

Amalgam and ART restorations in children: a controlled clinical trial

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Abstract

Objectives The aims of this study were to compare 2-year cumulative survival rates of amalgam and atraumatic restorative treatment (ART) restorations in primary molars and to investigate the determinants of the survival rate of restorations. **Materials and methods** A controlled clinical trial using a parallel group design was carried out on 258 children aged 6–7 years old, allocated to two treatment groups: conventional restorative treatment using amalgam and ART using high-viscosity glass ionomer. A total of 364 amalgam restorations and 386 ART restorations were placed by three pedodontists in 126 and 158 children, respectively, and were evaluated after 0.5, 1, and 2 years. Restorations were placed in vital primary molars with neither pain nor signs of pulp involvement. The survival analysis was conducted using the proportional hazard rate regression model with frailty correction.

Results The 2-year cumulative survival rates for all amalgam (77.3 %) and ART (73.5 %) restorations were not statistically significantly different, but there was an effect of “type of surface” (single/multiple) and “cavity filling time” on the survival rates. Both amalgam and ART single-surface restorations had higher survival rates than multiple-surface restorations of the same material. Secondary caries was responsible for 36 and 38 % of failures in amalgam and ART restorations, respectively. Mean time for restoring all type of cavities with amalgam and ART restorations was 13.6 and 13.7 min, respectively.

Conclusions Amalgam and ART restorations presented similar survival rates over a 2-year period for all, single-surface, and multiple-surface restorations.

Clinical relevance In the cause of finding alternatives to amalgam, ART restorations using high-viscosity glass ionomer might be a suitable option for managing cavitated dentine carious lesions in vital primary molars.

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Introduction

The majority of cavitated dentine carious lesions in primary teeth remain unrestored in many countries and communities worldwide [1]. The conventional restorative treatment is unaffordable for these communities because of expensive dental equipment and restorative materials and high maintenance costs [2]. Taking further into account that the use of amalgam has been banned in a number of countries [3] and that a discussion at the United Nations Environment Programme about reducing amalgam in the coming decades is ongoing, there is a need for testing environmentally friendly materials to restore dentine carious cavities in children [4, 5].

The atraumatic restorative treatment (ART) approach, which uses hand instruments and a high-viscosity glass ionomer cement (GIC), is considered a good alternative to conventional restorative treatment (CRT) in children due to its potential to cause less dental anxiety and pain [6]. A meta-analysis showed that ART can reliably be used to restore single-surface cavities in primary teeth but that its survival in multiple-surface cavities in primary teeth needs to be improved [7]. A systematic review concluded that, for most types of tooth cavities, no significant difference between the survival rates of amalgam and ART restorations in permanent and primary teeth was present but that this outcome should be confirmed by further research [8]. A Cochrane review, aimed to establish the most suitable restorative material for use in primary teeth, was inconclusive regarding the best restorative material available [9].

Survival rates of ART restorations using high-viscosity GIC were reported to be significantly higher than survival rates of those using medium-viscosity GIC [10]. If GIC with an even higher powder-to-liquid ratio (4.5:1.0) than the common high-viscosity GIC (3.5:1.0) was to be used, survival rates of ART restorations, and particularly those in class II restorations in primary teeth, might further increase [11]. Such a result may lead to a possible reduction in the percentage of unrestored cavitated dentine carious lesions in many communities worldwide. Furthermore, results of such a study would contribute to the discussion about alternative materials to dental amalgam.

The aims of this study were to compare cumulative survival rates of amalgam and ART restorations using a high powder-to-liquid ratio GIC and to investigate the determinants of the survival rate of restorations. The null hypothesis tested was that there is no difference between the cumulative survival rates of amalgam and ART restorations in primary molars over a 2-year period.

Materials and methods

Sampling procedure

The controlled clinical trial using a parallel group design was carried out in all the six public primary schools in Paranoá, a deprived suburban area of Brazil's Federal District. The sample of subjects for the present investigation was nested in an oral health epidemiological survey of 6- and 7-year-old children attending these schools [12]. Inclusion criteria for the trial were (1) good general health; (2) at least two cavitated dentine carious lesions in vital primary molars with neither pain nor signs of pulp involvement, assessed according to the ICDAS II index. The trial was approved by the Research Ethics Committee of the University of Brasília Medical School, reference 081/2008, and

was registered at the Dutch Trial Registration Centre (reference number 1699). A consent form was duly filled in and signed by one of the parents or a caretaker.

