbered from one to 100 were prepared. Each eligible student was asked to choose one envelope. The chosen number was taken as his/her identity code. If the number was odd, the molar on the right side was restored with material I while the molar on the left side was restored with material II. If an even number was chosen, the molar on the right side was restored with material II while the molar on the left side was restored with material I.

Operator training and ART cavity preparation and restorative procedures

Prior to producing ART restorations, the operator (MS) underwent theoretical (lectures) and practical training. Practical training was performed on patients to ensure standardization of the clinical

procedure. During five sessions (one/week), a total of 30 occlusal restorations were performed using the ART method under close supervision of the first author (EM), who had been trained by an experienced ART operator (the last author, JEF). ART treatments were provided on school days from March 2008 to May 2009 inclusive.

The ART method followed that recommended by Frencken et al. [4]. Isolation was achieved using cotton rolls only. Local anaesthesia (Mepivacaine-L, Alexandria Company for Pharmaceuticals, Alexandria, Egypt) was administered only on patient demand during clinical procedures. Cavities were prepared entirely using hand instruments, as follows: if needed to gain access to the carious dentine, the ART Cavity Opener (Henry Schein, NY, USA) was applied along with the ART Enamel Hatchet (Henry Schein, NY, USA). Soft carious dentine was excavated using small- and medium-sized ART Excavators (Henry Schein, NY, USA). Any weak undermined enamel that appeared after dentine excavation was removed using the enamel hatchet. The cavity was then rinsed using water-soaked cotton pellets. The cavity was dried using dry cotton pellets. Cavity dryness and wetness was maintained inside the cavity using small cotton pellets throughout the entire procedure. The floor and walls, of each prepared cavity, were conditioned using the manufacturer-supplied dentine conditioner (Cavity conditioner, GC, Tokyo, Japan) for 10 sec using a microbrush (Microbrush, São Paulo, Brazil). The conditioner was rinsed out using a small cotton pellet soaked in water until no visible remnants of the conditioner remained (approximately 10 sec). Then, the cavity was blotted using small cotton pellets (5 sec). The required number of bubble-free drops of restorative material liquid were dispensed, in accordance with the cavity size, mixed with the appropriate amount of powder with a plastic spatula on a paper pad according to the manufacturer's instructions.

The randomly selected restorative was placed in the prepared cavity, packed using the flat end of the ART applier/carver instrument (Henry Schein, NY, USA) and pressed into position for 30 sec using an index finger coated with a thin layer of petroleum jelly. Excess restorative material was removed using the carver end of the ART applier/carver instrument and a discoid excavator (Henry Schein, NY, USA). After removing excess material, the surface of the restoration was coated with petroleum jelly. The occlusion was checked using articulating paper (Hannel, Coltène/Whaledent GmbH, Langenau, Germany), and if found to be correct, the surface of the restoration was coated with another layer of petroleum jelly. The patient was instructed not to eat or to brush the restored side of the mouth for at least two hours and then to brush the teeth twice daily with a fluoride-containing toothpaste. Finally, the patient was advised to contact the operator (MS) in the case of any complaints or pain.

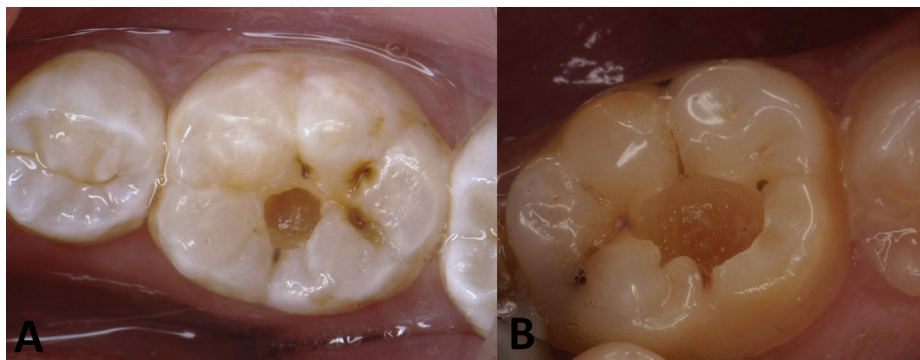


Fig. 1. Cavities indicated to be included in the study. A (Si/Sta 1.2); B (Si/Sta 1.3).

