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Cost and Time Differences Between Three Types of Restorations for Primary Teeth: Amalgam, Composite and Glass-ionomer Cement

Hanthao Thi Phan[1], John M Powers[2], Franklin Garcia-Godoy[3], Timothy Brown[4], Lilliam Marie Pinzon[1*]

[1]University of Utah, School of Dentistry, 530 South Wakara Way, Salt Lake City, Utah, USA

[2]Dental Consultants, Inc.: 3110 W Liberty, Ann Arbor, Michigan, USA

[3]University of Tennessee Health Science Center, College of Dentistry, 875 Union Avenue, Memphis, Tennessee, USA

[4]Berkeley Center for Health Technology, School of Public Health, University of California, Berkeley, California, USA

[*]**Corresponding author:** Lilliam Marie Pinzon, University of Utah, School of Dentistry, 530 South Wakara Way, Salt Lake City, UT 84108, USA

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Abstract

Background: Early Childhood Caries is the most prevalent chronic disease among children in the United States. Three common approaches for treatment of dental caries in general population include: amalgam, composite, and glass ionomer. The purpose of this study was to measure the treatment cost differences for amalgam, composite, and atraumatic restorative treatment (ART) restorations of primary teeth and evaluate possible factors that could influence the cost of treatment.

Methods: This cross-sectional study randomly selected data of 120 restorations from a clinical observational study of the restoration of primary teeth in children aged 5 – 10 years old. The 120 selected restorations in primary teeth, half with two surfaces and half with three surfaces, were performed by two operators at the Asian Health Center and Centro American Resources Center in California. Data were analyzed using multivariable linear regression.

Results: Performing ART was found to take 7.8 minutes less than amalgam ($p<0.01$) and 19.0 minutes less than composite. ART was found to be 6.4% ($p = 0.01$) less costly than amalgam and 62.4% ($p<0.01$) less costly than composite.

Conclusions: ART was found to be the least costly treatment compared to amalgam and composite restoration procedures. ART also required the shortest time during the clinical procedure.

Trial Registration: UCSF CHR Number: H55840-32823-02

Keywords: Minimally invasive, primary teeth, amalgam, composite, atraumatic restorative treatment, caries, cost effect, SAR-CoV-2

Abbreviations

ADA: American Dental Association; AHC: Asian Health Center; AMAL: Amalgam; ART: Atraumatic restorative treatment; CARECEN: Centro American Resources Center; CDC: Centers for Disease Control and Prevention; COMP: Composite; ECC: Early Childhood Caries; IRB: Institutional Review Board; WHO: World Health Organization

Introduction

Early Childhood Caries (ECC) is the most prevalent chronic disease among children in the United States; this public health issue is on the rise, according to recent reports [1,2]. Underserved children and those who come from economically disadvantaged backgrounds face a severe risk to their well-being because of ECC [2]. Nationally, ECC prevalence (any decayed, extracted or filled teeth among 2–5 year-olds) in 1988-1994 was 24% and rose to 28% in 1999–2004 [1,2].

Longitudinal studies have reported that preschool age children with ECC have a higher risk for caries and dental problems

in their permanent teeth later in life, affecting psychosocial well-being, growth, and development [3-7]. The adverse health effects, economic costs, disparities by race/ethnicity, and income posed by ECC demonstrate a compelling need for preventive strategies [2].

Two-thirds of all children in the state of California suffer from poor oral health by the time they reach third grade [8]. That is roughly 6.3 million children. In 2007, approximately 7 percent of California children missed school due to a dental problem (not including time for a cleaning or routine check-up). In addition, approximately 6 percent of all California adults between the ages of 21 and 65 missed work or school because of a dental problem (not including missed time for cleaning or a check-up) [9,10]. There were more than 83,000 visits to California hospital emergency departments for preventable dental conditions in 2007 [11]. Lastly, 73 percent of California adults are unaware that the disease, which causes tooth decay and dental caries, is an infection and spreads from person to person [12].