Two treatment groups were formed: CRT as the control group and ART as the test group. The unit of sampling was the school. As only two of six schools were equipped with unmovable rotary dental equipment, these schools were allocated to the CRT group. The remaining four schools were allocated to the ART group.

Implementation

The trial was performed by three trained and calibrated pedodontists, aided by trained dental assistants, at the school premises during May to July 2009. Children received an oral hygiene kit containing a toothbrush, fluoridated dentifrice, plaque-disclosing dentifrice, and dental floss. They were taught how to use each element of the kit and were encouraged to brush their teeth twice daily. Participating children in two of the ART schools were regularly screened for the status of cleanliness of their teeth using visual observation, as part of an additional investigation. In those schools, a trained dental assistant supervised the tooth brushing every other school day. In the ART group, the treatment was performed using a portable bed and an operating light.

CRT Dentine carious cavities in primary molars were prepared by rotary instruments and restored using a high-copper non-gamma 2 spherical and lathe cut amalgam (Permite Regular set[®]; SDI, Melbourne, Australia). Cavity outline was prepared according to modified Black's principles, without extension for prevention. Demineralized dentine was removed using a slow-speed round bur.

ART Dentine carious cavities in primary molars were accessed and cleaned with hand instruments only (ART Kit; Henry Schein[®], Chicago, USA), conditioned for 10 s with a wet cotton wool pellet saturated with the GIC liquid (polyacrylic acid), washed for 5 s and dried for 5 s with dry cotton wool pellets, and restored using a high-viscosity GIC (Ketac Molar Easymix[®]; 3M ESPE, Seefeld, Germany). Trained chairside assistants mixed the GIC on a glass plate with a metal spatula according to the manufacturer's instructions. The GIC was inserted in the cavity using an applier/carver instrument (ART Kit, Henry Schein[®]), overfilled and pressed down using a petroleum jelly-coated finger [2]. The bite was checked and excess material was removed using the applier/carver instrument.

In each treatment group, local anesthesia was administered when children indicated pain or whenever the operator judged necessary. In deep cavities, a calcium hydroxide liner (Hydro C[®]; Dentsply, Petrópolis, Rio de Janeiro, Brazil)

covered with a GIC liner (Vitreon F®; SS White, Rio de Janeiro, Brazil) was applied. In proximal cavities, a wooden wedge and steel matrix band (Injecta®; Diadema, São Paulo, Brazil) in a Tofflemire matrix retainer (Golgran®; São Paulo, Brazil) were used. Restorations were performed using cotton wool rolls for isolation. The time spent to prepare and to restore the cavity were measured separately using a stopwatch.

Evaluation

Two independent evaluators (dentists) assessed restorations according to the ART restoration criteria (Table 1) at the school premises after 6 months and 1 and 2 years. Evaluators were trained and calibrated before each evaluation session by an experienced dentist. Dental caries was defined as an obvious dentine carious cavity. Battery-illuminated dental mirrors (Kudos®; Hong Kong, China), CPITN probe (Golgran®), and compressed air (in the ART group, from a portable air compressor) aided the evaluation. Restorations coded 0 and 1 were considered to have survived, those coded 2 to 6 were considered failures, and codes 7 to 9 were considered censored observations. The presence of a dentine carious cavity alongside the restoration (secondary caries) was considered a failure. Inter-evaluator reliability (κ) in assessing restoration failure over the three evaluation times was 0.77. The percentage of observed agreements was 96 %.

Statistical analysis

The sample size was based on a power calculation using an α of 0.05 and a $1-\beta$ of 0.8. On the basis of an expected increase in the survival rate of multiple-surface ART restorations after 2 years from 65 % [10] to 70 %, the survival

rate of amalgam restorations of 80 % [13], a 10 % correction for dependency of restorations, and an estimated annual loss of children of 8 %, the required sample size was 365 restorations for each type of restoration.