Restoration evaluation

Digital clinical photographs were taken preoperatively, after cavity preparation and at each of the 4 subsequent evaluations using a Nikon D40 digital camera (Nikon, Tokyo, Japan) and a Macro lens (Sigma Macro Lens, 105 mm, F2.8, Sigma Corp., Tokyo, Japan) with a ring flash.

Along with the digital clinical photographs, a replica of all restorations was made using a silicon base (putty/light material, two-step technique) (EXAFLEX Putty, GC Corporation, Tokyo, Japan) at each of the four evaluations. A sectional tray was cut short and modified to cover three teeth only: the treated tooth and the immediately mesial and distal teeth. The putty material was mixed according to the manufacturer's instructions, placed in the sectional tray and positioned on the area of interest under steady pressure applied using two fingers. After setting the impression material, the tray was removed from the mouth, rinsed, dried and checked. Excess putty material that extended into the buccal and/or lingual vestibules was cut away with a sharp knife. Light body paste (EXAMIX NDS, GC Corporation, Tokyo, Japan) was injected onto the occlusal surface, minimizing the incidence of air bubble entrapment over the adapted putty impression. Then, the tray with putty impression was resealed over the occlusal surface of the teeth. After setting the paste, the tray was removed from the mouth, rinsed, dried and inspected under illumination for the presence of any defects. A type IV extra-hard stone (Fuji Rock EP, GC Corporation, Tokyo, Japan) was poured into the impression to produce a replica of the restored tooth. A plaster base was fabricated for situating the set stone replica.

The students were contacted by phone to arrange an appointment for the follow-up assessment of the restorations at the school compound. If the research team failed to contact the student by telephone or to meet him/her at school because of absenteeism, a home visit was made for the collection of clinical photographs and a dental impression (MS, EM, and HE). Students who could not be contacted at all were considered to have dropped out.

Restoration evaluations were performed at baseline and after 0.5, 1, 1.5, and 2 years using the ART restoration criteria (codes 0–9) [17] and 5 categories of the set of criteria proposed by the FDI [18]. These categories include fracture and retention, marginal adaptation, wear, recurrence of caries, erosion and abfraction, and tooth integrity. According to both sets of criteria, which are internationally accepted, a restoration is failed for the presence of dental caries when a dentine carious lesion is present. Evaluation was carried out using digital photographs and replicas by two evaluators who did not participate clinically, as recommended by Hickel et al. [18], and who were blinded to the restorative material used. Baseline evaluations were performed one week after completion of the restorations [18] to exclude any faulty restorations (i.e., those with initial persistent pain, unbearable hypersensitivity or improper occlusal contacts). The 3-year evaluation could not be performed because of political circumstances in Egypt.

Statistical analyses

Imputation was performed for missing data over the five evaluation times (series) from the two constructed databases: one database comprised all 9 ART restoration codes, and one database comprised the success or failure (2 constructed codes) of the combined 5 categories of the FDI restoration criteria evaluated. In most cases, imputation was straightforward. Imputation was not straightforward in 22 series in the ART restoration criteria-related database and in 4 series in the FDI restoration criteria-related database. Using a flip of the coin, the score on the left and right side of the missing score was chosen alternately to complete a series.

The analyses were performed by a statistician using SAS 9.2 software (Cary, NC, USA). Survival curve estimation was performed using the Kaplan-Meier method. A log-rank test was used to test for differences in the survival percentage between the test and control groups. Because of the low number of failures in both groups and the high *P*-value for the difference between them, we decided not to apply a complex proportional hazard model including a comparison within subjects, which is normally used in survival analyses. Statistical significance was set at *P* = 0.05.

Results

The study CONSORT diagram is presented in Fig. 2. A total of 100 students (53 girls and 47 boys), with a mean age of 14.4 years (SD = 0.3; range, 13.1–14.9 years), met the inclusion criteria and had a signed consent form. The mean D₃MFS score was 4.02 (SD = 1.1), and the mean OHI-S score was 0.13 (SD = 0.1). The distribution of the restorations using the test and control restoratives by tooth type is shown in Table 2. The majority of restorations in both groups were placed in the first molars in the mandible. Only one local anaesthesia injection was administered.

