

Six-year follow up of atraumatic restorative treatment restorations placed in Chinese school children

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Abstract - Objectives: This study aimed to evaluate the clinical performance of atraumatic restorative treatment (ART) restorations placed in school children in China over a 6-year period. Methods: This study was implemented in 1996 and 294 ART restorations were placed in 197 children aged 12-13 years by five assistant dentists in four schools. Standard ART procedures and instruments were used combined with a high-strength glass-ionomer restorative material. One examiner evaluated the restorations annually using the ART criteria while at 5 years an independent external examiner used US Public Health Service (USPHS) criteria. Results: Fifty-eight per cent of the restorations were followed for 6 years. At the 6-year evaluation examination, 76% and 59% of the small and large restorations respectively were present and were without major wear or defect (P < 0.01). Similar results were obtained when using the USPHS criteria. Results of a multilevel survival analysis show that the correlation between restoration failure and operator was small but failure of restorations placed in the same child was substantial. Net wear of the small and large restorations after 6 years were 176 and 172 μ m respectively (P > 0.05). Conclusion: The 6year survival rate of the class I ART restorations in this study, especially the smaller ones, was satisfactory. This suggests that the ART approach can be used in the school setting to improve the oral health of large populations of underserved children.

The atraumatic restorative treatment (ART) approach was introduced as an innovative approach to provide dental restorative treatment to underserved populations in economically less developed countries (1). ART treatment has been found to be very useful in outreach dental services for children (2, 3) and is used also in standard dental clinic settings (4, 5). It is one of the accepted techniques in minimal intervention/ invasive dentistry (6, 7).

High survival rates of ART restorations placed in permanent teeth in school children have been reported. However, most clinical studies have been Edward C. M. Lo¹, Christopher J. Holmgren^{1,2}, Deyu Hu³ and Wim van Palenstein Helderman²

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of only 3-year duration. The 3-year survival rates of single surface or class I ART restorations in the recent studies ranged from 81% to 92% (8–11). Although the need for ART field trials with improved materials for periods longer than 3 years had been expressed in an international symposium in 1995 (12), so far only one longer-term ART study has been reported (13). In that study conducted in Tanzania, 76 ART restorations placed in occlusal surfaces of permanent molars in 47 children were evaluated 6 years after placement. The survival rate of these ART restorations was 67%, which was similar to that of amalgam restorations placed in the children using conventional technique in the same study.

Findings of the latest Chinese national survey of oral health (14) showed that around half of the 12-year-old children in China had experienced dental caries in their permanent teeth and the national mean DMFT score was 1. Furthermore, over 90% of the DMFT score in the surveyed children was related to DT, i.e. untreated decayed teeth. It is obvious that the utilization of conventional dental care services is rather low among the children in China due to various reasons (15) and that an alternative approach to provide restorative dental care services to school children should be explored.

The objectives of this clinical study were to assess whether ART restorations could be provided to children in a school environment in China, and to evaluate on a longitudinal basis their clinical performance. The 3-year outcomes of the ART restorations placed in this study have been reported (9) and the present paper reports on the 6-year outcomes.

Materials and methods

This study was implemented in September 1996. The study children, mostly aged 12–13 years, were recruited from four schools in Deyang City, Sichuan Province, in western China. Free dental examination and ART treatment in school were offered to the children and their parents were free to opt for their children not to participate. No refusals were encountered. The children were examined by two calibrated dentists (ECML and CIH) to assess their dental caries status and treatment needs. The mean DT and DMFT scores in this group of children were found to be 0.4 and 0.6 respectively (16). Restorations were placed in permanent teeth with carious lesions extending into dentine using the ART approach (1) by five local assistant dentists who had received a shorttraining course in placing ART restorations. Teeth with obvious pulpal involvement or judged to be unrestorable were excluded from the study. In such cases, the child was advised to seek care in a dental clinic.