Data were entered into a database and checked for accuracy. The analyses were performed by a biostatistician using SAS version 9.2 software. The dependent variable was the survival rate of restorations. Independent variables were type of restoration (amalgam, ART), type of surface (single surface, multiple surfaces), gender, operator (1–3), and cavity preparation time and cavity filling time in minutes (continuous variables). Differences between independent variables at baseline were tested using ANOVA (child level) and chi-square (surface level). The survival rates were obtained after correction for dependency of restorations within each child. For this purpose, the Jackknife method [14] was applied to calculate standard errors, and the proportional hazard rate regression model [15] with frailty correction [16] was used to calculate cumulative survival rates of amalgam and ART restorations and to analyze the effect of independent variables on the survival rate over the 2-year period. Differences between survival rates were tested using the Wald test. Statistical significance was set at $\alpha=0.05$.

Results

Baseline

A CONSORT flow diagram showing the number of children and restorations present and absent at the three evaluation times is presented in Fig. 1. The mean age of the children was 6.8 ± 0.4 years. The mean and standard deviation of cavities per child were 3.2 ± 2.0 , respectively, with a range from 1 to 14. At baseline, there were no effects of gender ($p=0.91$), mean dmft ($p=0.78$) and DMFT ($p=0.67$) scores, and type of surface ($p=0.72$), but an age ($p<0.001$) effect between children treated with amalgam and ART restorations was observed. Children treated with amalgam restorations were on average 0.2 years younger. The mean dmft and DMFT scores for the 284 children treated with ART or amalgam restorations were 5.8 ± 2.9 and 0.2 ± 0.6 , respectively. The non-response analyses revealed no effect for type of restoration ($p=0.19$), age ($p=0.6$), gender ($p=0.17$), type of surface ($p=0.72$), and baseline mean dmft ($p=0.66$) and mean DMFT ($p=0.67$) scores.

Handling of longitudinal data

Three evaluation times of 750 restorations corresponded to 2,250 different sequences of evaluation scores, which were clearly interpretable in 96.5 % of the cases (no errors,

Table 1 ART restoration criteria

Code	Criteria
0	Present, satisfactory
1	Present, slight deficiency at cavity margin of less than 0.5 mm ^a
2	Present, deficiency at cavity margin of 0.5 mm or more ^a
3	Present, fracture in restoration
4	Present, fracture in tooth
5	Present, overextension of approximal margin of 0.5 mm or more ^a
6	Not present, most or all of restoration missing
7	Not present, other restorative treatment performed
8	Not present, tooth is not present
9	Unable to diagnose

