Atraumatic Restorative Treatment (ART): A Three-year Clinical Study in Malawi—Comparison of Conventional Amalgam and ART Restorations

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Abstract

Objective: *This study compares the quality of class I restorations made with the atraumatic restorative treatment (ART) technique and conventional class I amalgam restorations.* ***Methods:*** *The study was carried out among secondary school students in Mzuzu, Malawi. First-year students in 1987 who needed at least two class I restorations were selected. Based on a split-mouth design, each participant received both ART and conventional restorations. The 89 pairs of class I cavities were divided randomly into two groups, since two different cermet ionomer cement (CIC) filling materials were used. Impressions of the restorations and subsequent models were made shortly after restoration, after six months, one year, two years, and three years. The quality of the restorations was determined on the models following the US Public Health Service criteria. Bulk fracture, contour, marginal integrity, and surface texture of the restorations were recorded and evaluated separately. Survival rates were determined by the resultant score of all criteria.* ***Results:*** *Though conventional amalgam restorations performed better on all criteria, this difference was significant only for the contour criterion. The survival rates of ART restorations after three years (81.0%) were lower than those of amalgam restorations (90.4%) (P=.067).* ***Conclusions:*** *The quality of ART class I restorations is competitive with that of conventional amalgam restorations. [J Public Health Dent 2003;63(2):99-103]*

Key Words: Atraumatic Restorative Treatment, glass ionomer, amalgam, dental restoration wear, dental restoration failure, survival rates.

Conservative dentistry in developing countries has long been problematic. Attempts to copy Western dentistry have failed because large areas lack electricity and expensive dental equipment. Highly qualified personnel often is not available, and delicate dental equipment is often hard to repair. In the 1980s simultaneously with the introduction of glass ionomer cements (GIC) in dentistry, a new approach to conservative dentistry was developed: cavities were prepared using hand instruments only and subsequently filled with GIC. Studies by Frencken and Makoni (1) and Pilot et al. (2) finally led to the introduction of the atraumatic restorative treatment technique (ART) in 1994.

As early as 1987 a clinical trial had been started in Malawi, Central Africa, to compare the quality of class I GIC restorations prepared only by hand instruments with conventional class I amalgam restorations. The study was approved by both local and national governments. The evaluation after one year was promising and published in 1990 (3). It indicated that the quality of the experimental restorations had not significantly decreased compared to the amalgam restorations. A more extensive evaluation was done after three years.

In the meantime, the ART technique has been subject to more study. In 1996 the *Journal of Public Health Dentistry* published a special issue about minimal intervention techniques for managing dental caries, including ART (4). In the beginning of the 1990s Phantumvanit et al. (5) compared ART and amalgam restorations in two villages in rural Thailand and found that amalgam performed significantly better. In their evaluation they did not use the internationally accepted US Public Health Service (USPHS) criteria as formulated by Ryge (6). In Tanzania, Mandari et al. (7) compared the ART and conventional preparation technique in combination with both glass ionomer and amalgam restorations. After two years they found no statistically significant differences.

The purpose of the Malawi study is to contribute to the knowledge about ART by a clear comparison of ART glass ionomer restorations and conventional amalgam restorations. This is done by using a split-mouth design and by evaluating the data according to the USPHS criteria. The current paper presents the results of the three-year evaluation of the Malawi study.

Methods

Sampling. In 1987 all first-year secondary school students in Mzuzu, Malawi, were checked. The students ranged in age from 14 to 20 years. Those who needed at least two (one pair) class I fillings were selected, leading to a total of 83 students and 178 (89 pairs) class I cavities in the study. The pairs of class I cavities were divided randomly into two groups, since two different GIC filling materials were used.

The split-mouth technique was

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used: one cavity in the mouth of the participant was prepared and filled with amalgam in the conventional way; the other was prepared using hand instruments only and filled with one of the GIC filling materials. Therefore, a matched control-group was not necessary.

Filling Materials. Two experimental filling materials were used, both GICs: Chelon Silver, a cermet ionomer (ESPE, Seefeld, Germany), and a metal-reinforced GIC—the so-called "miracle mix," a combination of Chelon Fil (ESPE, Seefeld, Germany) and amalgam powder. The mixture consisted of 20 g Chelon Fil with 22.7 g alloy powder, roughly equivalent to a 7:1 ratio if measured by volume as recommended by Simmons (8). The amalgam used for both "miracle mix" and amalgam fillings was spherical nongamma-2 (Cavex, Haarlem, The Netherlands).