The ART treatments were carried out using only hand instruments and a portable light in the schools. Cotton wool rolls were used for isolation and moisture control. Soft carious dentine was removed with excavators and the prepared cavity was conditioned for 10 s using the liquid component of the glass–ionomer material diluted with approximately an equal amount of water. The cavity was then washed and dried. A high-strength glass–ionomer restoration material (Ketac-Molar; 3MESPE, Seefeld, Germany) was hand mixed according to the manufacturer's instructions and placed into the cavity. The 'finger-press' technique was then used to condense the material into the cavity and any adjacent pits and fissures, resulting in a sealant restoration. Excess material was removed with an excavator or carver and the occlusion checked.

Status of the ART restorations was evaluated annually for 6 years after placement. One dentist (ECML), who was not involved in the provision of treatment, carried out all follow-up examinations. WHO CPI probes, sharp sickle-shaped explorers, plane front-surface mirrors and an intra-oral fibreoptic light source were used. The tooth surfaces involved and the size of the restorations were recorded. A restoration was classified as 'large' when it extended over more than half of the involved surface either in a mesio-distal or buccolingual direction, or involved more than one tooth surface, e.g. occluso-buccal surfaces. Single-surface restorations that did not involve more than half of the involved surface in any direction were classified as 'small'. The codes and criteria used to evaluate the restorations were similar to those adopted in other ART studies (17). In the fifth year examination, an additional independent examiner (WvPH) evaluated all the restorations using the US Public Health Service (USPHS) criteria (18). Duplicate examinations were conducted on a random 10% sample of the children in each follow-up examination to assess intra-examiner reproducibility.

In the annual examinations, vinyl polysiloxane impressions of one in three restorations selected systematically were taken. Stone tooth replicas were poured from the impressions. Indirect evaluation of the wear of the restorations was made on the replicas with the aid of a standard Rheinberger scale (Vivadent, Schaan, Liechtenstein). The Rheinberger scale consists of a series of ivorine tooth-sized replicas with restoration-like incremental wear ranging from 25 to 1000 μ m. This semiquantitative standard has 25 μ m increments for wear values below 200 μ m, and 50 μ m increments for wear values >200 μ m. Occlusal wear for a restoration is represented by the distance from the cavosurface margin to the occlusal surface of the restoration (19).

The collected data were entered into a personal computer and analysed using the statistics software sPSS (SPSS Inc., Chicago, IL, USA) for Windows. Differences in results between the two types of restorations were tested using the chi-squared test. Repeated measures ANOVA and the *post hoc* Bonferroni test were used to compare differences in wear values at different evaluations. A difference was considered to be statistically significant if the *P*-value of a statistical test was ≤ 0.05 .

Since the clinical status of the ART restorations in this study was evaluated annually for 6 years after placement, the failure times of the restorations could only be recorded as between 0 and 12, 12 and 24, 24 and 36, 36 and 48, 48 and 60, or 60 and 72 months. A Bayesian approach was used to analyse this set of multilevel clustered intervalcensored data (20). A three-level model was adopted in the survival analysis with the restorations as level-1 units, children as the level-2 units, and dentists (the operators) as the level-3 units. The gender of the child (boy versus girl), type of the restoration (large versus small restoration) and location of the restoration (placed on teeth in the upper versus lower dental arch) were included as covariates. The software WinBUGS (MRC Biostatistics Unit, Cambridge, UK) was used in this multilevel statistical analysis.

Results

The mean age of the study subjects at baseline was 12.5 years (SD = 0.6). A total of 294 ART restorations were placed in 197 children. Of these, 230 (78%) were small single-surface restorations and 64 (22%) were large restorations among which 16 were class II restorations.

Intra-examiner reproducibility in the evaluation of ART restorations in the six annual examinations was good to excellent, with kappa-statistic values between 0.67 and 0.92. The intra-examiner reproducibility of the examiner who evaluated the restorations using the USPHS criteria at the 5-year examination was also very good, the mean kappastatistic value across the six different aspects being 0.95 (range 0.64–1.0). The weighted kappa-statistic value for the duplicate wear assessments was 0.75.