^a Assessed using the 0.5 mm ball end of CPITN probe

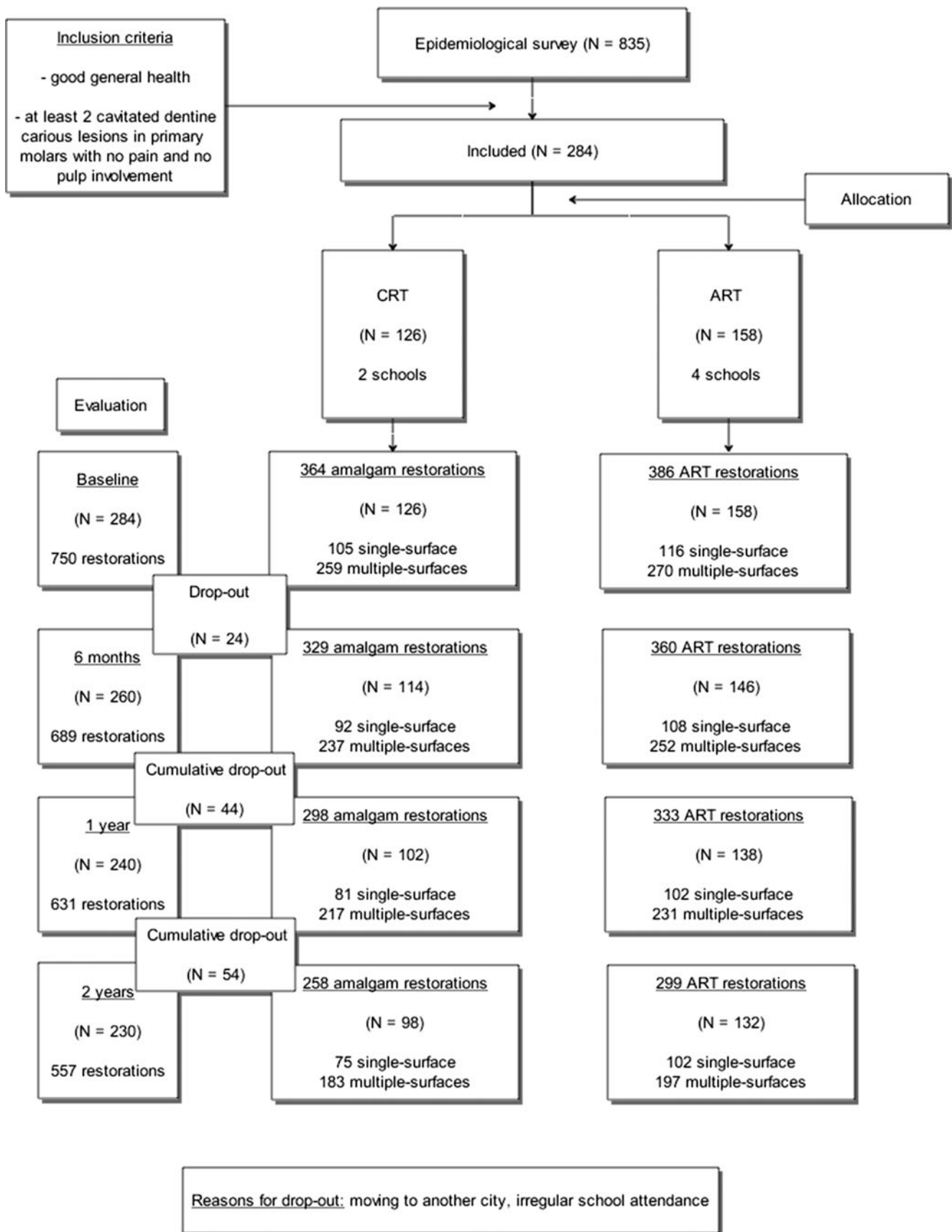


Fig. 1 Consort flow diagram of the trial. *N* number of children, *CRT* conventional restorative treatment, *ART* atraumatic restorative treatment

distinct moment of failure, or censored observation). In 2.7 % of the cases, a missing observation was considered a success because the subsequent score was a success. In 0.8 % of the cases, the distinct moment of failure could not be determined. It was decided to allocate these missing observations alternately to “having survived” and “failed.”

Survival of restorations over 2 years

Cumulative survival rates for single-surface, multiple-surface, and all amalgam and ART restorations in primary molars for each evaluation time are presented in Table 2. No statistically significant differences were observed between cumulative survival rates of amalgam and ART restorations over 2 years for all restorations ($p=0.60$), single-surface restorations ($p=0.20$), and multiple-surface restorations ($p=0.53$). There was no statistically significant difference observed in the cumulative survival rate between ART restorations that had been cleaned with supervised tooth brushing during schooldays and those that were not brushed under supervision ($p=0.08$). The survival analysis showed no effects of gender ($p=0.70$), operator ($p=0.09$), cavity preparation time ($p=0.06$), and type of restoration ($p=0.66$) on the survival rate of restorations placed in primary molars over 2 years. There was only a borderline effect of cavity filling time ($p=0.04$) and an effect of the type of surface ($p<0.0001$). Additional survival analysis with only the effect variables type of restoration, type of surface, and cavity filling time on the survival of restorations of both type of materials confirmed the effects of cavity filling time ($p=0.0009$) and type of surface ($p<0.0001$). The type of restoration (amalgam or ART) did not show an effect ($p=0.17$). Both amalgam and ART single-surface restorations had higher survival rates than multiple-surface restorations of the same material after 2 years (Table 2).