Three common approaches for treatment of dental caries in general population include: amalgam, composite, and glass ionomer (atraumatic restorative treatment (ART)) restorations for which The American Academy of Pediatric Dentistry established guidelines [13-15].

ART was initially tested in Tanzania (Africa) in the mid 1980s and was presented to the World Health Organization on World Health Day in 1994 as a new approach to treat dental caries [16]. ART was created to treat special population groups such as refugees and poor communities that could not otherwise afford dental care. The ART technique consists of excavation and removal of the softest portions of carious lesions using only hand instruments and restoration of the cavities, pits and fissures with glass ionomers [16]. ART has also been shown to be a valuable treatment for underprivileged school children not treated in conventional dental environments [17].

In previous clinical trials, the success and failure rates (longevity) of class II restorative treatments (amalgam, composite and glass ionomer) in children with primary teeth were compared. A key conclusion of these trials was that no caries were present on a cavo-surface margin or around glass ionomer restorations in primary teeth [18]. A recent meta-analysis concluded that ART restorations on single surfaces of primary and permanent teeth using a high-viscosity glass ionomer resulted in high survival rates [19]. In general, the success rates of ART restorations are high, especially for single-surface restorations. Other advantages of ART compared to amalgam and composite include caries preventive effects, decrease in cost and time for the clinician, acceptance by patients, and the effective treatment of carious lesions with apparent remineralization [16].

There have been no studies of ART restorations conducted in the US. One reason for this may be the perception that the ART technique is not part of the accepted standard of care. While ART is considered a useful aid for use in undeveloped countries and for communities that cannot afford standard dental care, [20] ART is not currently considered to meet the American standard of dental care as there is no specific ADA (American Dental Association) code for ART in order to charge it for reimbursement.

In the U.S. and specifically in California, there are numerous vulnerable populations where the use of ART might prove extremely helpful. These populations include those that cannot afford dental care (12.8% persons living at and below the poverty level in California and 11.8% in the U.S. as of 2018), young children who cannot tolerate local anesthesia, Native Americans living on reservations, cancer patients with xerostomia as a secondary effect of cancer treatment, the elderly confined to nursing homes, and those with physical and mental disabilities (nearly 2,700,000 in California under age 65 years and nearly 28,000,000 in US as of 2018) [21].

Because of its minimally invasive technique, ART would be a good approach for treatment of dental caries during pandemics. In March 2020, the World Health Organization (WHO) declared the coronavirus disease (COVID-19) outbreak a pandemic [22]. As of July 04, 2020, there were 2.2 million confirmed cases and 119, 318 deaths in the U.S. due to COVID-19 [23,24]. SARS-CoV-2, the virus that cause COVID-19, is primarily transmitted through respiratory droplets and has been shown to persist in aerosol for hours [25]. Conventional restorative techniques require the use of dental handpieces and burs that generate visible spray that contains droplets of saliva, blood and microorganism. On other hand, ART requires manual instrument that is minimally invasive and generates much less aerosol. The Centers for Disease Control and Prevention (CDC) has recommended that dentists prioritize minimally invasive/atraumatic restorative techniques, such as ART, and avoid dental procedures that generate aerosol whenever possible [25].

This cross-sectional study evaluated the cost difference of three dental restorative procedures in high-caries-risk children from lower socio-economic status households, many of whom rely on public assistance and all of whom are eligible for Denti-Cal (Medicaid) coverage. Our population was treated at the Asian Health Center (AHC) in Oakland, California, and Centro American Resources Center (CARECEN) in San Francisco, California.

The null hypotheses were:

1. There are no differences in the time to provide the different restorative procedures (amalgam, composite, and ART) performed at the AHC Dental Clinic and CARECEN by two clinicians after taking into account the characteristics of the teeth treated, and
2. There are no differences in the cost of the different restorative procedures (amalgam, composite, and ART) performed at the AHC Dental Clinic and CARECEN by two clinicians after taking into account the characteristics of the teeth treated.