The survival percentage and standard error of the test (ART/HVGIC/CHX) and control (ART/HVGIC) restorative materials by time interval are presented in Tables 3 and 4 according to the ART and FDI restoration criteria, respectively. The 2-year survival percentages of both occlusal ART restorations were high and were not statistically significantly different (*P* = 0.47, Table 3) and (*P* = 0.65, Table 4). The 2-year survival percentages of ART/HVGIC/CHX and ART/HVGIC according to the ART restoration criteria were 96.8 and 94.8, respectively. According to the FDI restoration criteria, the 2-year survival percentages were 97.9 (ART/HVGIC/CHX) and 96.9 (ART/HVGIC).

A total of 8 occlusal restorations failed according to the ART restoration criteria, while 5 failed according to the FDI restoration criteria. All restoration failures were material-related; no dentine carious lesions along the restoration margin or abscessed teeth were observed. According to the FDI criteria, one restoration failed due to excessive wear, 2 failed due to major marginal integrity, and 2 failed due to deep chipping in the restorative material. The ART restoration criteria failed all defective restorations for a deficiency at the restoration margin of more than 0.5 mm (code 2).

Discussion

The present investigation shows that the 2-year survival percentage of HVGIC and HVGIC/CHX restorations in ART-treated occlusal cavities was not significantly different, the first null hypothesis was accepted. A search of the literature up to November 2018 showed no other survival studies comparing cavities in permanent teeth restored using HVGIC with and without CHX. We concluded that there is currently no evidence for modifying HVGIC by incorporating chlorhexidine to improve the survival of ART restorations in the occlusal surface of permanent teeth. This early conclusion holds true for primary dentition. A study in which ART/HVGIC/CHX was compared with ART/HVGIC was investigated among children with an average age of 46 months (*n* = 36) revealed no difference in the 1-year survival percentage [19].

The methodology applied in the present study was performed adequately. Different from many restorative material studies, the randomization procedure, restoration procedure and restoration evaluation were carried out in a blinded manner, and the students were blinded to the restorative material that was inserted in the cavity. This was achieved because the colour of neither the materials nor the bottles differed and because the students in essence received the same kind of treatment. In contrast to many studies