After 6 years, 117 children or 59% of the cohort remained in the study. The proportions of the small and the large restorations that were followed for 6 years were similar, being 57% and 61% respectively (chi-squared test, P > 0.05). At the 6-year examination, most of the restorations were in a good condition or had only some minor defects or wear which did not warrant further treatment (Table 1). Failure occurred in 24% of the small restorations and 41% of the large restorations. The main cause of failure for both the large and the small restorations was loss of the restoration and replacement by another restoration. Unacceptable marginal defects or excessive wear were found in around 5% of the restorations. Caries related to the restoration was found in only eight teeth (5%).

Among the restorations that were evaluated with the USPHS criteria at the 5-year examination, unacceptable marginal integrity, either a crevice extending to the enamel–dentine junction or the restoration being fractured, was found in 9% of the small and 21% of the large restorations (Table 2). For the restorations without fractures, nearly all were acceptable to good with regard to marginal discoloration, anatomical form, colour match and surface texture. Recurrent caries was found in only 6% of the small restorations.

The cumulative survival rates of the small restorations remained high throughout the study, being above 90% over the first 3 years and 85% up to 6 years (Fig. 1). The survival rates of the large restorations were lower, being 77% and 46% after 3 and 6 years respectively. The estimated median survival time of the large restorations was 67 months. The large restorations had a higher

Table 1. Status of the atraumatic restorative treatment restorations at the	year 5 and y	vear 6 examinations (%)
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	Year 5		Year 6	
	Small ($n = 134$)	Large ($n = 41$)	Small ($n = 131$)	Large ($n = 39$)
Success, good condition	58	29	44	31
Success, slight defect	10	10	15	8
Success, slight wear	15	22	17	20
Failed, gross defect	4	3	5	5
Failed, gross wear	0	2	2	0
Failed, partly or completely missing	8	12	11	13
Failed, replaced by another restoration	5	22	6	23

Table 2. Status of the atraumatic restorative treatment restorations after 5 years according to the US Public Health Service (USPHS) criteria (%)

Status	Small restorations	Large restorations
Retention		
Yes	86	66
No	14	34
Marginal integrity		
No crevice	62	52
Crevice, no dentine exposed	29	27
Defect extended to EDJ	3	6
Restoration fractured	6	15
Recurrent caries		
Yes	6	0
No	94	100
Marginal discoloration		
No discoloration	93	93
Discoloration,	7	7
no penetration		
Anatomical form		
Continuous	92	82
Discontinuous,	8	18
within enamel		
Colour match		
Within normal range	100	100
Surface texture		
Similar to enamel	1	0
Gritty, similar to	95	96
white stone		
Coarse	4	4

The percentages given for marginal integrity relate to all restorations examined while percentages for all other USPHS criteria relate to restorations present and without fracture.



Fig. 1. Survival curves of atraumatic restorative treatment restorations according to size.

relative risk of failure, 5.87, compared with the small restorations (Table 3), while the relative risk of failures among the restorations placed in boys and girls, or in upper and lower teeth were not statistically significant (the 95% CI including 1). It

was further found that the correlation between the failure times of restorations placed by the same dentist was very small, correlation coefficient being 0.07. However, the intracluster correlation among the failure times of restorations from the same child was strong, correlation coefficient being 0.51.

The mean net wear of the small restorations after 3 years was 107 μ m (SD = 66) and that after 6 years was 176 μ m (SD = 116) (Fig. 2). The respective values for the large restorations were 113 and 172 μ m. The net wear rate for both the small and large restorations in the first year after placement was about 48 μ m, which was significantly higher (*P* < 0.05) than the 20–25 μ m annual wear rate in later years. Furthermore, the small and the large restorations were found to exhibit similar annual net wear rates (*P* > 0.05).

Discussion

So far only one ART study of longer than 3-year duration has been reported (13). A main reason for not following up the ART restorations for a longer time in the earlier studies is a high subject dropout rate (3, 21). In this study the dropout rate was low up to 3 years, <10% (9), and thereafter the rate increased as children left school to seek employment or to follow higher education. Substantial efforts had been made to follow the study subjects through telephone calls and multiple site visits were made to reduce drop out.