Preparation Technique. All treatments were done at the fully equipped dental clinic in Mzuzu. The preparation of the cavities to be filled with either Chelon Silver or "miracle mix" was done with hand instruments only: the cavities were excavated using explorers, excavators, and hatchets. The cavity was considered clean when a hard layer was detected on probing and the grossly undermined enamel had been removed. The preparation of the cavities to be filled with amalgam was done in the conventional way using high- and slow-speed drills and a suction machine, following the rules of "extension for prevention" as formulated by Black (9).

Restoration. Before restoration with one of the cermet GIC filling materials, cavities were dried with cotton pellets. The smear layer was not removed. For Chelon Silver (hand-mixed) we followed the manufacturer's instructions. "Miracle mix" was hand-mixed to the same consistency. In cases in which the cavities were overfilled, they were carved into shape with a discoid-cleoid carver. No varnish was used. Amalgam fillings were polished with hard steel polishing burs in a handpiece after two days.

In total 178 class I restorations were made, 89 filled with amalgam, 43 with Chelon Silver, and 46 with "miracle mix." Most of the preparations and restorations were made by one dentist, and a few (fewer than 10) by a second dentist under supervision of the first.

TABLE 1
Codes and Criteria Used to Evaluate ART and Amalgam Restorations*

Bulk fracture	1 None 2 This rating does not exist in this survey 3 Crack(s): over the entire width of the restoration a line is seen, indicating a cracked restoration 4 Fracture: restoration and/or tooth structure is fractured
Margin integrity	1 No crevice: no visible evidence of a crevice along the margin 2 Crevice: visible evidence of a crevice along the margin 3 Deep crevice: a deep crevice along the margin with probably exposed dentine 4 Caries continuous with margin of restoration (caries cannot be detected on a model; this rating is impossible in this survey)
Contour	1 Continuous with anatomy: restoration's contour is continuous with existing anatomical form. On the model a line marking the contours of filling may be seen, but a step from tooth to filling or vice versa should be absent 2 Slightly over-/undercontoured: occlusal contour is not continuous with that of cusps and planes 3 Over-/undercontoured: restoration is clearly overcontoured, resulting in faulty occlusion/a clearly visible step from tooth to filling material can be seen indicating undercontoured filling with probably exposed dentine 4 Restoration missing
Surface texture	1 Smooth/slightly rough or pitted: surface of restoration is smooth or slightly rough or pitted, but shows no irregular surface 2 Rough and irregular: surface of restoration is rough and irregular,but shows no little cracks 3 Deeply pitted: surface of restoration is deeply pitted or shows small cracks and grooves not related to anatomy 4 Flaking: surface is flaking or fractured

*Based on US Public Health Service criteria.

TABLE 2
Determination of Clinical Success

A. Meets all standards: the restoration has a ranking of 1 in all four evaluated criteria (Table 1).
The restoration is of satisfactory quality and is expected to protect the tooth and its surrounding tissues.
B. Meets basic standards: the restoration has at least one ranking of 2 in the four evaluated criteria (Table 1), and none higher than 2.
The restoration is of acceptable quality, but exhibits one or more features that deviate from ideal conditions.
Restorations in category A and B are rated as "successful."
C. Replace for prevention: the restoration has at least one ranking of 3 in the four evaluated criteria (Table 1), and none higher than 3.
The restoration is not of acceptable quality. Future damage to the tooth and/or its surrounding tissues is likely to occur.
D. Replace: the restoration has a ranking of 4 in at least one of the evaluated criteria (Table 1).
The restoration is not of acceptable quality. Damage to the tooth and/or its surrounding tissues is now occurring.
Restorations in category B and C are rated as "failures."

Evaluation. Shortly after restoration and polishing (amalgam only) (T0), impressions were made using partial individual impression trays and Impregum impression material (ESPE, Seefeld, Germany). The impressions were then cast in pink, nonvacuum mixed stone. After six months (T0.5), one year (T1), two years (T2), and three years (T3) impressions were made again and cast in nonvacuum mixed stone. Impressions were taken at school. Students who needed dental treatment were advised to come to the dental clinic for free treatment. The evaluation of the restorations was done after T3 and on the models only. Clinical aspects like secondary caries and postoperative pain are not included in this survey.