The mean cavity preparation, cavity filling, and total time used to place amalgam and ART restorations in primary molars are shown in Table 3. There were statistically significant differences observed between all amalgam and ART restorations regarding cavity preparation ($p<0.0001$) and cavity filling times ($p=0.02$), but not regarding total time

($p=0.7$) (13.6 min for amalgam and 13.7 min for ART restorations), and between single-surface amalgam and ART restorations for cavity preparation, cavity filling, and total time ($p<0.0001$). Total time for cavity filling single-surface cavities with amalgam took on average 2.4 min shorter than restoring comparable cavities with high-viscosity glass ionomer (Table 3).

Reasons for failure of amalgam and ART restorations are presented in Table 4. There was no statistically significant difference between amalgam and ART restorations regarding the reasons for failure ($p=0.08$).

Discussion

Research methods

The allocation of children over the two treatment groups was not performed randomly for practical reasons, as a static, fully equipped dental unit was available in two of six schools. However, it can be argued that the included children were sufficiently comparable on the most important studied aspects and that the selection bias was minimal. There were no gender, type of surface, nor mean dmft/DMFT effects at baseline between children treated with amalgam and ART restorations, but only an age effect was observed. Considering that children who received amalgam restorations were only 0.2 years younger than those receiving ART restorations, we do not think that this small difference in age has had an effect on the survival outcomes of the present study. Although the socioeconomic status of the children had not been assessed, it should be highlighted that the six public schools were located in the same deprived suburban area and were attended by non-privileged children with a similar level of socioeconomic deprivation. The low provision of dental care was also similar among the six schools, even in the two schools with a fully equipped dental unit, as the units had not been in operation for many years as no dentist/dental hygienist had been employed. We, therefore, can assume with reasonable certainty that children from the CRT group had no more access to preventive/operative

Table 2 Cumulative survival rates (in percent) and stand errors (SE), calculated by the Jackknife method, of amalgam and ART restorations placed in primary molars by interval

Interval	All restorations		Single surface		Multiple surfaces	
	Amalgam N_{Fail} (% ± SE)	ART N_{Fail} (% ± SE)	Amalgam N_{Fail} (% ± SE)	ART N_{Fail} (% ± SE)	Amalgam N_{Fail} (% ± SE)	ART N_{Fail} (% ± SE)
6 months	21 (93.8±1.3)	29 (92.4±1.4)	01 (98.9±0.1)	01 (99.1±0.1)	20 (91.9±1.8)	28 (89.5±1.9)
1 year	28 (84.6±2.5)	21 (86.5±2.0)	0 (98.9±0.1)	01 (98.2±0.9)	28 (79.2±3.1)	20 (81.5±2.7)
2 years	18 (77.3±2.9)	38 (73.5±2.8)	01 (97.5±1.1)	05 (92.8±2.5)	17 (69.5±3.6)	33 (64.9±3.6)

N_{Fail} number of failures

Table 3 Mean time in minutes (\bar{x}) and standard errors (SE) to place amalgam and ART restorations in primary molars

Time	Amalgam			ART		
	All restorations $\bar{x} \pm SE$	Single surface $\bar{x} \pm SE$	Multiple surfaces $\bar{x} \pm SE$	All restorations $\bar{x} \pm SE$	Single surface $\bar{x} \pm SE$	Multiple surfaces $\bar{x} \pm SE$
Cavity preparation	3.8±0.1 ^a	2.4±0.2 ^c	4.3±0.2	4.7±0.1 ^b	3.7±0.2 ^f	5.1±0.2
Restoring	9.8±0.3 ^c	5.2±0.2 ^c	11.7±0.3	9.0±0.2 ^d	6.3±0.1 ^f	10.2±0.2
Total	13.6±0.4	7.6±0.3 ^e	16.0±0.4	13.7±0.3	10.0±0.3 ^f	15.3±0.3

^{a-b} $p < 0.001$; ^{c-d} $p = 0.02$; ^{e-f} $p < 0.0001$

dental care than those from the ART group before the study started.