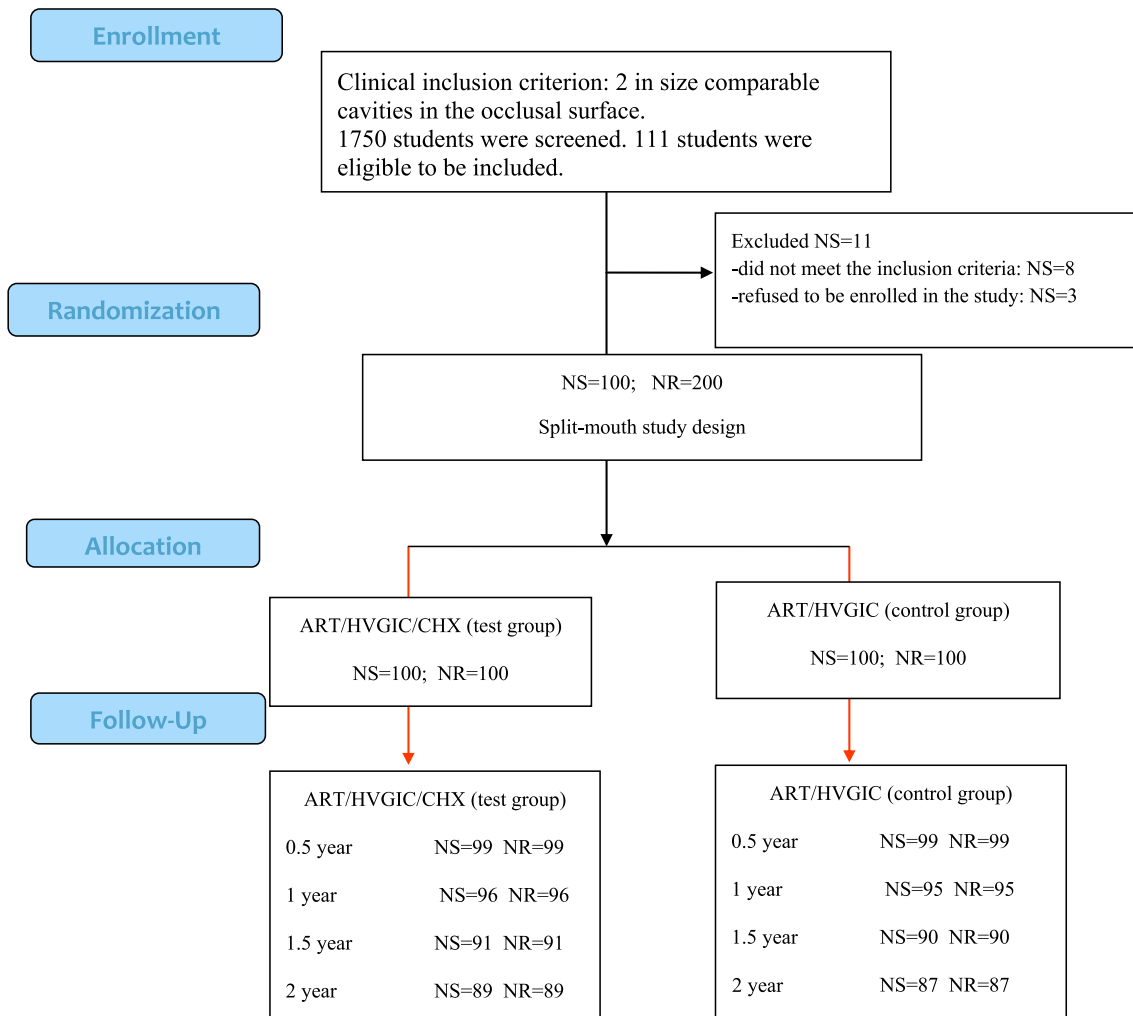


Fig. 2. Consort study flowchart based on the ART caries assessment criteria. NS: number of students; NR: number of restorations.

Table 2

Distribution of number of restorations (N) using the test (ART/HVGIC/CHX) and control (ART/HVGIC) restorative by tooth type.

Tooth type	ART/HVGIC/CHX	ART/HVGIC
	N	N
17	–	3
16	16	10
26	11	16
27	2	–
36	29	27
37	6	9
46	27	30
47	9	5

that have used a parallel-group design, the present study applied a split-mouth design as it allowed investigation of the test and control restorations under the same individual conditions and caries risk. The restoration assessment was performed on replicas supported by clinical photographs, to which the evaluators were also blinded. Lastly, the statistician was blinded as the randomization key was released after the data analyses were completed. An evaluation was performed after 2 years for all available replicas. The quality of the data was enhanced by the availability of an image of the restoration taken at each evaluation time, allowing the evaluator to assess the quality of the restoration longitudinally.

Although the preparation of replicas and clinical pictures consumes more time and is more expensive than performing a visual clinical evaluation, in a longitudinal study, the extra cost is justified. The quality of the database was further enhanced by application of the imputation process, which could be performed without problems for most cases. The dropout rate was kept low as the researchers performed home visits when necessary to collect clinical photographs and impressions.

A disadvantage of the present study is the absence of cavity depth measurements. It is unknown whether there were significant differences in the initial cavity depth distribution within and between the 2 groups. To what extent this omission may have had an effect on the outcome is difficult to estimate, but considering the very few restoration failures observed in both groups and the absence of abscessed teeth and pain, we consider the possible effect of ‘cavity depth’ on the outcome insignificant. This assumption is further supported by the fact that only cavities classed as Si/Sta 1.2 or 1.3 score were restored.

Most teeth included in the study were first permanent molars, which reflects the age and the caries risk period of the study participants. There was no significant difference in the type of tooth allotted to the two groups, which is considered a methodological advantage.

All ART restorations were assessed using two sets of assessment criteria. The survival percentage of both types of ART restorations was insignificantly higher when assessed using the FDI criteria.

Table 3
Survival percentages (Surv) and standard error (SE) of the test (ART/HVGIC/CHX) and control (ART/HVGIC) restorative by time interval according to the ART restoration criteria.