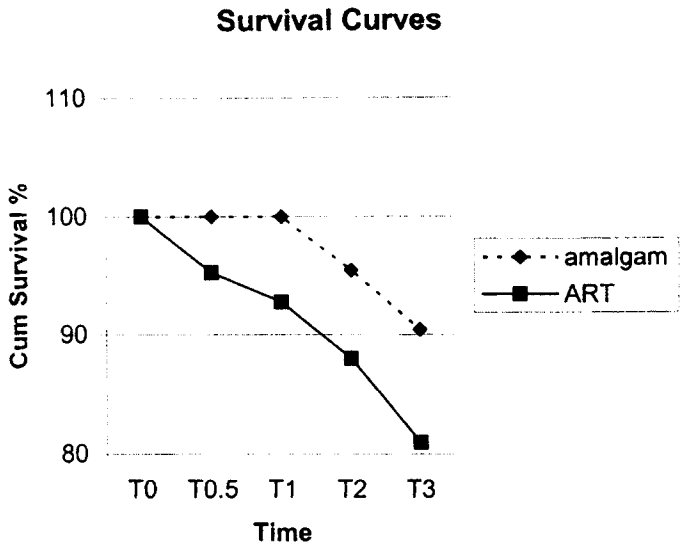
The models were evaluated using the USPHS Ryge criteria (6). Because the evaluation was performed on models rather than in the mouth of a patient, the criteria were slightly modified (Table 1). Four different quality criteria were rated separately: contour, marginal integrity, surface texture, and bulk fracture. Scores 1 and 2 meant success; scores 3 and 4 indicated failure. Because bulk fracture is the only criterion with a three-level-assessment, score 2 was omitted to standardize for all criteria (Table 1). The clinical success or failure of the restoration as a whole was determined by the highest score of that restoration (Table 2).

The evaluation of the models was done by three dentists. The examiner was unaware of the age of the restoration, nor was he or she informed about the filling material used. A calibration was done before starting the evaluation. All examiners evaluated all models in five sessions. After each session ratings were compared and differences discussed, leading to a consensus for each model.

Statistical Analysis. The analysis of the data was carried out using the SPSS 10.0 software package (SPSS Inc., Chicago, IL). The survival of the restorations was calculated by means of Kaplan-Meier estimates according to standard procedures. A difference between Kaplan-Meier curves was tested using the log rank test. Participants were considered at risk for failure until their final assessment or until an event occurred.

Comparison of the scores for the four quality criteria (contour, marginal integrity, surface texture and bulk fracture) was performed at T0 and T3 using the Wilcoxon signed ranks test (WSRT).

FIGURE 1
Survival Curves of Class I ART Restorations and Amalgam Restorations over a 3-year Period



Results

Follow-up. Twenty-two of the 83 students (27%) participating in the survey had left school before the end of the study and could not be traced, leading to a dropout of 24 amalgam, 13 Chelon Silver, and 11 "miracle mix" restorations. At T3, 3 amalgam and 6 cermet-restorations could not be evaluated due to the models being of poor quality or missing.

Survival Rates. The Kaplan-Meier survival estimate after three years of follow-up was 90.4 percent (95% confidence interval [CI]=83.1, 97.7) for amalgam and 81.0 percent (95% CI=71.5, 90.5) for ART restorations. The log rank test tended toward significance (P=.067). The survival functions are shown in Figure 1.

Quality Criteria. Table 3 shows the scores for contour, marginal integrity,

TABLE 3
Quality Criteria Scores at T0 and T3

Time/Material		Bulk Fracture		Contour			Marginal Integrity			Surface Texture			
	n	1	4	1	2	3	1	2	3	1	2	3	4
T0 am	89	100%		51%	49%		97%	3%		98%			2%
T0 cs	43	100%		33%	67%		91%	9%		98%	2%		
T0 mm	46	100%		26%	74%		87%	13%		41%	7%		2%
T3 am	65	94%	6%	23%	75%	2%	74%	21%	5%	87%	7%		6%
T3 cs	29	86%	14%		100%		72%	14%	14%	92%	4%		4%
T3 mm	30	93%	7%	4%	89%	7%	79%	14%	7%	85%	8%	4%	4%

am=amalgam; cs=Chelon Silver; mm="miracle mix."

surface texture, and bulk fracture at T0 and T3. During the entire evaluation period amalgam restorations had a significantly better contour than Chelon Silver and "miracle mix" restorations (WSRT: amalgam vs Chelon Silver, T0, P=.04; T3, P=.03 and amalgam vs miracle mix, T0, P=.03; T3, P=.02).