Because of the nature of this investigation, neither the operators nor the evaluators could be blinded to the treatment. The child may be considered blinded, as the restorative treatment performed in this trial was for the majority the first ever encounter with dental care. Having the assessment undertaken by independent evaluators and having obtained high inter-evaluator consistency scores over the 2 years, it can be concluded that the data were collected reliably. Nevertheless, the internal and, consequently, the external validity of this trial may have been compromised to a certain extent, but that is unavoidable in a trial in which the control and test groups are distinguishable.

Handling of missing data in the survival analysis of restorations is essential, but not always reported. If incomplete cases are excluded from the analysis, as usually done, possible differences between the complete cases and incomplete ones are ignored, and the analysis outcome may not be applicable to the population of all cases [17]. In this study, only 3.5 % of the longitudinal series needed to be repaired through an imputation method, which could not be done reliably in only 0.8 % of cases. Considering that this was a field trial, the study outcomes appear to be a true reflection of the potential of the two different treatments.

Main findings

The null hypothesis was not rejected. There was no significant difference between amalgam and ART restorations over the 2-year period. This outcome is in line with the conclusion of a systematic review regarding the survival of amalgam and ART restorations in primary teeth [8]. As the ART approach does not demand a dental clinic setting, the study outcome supports the likelihood that, through the use of ART, children with untreated cavitated carious lesions in primary molars will have a higher chance of being treated restoratively than through conventional treatments using drill and burs. A comprehensive overview on the 25 years of the ART approach has highlighted its potential to reduce inequality in oral care, particularly in deprived areas where the conventional restorative treatment scheme is unable to meet all the population's demands [18].

The fact that children in two schools from the ART group had their teeth regularly cleaned under supervision had not influenced the survival rate of ART restorations significantly. One could argue that supervised tooth brushing could have positively influenced the survival of ART restorations. However, ART restorations with and without supervised regular cleaning presented similar survival rates. Therefore, it was assumed that the success rate of ART restorations,

Table 4 Percentage distribution of reasons for failure of amalgam and ART restorations by type of restoration

	Amalgam				ART			
	Single surface		Multiple surfaces		Single surface		Multiple surfaces	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Secondary caries	0	0.0	24	36.9	2	28.6	31	38.3
ART restoration criteria								
Marginal deficiency ≥ 0.5 mm (code 2)	0	0.0	15	23.1	1	14.3	16	19.8
Fracture in restoration (code 3)	0	0.0	2	3.1	1	14.3	0	0.0
Fracture in tooth (code 4)	0	0.0	3	4.6	0	0.0	0	0.0
Most or all restoration is missing (code 6)	2	100.0	21	32.3	3	42.9	34	42.0
Total	2	100.0	65	100.0	7	100.0	81	100.0

N number of restorations

when compared to that of amalgam restorations, had not been influenced by the supervised tooth brushing implemented in these two schools.

The 2-year survival rates of ART restorations for a single surface (93 %) and multiple surfaces (65 %) in primary molars of the present study are consistent with the results of a meta-analysis (93 and 62 %, respectively) [7]. The use of a high-viscosity GIC with a higher powder-to-liquid ratio than common did not result in the expected survival rate of 70 % for multiple-surface ART restorations. Possible reasons include the absence of a difference in Knoop hardness [19] and in wear resistance, Knoop hardness, and flexural and compressive strength [20] between the material used in the present study (Ketac Molar Easymix®) and the current frequently tested high-viscosity GIC (Ketac Molar and Fuji IX).

The success rate of multiple-surface amalgam restorations in primary molars herein obtained (69.5 %) was lower than that reported in a literature review for class II amalgam restorations placed in the context of a controlled clinical environment (between 78 and 100 %) [13, 21]. One possible explanation could be the stringency of the ART restoration criteria used in the present study when compared to the original U.S. Public Health Service (USPHS) criteria, which are the most used criteria to assess amalgam restorations in clinical trials [21]. Indeed, a marginal defect ≥ 0.5 mm is considered a failure according to the ART restoration criteria (code 2) while only marginal defects with visible dentine, regardless of the size, are considered failures according to the original USPHS criteria. In the present study, code 2 of the ART restoration criteria contributed to 22.4 % of failures for amalgam restorations and to 18.4 % of failures for ART restorations. In primary molars, where the enamel is on average 1 mm thick [22], the ART restoration criteria will fail marginal defects more than if the original USPHS criteria are used. In short-term clinical trials as the present one, different ways of assessing marginal defects may lead to lower survival rates for any type of restoration if ART restoration criteria are used [23].