Time interval (year)	ART/HVGIC/CHX					ART/HVGIC				
	N _{entry}	N _{failcum}	N _{censcum}	Surv	SE	N _{entry}	N _{failcum}	N _{censcum}	Surv	SE
0.0–0.5	100	0	1	100.0	0.0	100	1	1	99.0	1.0
0.5–1.0	99	0	4	100.0	0.0	98	1	4	99.0	1.0
1.0–1.5	96	2	9	97.9	1.5	95	4	9	95.9	2.0
1.5–2.0	89	3	–	96.8	1.8	87	5	–	94.8	2.3

N_{entry} = number of restorations at start of the study.

N_{failcum} = cumulative number of failures.

N_{censcum} = cumulative number of censored data.

ART = atraumatic restorative treatment.

CHX = chlorhexidine.

HVGIC = high-viscosity glass-ionomer cement.

Table 4
Survival percentages (Surv) and standard error (SE) of the test (ART/HVGIC/CHX) and control (ART/HVGIC) restorative by time interval according to the FDI restoration criteria.

Time interval (year)	ART/HVGIC/CHX					ART/HVGIC				
	N _{entry}	N _{failcum}	N _{censcum}	Surv	SE	N _{entry}	N _{failcum}	N _{censcum}	Surv	SE
0.0–0.5	100	0	1	100.0	0.0	100	1	1	99.0	1.0
0.5–1.0	99	0	4	100.0	0.0	98	1	4	99.0	1.0
1.0–1.5	96	2	9	97.9	1.5	95	3	9	96.9	1.8
1.5–2.0	89	2	–	97.9	1.5	88	3	–	96.9	1.8

N_{entry} = number of restorations at start of the study.

N_{failcum} = cumulative number of failures.

N_{censcum} = cumulative number of censored data.

ART = atraumatic restorative treatment.

CHX = chlorhexidine.

HVGIC = high-viscosity glass-ionomer cement.

This finding was also observed in a previously published study that used these two sets of assessment criteria [20]. The ART restoration assessment criteria seem to be more stringent than the FDI or the United States Public Health Services (USPHS) criteria. The main reason is related to the way marginal integrity of the restoration is scored. The FDI/USPHS criteria fail a restoration when the dentine is visible at the restoration margin, while more than 0.5 mm of exposed enamel is a reason for failing a restoration according to the ART restoration criteria. The 0.5-mm cut off point was considered sufficiently deep for plaque stagnation that would make the spot vulnerable to the development of dentine carious lesions adjacent to the restoration. The reasons for failure in the present study were all related to the material and not to the development of new dentine carious lesions. As this study was carried out between 2008 and 2009, the result that no dentine carious lesions adjacent to the restoration were observed in the present study is in line with the result of a recent report showing that the prevalence of secondary dentine carious lesion development at the margin of single-surface ART restorations was very low: 0.5% annually over the first 5 survival years [21]. Thus, the second null hypothesis was accepted.

The 2-year survival percentage of ART/HVGIC restorations in the present study, 94.8 (ART restoration criteria) and 96.9 (FDI restoration criteria), are somewhat higher than the 2-year weighted mean survival percentage of single-surface ART restorations (92.6) reported in the latest meta-analysis on ART [22]. Several studies have used HVGIC with a coating to restore single-surface cavities in private practices in the conventional manner, with survival percentages of 100.0 and 98.8 after 4 years [23,24] and 100% after 2 years [25]. Restorations using a light-cured resin monomer-coated HVGIC have performed extremely well and may extend the indication for glass-ionomer use in restorative care. However, there was no difference in the survival of HVGIC restorations that were coated or not coated with a resin monomer [20].

Conclusions

Although studies have shown that the addition of chlorhexidine to HVGIC exerts an antibacterial effect, the present study shows that the 2-year survival of ART/HVGIC/CHX and ART/HVGIC restorations in occlusal cavities in permanent teeth is not significantly different. Furthermore, none of the restoration failures were related to the development of carious dentine lesions adjacent to the restoration. Thus, there is no evidence for modifying HVGIC by incorporating chlorhexidine in order to prevent dentine carious lesion development or to improve the survival of ART restorations in occlusal surfaces in permanent teeth. HVGIC without chlorhexidine can be used to successfully restore occlusal 'ART-prepared' cavities in permanent teeth.

Acknowledgements

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Conflict of interest

The authors have declared no conflict of interest.

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