The marginal integrity of amalgam restorations seemed to show a trend from "perfect" to "crevice." ART restorations seemed more stable, but were scored as "crevice" more often. The differences were not significant in the WSRT. Both amalgam and ART restorations were scored mainly as "smooth or slightly rough" surface during the entire evaluation period. After 3 years, 4 of 65 amalgam, 4 of 29 Chelon Silver, and 2 of 30 miracle mix restorations had fractured.

Reasons for Failure. The reasons for failure are presented in Table 4. The main reason for failure was fracture. Cases in which there was more than one reason for failure are shown in brackets. In four participating students, both the amalgam and the ART restoration (2 Chelon Silver, 2 "miracle mix") failed.

TABLE 4
Reasons for Failure in a 3-year Period

Restorations	*n*	Amalgam	Chelon Silver	Miracle Mix
Fracture	10	4	4	2
Deep crevice	8	1 [+1]	1 [+3]	1 [+1]
Undercontour	3	1		2
Rough/flaking surface	3	[+1]		[+2]

Extra reasons for failure (next to fracture) are put in brackets.

Discussion

A loss to follow-up of 27 percent of the participants is not high compared to other studies in developing countries (12). Moreover, their reason for leaving school (i.e., failure of exams; personal problems) bears no relation to the quality of their dental restorations. Therefore, it is not likely that their absence influences the results of the study. Nine casts (three of amalgam, six of cermet restorations) were missing for evaluation after three years. When tracing the written history, none of them had failed at the three-year evaluation. Their presence at T3 probably would have resulted in a slightly higher survival rate of the restorations.

The design of this study enabled a proper comparison between conventional amalgam and ART restorations: with one operator there was no operator effect to take into account, the split-mouth technique prevented poorly matched experimental and control groups, and the consensus score in the evaluation procedure eliminated an interexaminer effect. The relatively small sample makes it hard to draw firm conclusions.

The three-year survival rates were 90.4 percent for amalgam and 81.0 percent for ART cermet restorations. Taking the small sample size into account, we should consider this difference significant. Fracture was the main reason for failure, both for amalgam and ART restorations. Since the beginning of the study, the properties of glass ionomer restorative materials have been improved. Metal-reinforced and cermet ionomers such as "miracle mix" and Chelon Silver are no longer used in combination with ART. Their adhesive performance is inferior to metal-free GICs and they have not proved to be any stronger or more durable (10,11).

In four students both the amalgam and the ART restoration failed, suggesting that in these cases factors other than the preparation and restoration technique were the reason for failure. Also, it emphasizes the importance of the split-mouth design when comparing amalgam and ART in relatively small numbers.

Looking at the quality criteria, there was one aspect in which conventional amalgam restorations performed significantly better than the ART cermet restorations: contour. Amalgam restorations were carved and polished, which in fact is the only way to create a contour that is continuous with the anatomy of the tooth. However, their performance in contour decreased during the evaluation period. Most ART restorations had a stable contour score of 2 during the entire evaluation period, indicating a slight over- or undercontour. A slight overcontour is almost inevitable in the ART technique. These days, slight overcontour is deliberately created with the so-called pressed-finger technique, combining the ART restoration with a sealant (13). Slight undercontour could have been caused by mild wear of the filling material. The clinical success of the ART restorations in this survey is not influenced by their slight over- or undercontour. Two "miracle mix" restorations failed due to gross undercontour with probably exposed dentine. On a model no difference can be seen between gross undercontour and loss of the restoration. We did not remove the smear layer before restoration, so the bonding of the GIC to the dental tissues was not optimal.

In Thailand, Phantumvanit et al. (5) compared class I ART and amalgam restorations and found that amalgam performed significantly better than ART with survival rates of 85 percent for amalgam and 71 percent for ART after three years. It should be noted that they did not use the USPHS criteria for the evaluation and that all treatments in Thailand were carried out in a field setting. Mandari et al. (7) compared both ART and conventional preparation techniques in combination with glass ionomer and amalgam restorations made in different settings. Although the ART group had lower survival results after two years, this difference was not significant.

ART is a low-cost technique and is appropriate for a field setting. It is promising for the relatively new technique ART to be competitive with conventional amalgam restorations in more than one study, carried out under different circumstances.

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