The ART restorations in this study had a rather high long-term survival rate, 76% for the small restorations evaluated at the 6-year examination. This is slightly higher than the 69% survival rate of single-surface ART restorations in the 6-year Tanzanian study (13). From the findings of these two long-term studies, it can be seen that the longevity of small single-surface ART restorations is comparable with conventional amalgam restorations while that of large ART restorations is lower (22, 23). In a recent review of 42 published studies, the pooled 6-year survival rate of amalgam restorations was reported to be around 70%, notwithstanding that the annual failure rate of the restorations reported in articles published after 1990 are lower than those reported in the earlier papers, 2.4% versus 4.8% (23). In a recent systematic review of clinical trials in which single-surface ART restorations were compared directly with amalgam restorations, it was found that there was no significant difference between the two types of restora-

Table 3. Parameter estimates for Weibull regression model in the survival analysis

	Log hazard ratio	Relative risk (hazard ratio)
Type (large versus small)	1.77 (0.90 to 2.85)	5.87 (2.46 to 17.29)
Gender (male versus female)	-0.07 (-0.82 to 0.67)	0.93 (0.44 to 1.95)
Location (lower versus upper)	0.48 (-0.32 to 1.33)	1.62 (0.73 to 3.78)
Constant	-9.26 (-11.2 to -7.30)	
Intracluster correlation		
Dentist $= 0.07$		
Child $= 0.51$		

Values given are median (95% CI). Median means median of the estimates drawn from the posterior distributions based on 10 000 simulations; 95% CI, 95% credible interval.



Fig. 2. Mean net wear of the atraumatic restorative treatment restorations according to size.

tions in the recent studies (24). However, the studies reviewed were of 2- to 3-year-duration only.

It is important to note that the survival rate of small ART restorations is much higher than that of the large ones. This finding is in agreement with those from other studies on direct restorations placed in posterior teeth (23). The importance of implementing early intervention rather than waiting till the dental caries reach an advanced stage should be emphasized. The ART approach has a distinct advantage here in that it can be used both for sealant placement for caries prevention and treatment of enamel carious lesions in the pits and fissures as well as for restoring carious cavities (9).

The main reasons for failure of restorations in this study were loss of the restoration or replacement by another restoration. The replacement of the ART restorations in this study was usually found subsequent to the failure of the restoration due to loss, fracture or major marginal defect. Gross wear accounted for the fewest failures. This finding is in agreement with those from other ART studies (3, 8, 21). The annual wear rate of the highstrength glass–ionomer material used in this study was rather stable at around 20–25 m after the first year and this did not increase much with time or size of the restoration. This rate is very satisfactory and may help to alleviate some of the concerns of earlier reviews on ART (25). The use of an adhesive material in ART restorations also makes repair of restorations with gross defects and wear possible and total replacement may not be necessary (26).

In this study, the operator effect on ART restoration survival rates was found to be insignificant, which is in agreement with earlier ART studies conducted in Thailand (21) and in Syria (27). In the present study, the background of the five operators was similar. They were all assistant dentists who had received 3 years basic dental training in a health worker training school, but differed in the number of years they had been in practice. Although some operator effect is expected in any dental treatment procedure, the present findings suggest that operators who have received adequate training in the ART approach can produce reliable results. While ART may be considered by some to be a simple approach, it is recommended that educational courses for operators new to the approach be organized before applying it in the field and in dental clinics.

The finding that failures of ART restorations placed in the same child were correlated suggests that some factors related to the individual subjects such as diet, occlusion, and caries risk may influence restoration survival (22, 23). It is recommended that studies be conducted to find out which are the important factors influencing the longevity of ART restorations. The information would be very useful for proper selection of patients and teeth for receiving the treatment.

In conclusion, the 6-year survival rate of the ART restorations placed for the treatment of caries in the permanent teeth of the study in Chinese school children was high and was related to the size of the restoration. As the ART approach, a minimally invasive procedure, is not dependent upon expensive and sophisticated dental equipment, this approach may be used in the school setting to improve the oral health of large populations of underserved children.

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