Mechanical failures (marginal defect, tooth/restoration fracture, and loss of restoration) were more prevalent than failures related to secondary caries for both amalgam and ART restorations. Secondary caries was responsible for about one-third of failures in both amalgam and ART restorations. These results corroborate with the conclusion of two meta-analyses reporting no difference in the occurrence of carious lesions at margins of amalgam and ART restorations in primary teeth [24, 25].

The use of drill to remove carious tissues, in comparison to the removal of carious tissues with hand instruments, is most probably the reason for the significantly lower cavity preparation time needed for amalgam restorations. In contrast, ART restorations needed significantly lower time to fill cavities than amalgam restorations did, which eventually

led to a similar time for completing both types of restorations. In this study, restorations that took longer to fill the prepared cavities survived less often, but no effect of cavity preparation time on the survival rates was observed.

Besides the restoring time, the type of surface was the only other variable to show an effect on the survival rates of restorations in the present study. This finding has been previously described for amalgam [26, 27] and for ART restorations [27–29] in primary teeth, which indicates that multiple-surface restorations tend to survive shorter than single-surface restorations in the primary dentition, regardless of the type of restoration performed.

In summary, no significant differences on the survival rates of single-surface, multiple-surface, and all restorations were found between amalgam and ART restorations in primary molars over 2 years. Multiple-surface restorations survived shorter than single-surface restorations for both types of restorations. The outcomes suggest that ART may be considered a viable option alongside the conventional restorative treatment using amalgam in treating dentine carious cavities in vital primary molars.

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Conflict of interest The authors declare that they have no conflict of interest.

References

- Baelum V, van Palenstein Helderma WH, Hugoson A, Yee R, Fejerskov O (2007) A global perspective on changes in the burden of caries and periodontitis: implications for dentistry. *J Oral Rehabil* 34:872–906
- Frencken J, van Palenstein Helderma WH, Holmgren C (2002) Basic package of oral care. WHO Collaborating Centre for Oral Health Care Planning and Future Scenarios. Radboud University Nijmegen Medical Centre, College of Dental Sciences, Nijmegen, the Netherlands
- Edlich RF, Cross CL, Dahlstrom JJ, Long WB 3rd, Newkirk AT (2008) Implementation of revolutionary legislation for informed consent for dental patients receiving amalgam restorations. *J Environ Pathol Toxicol Oncol* 27:1–3
- FDI World Dental Federation (2010) FDI General Assembly Resolution, September 2010. Available at http://www.fdiworldental.org/c/document_library/get_file?uuid=0b872daa-5d02-4d21-a408-fcef4205bd66&groupId=10157. Accessed 10 Feb 2012
- World Health Organization (2011) Future use of materials for dental restoration. Report of the meeting convened at WHO HQ, Geneva, Switzerland, 16–17 November 2009. WHO, Geneva, 2011
- Leal SC, Abreu DM, Frencken JE (2009) Dental anxiety and pain related to atraumatic restorative treatment. *J Appl Oral Sci* 17:84–88

7. de Amorim RG, Leal SC, Frencken JE (2012) Survival of atraumatic restorative treatment (ART) sealants and restorations: a meta-analysis. *Clin Oral Invest* 16:429–441
8. Mickenautsch S, Yengopal V, Banerjee A (2010) Atraumatic restorative treatment versus amalgam restoration longevity: a systematic review. *Clin Oral Invest* 14:233–240
9. Yengopal V, Harneker SY, Patel N, Siegfried N (2009) Dental fillings for the treatment of caries in the primary dentition. *Cochrane Database Syst Rev* 2:CD004483
10. Van't Hof MA, Frencken JE, Van Palenstein Helderma WH (2006) The atraumatic restorative treatment (ART) approach for managing dental caries: a meta-analysis. *Int Dent J* 56:345–351
11. Peetz R, Frank S (2006) The physical-mechanical performance of the new Ketac Molar Easymix compared to commercially available glass ionomer restoratives. *J Dent* 34:582–587
12. de Amorim RG, Figueiredo MJ, Leal SC, Mulder J, Frencken JE (2012) Caries experience in a child population in a deprived area of Brazil, using ICDAS II. *Clin Oral Invest* 16:513–520
13. Hickel R, Kaaden C, Paschos E, Buerkle V, Garcia-Godoy F, Manhart J (2005) Longevity of occlusally-stressed restorations in posterior primary teeth. *Am J Dent* 18:198–211
14. Efron B (1982) The jackknife, the bootstrap, and other resampling plans. SIAM-NSF, Philadelphia
15. Cox DR (1972) Regression models and life tables (with discussion). *J R Stat Soc B* 34:187–220
16. Hougaard P (1995) Frailty models for survival data. *Lifetime Data Anal* 1:255–273
17. Schafer JL (1999) Multiple imputation: a primer. *Stat Methods Med Res* 8:3–15
18. Frencken JE, Leal SC, Navarro MFL (2012) Twenty-five-year atraumatic restorative treatment (ART) approach: a comprehensive overview. *Clin Oral Invest* 16:1337–1346
19. Raggio DP, Bonifácio CC, Bonecker M, Imparato JCP, Gee AJ, van Amerongen WE (2010) Effect of insertion method on Knoop hardness of high viscous glass ionomer cements. *Braz Dent J* 21:439–445
20. Bonifácio CC, Kleverlaan CJ, Raggio DP, Werner A, de Carvalho RCR, van Amerongen WE (2009) Physical-mechanical properties of glass ionomer cements indicated for atraumatic restorative treatment. *Austr Dent J* 54:233–237
21. Kilpatrick NM, Neumann A (2007) Durability of amalgam in the restoration of class II cavities in primary molars: a review of the literature. *Eur Arch Paediatr Dent* 8:5–13
22. De Menezes Oliveira MA, Torres CP, Gomes-Silva JM, Chinelatti MA, De Menezes FC, Palma-Dibb RG, Borsatto MC (2010) Microstructure and mineral composition of dental enamel of permanent and deciduous teeth. *Microsc Res Tech* 73:572–577
23. Lo ECM, Luo Y, Fan MW, Wei SHY (2001) Clinical investigation of two glass ionomer restoratives used with the atraumatic restorative treatment approach in China: two-year results. *Caries Res* 35:458–463
24. Mickenautsch S, Yengopal V, Leal SC, Oliveira LB, Bezerra AC, Bönecker M (2009) Absence of carious lesions at margins of glass-ionomer and amalgam restorations: a meta-analysis. *Eur J Paediatr Dent* 10:41–46
25. Mickenautsch S, Yengopal V (2011) Absence of carious lesions at margins of glass-ionomer cement and amalgam restorations: an update of systematic review evidence. *BMC Res Notes* 4:58. doi:10.1186/1756-0500-4-58
26. Hickel R, Voss A (1990) A comparison of glass cermet cement and amalgam restorations in primary molars. *ASDC J Dent Child* 57:184–188
27. Taifour D, Frencken JE, Beiruti N, Hof MA, Truin GJ (2002) Effectiveness of glass-ionomer (ART) and amalgam restorations in the deciduous dentition—results after 3 years. *Caries Res* 36:437–444
28. Menezes JPL, Rosenblatt A, Medeiros E (2006) Clinical evaluation of atraumatic restorations in primary molars: a comparison between 2 glass ionomer cements. *ASDC J Dent Child* 73:91–97
29. Ersin NK, Candan U, Aykut A, Onçag O, Eronat C, Kose T (2006) A clinical evaluation of resin-based composite and glass ionomer cement restorations placed in primary teeth using the ART approach: results at 24 months. *J Am Dent Assoc* 137:1529–1536