Materials and Methods

This cross-sectional study was part of a clinical observational study that was approved by the institutional review board (IRB) of the University of California. Data of 120 restorations included in this cross-sectional study were randomly selected from 209 participants in the clinical observational study following the inclusion and exclusion criteria approved by IRB. Parental written informed consent was obtained in Cantonese, Mandarin, Vietnamese, Korean, Chiuchow, English, or Spanish as appropriate and child assent obtained for children age 7 and older. Eligible children were healthy, from 5 to 11 years-old at enrollment, and registered as patients at AHC Dental Clinic in Oakland, California and CARECEN in San Francisco, California. At enrollment, the children had caries in at least one primary molar (2 to 3 surfaces cavitated) that could be treated with ART, composite, or amalgam restoration. All the children with any mental or physical incapacity, uncooperative or behaviorally unsuited for outpatient dental treatment, children with cleft lip and/or palate, children with immune compromised conditions or on xerostomic medications that might affect the oral flora were ineligible. Children with teeth receiving crowns, pulpotomy or pulp cap procedures were also ineligible.

Among 120 restorations selected for this cross-sectional study, sixty restorations with two surfaces (20 amalgam, 20 composite and 20 ART) and sixty with three surfaces (20 amalgam, 20 composite and 20 ART) were performed by two operators at the AHC and CARECEN. The total times for 120 procedures were recorded by one researcher (LMP) using a standard chronometer. The time starting point included the preparation of the cavity with a hand piece for amalgam and composite restorations and/or cavity preparation using hand instruments for ART. Also included were the restorative steps required for the different restorative procedures such as conditioners, etching, priming, and/or bonding, the placement of the restorative material, and finally polishing, if necessary.

The two dentists participating in the study were classified as DDS1 and DDS2. The estimated annual salaries were $120,000 for DDS1, $100,000 for DDS2, and $40,000 for the dental assistant. To calculate labor costs per hour for each provider, each annual salary was divided by 2000 under the assumption that each worked 2000 hours per year. The cost of materials for two-surface restorations using amalgam, composite, and ART were $4, $34, and $10, respectively. The cost of materials for three-surface restorations using amalgam, composite, and ART were $6, $51, and $15, respectively. Overhead cost was a fixed cost and was thus economically irrelevant for cost comparison purposes.

Time data were analyzed using ordinary least squares. Cost data were analyzed by following a standard algorithm from the health economics literature [26]. The appropriate cost model was found to be a generalized linear model with a Poisson distribution and a log link. Standard errors were corrected for arbitrary forms of heteroscedasticity in all models. Each model included the same set of independent variables: restoration type (amalgam, composite, or ART), tooth type (7 types), number of surfaces (2 or 3 surfaces), and dental provider (1 or 2).

Results

Table 1 presents mean treatment times and standard deviations for dentist one (DDS1) and dentist two (DDS2) for amalgam (AMAL), composite (COMP) and atraumatic restoration (ART). Table 2 presents descriptive statistics for all variables used in the multivariable regression.

		DDS1			**DDS2**	
	Amalgam	Composite	ART	Amalgam	Composite	ART
Median	23.5	36.0	16.0	24.5	36.0	17.5
Mean	23.1	34.1	15.4	24.2	35.8	16.4
Standard Deviation	3.3	4.8	3.3	2.7	3.2	3.5

Table 1: Treatment time (minutes) difference of amalgam, composite and ART restorations between DDS1 and DDS2.

Variables	Mean	Standard Deviation
Total Cost ($)	47	25
Total time (minutes)	24.8	8.6
Restoration Type, %		
Amalgam	33.3	-
Composite	33.3	-
ART	33.3	-
Tooth type, %		
1	8.3	-
2	14.2	-
3	15.8	-
4	12.5	-
5	12.5	-
6	13.3	-
7	15.0	-
Number of surfaces, %		
2	50	-
3	50	-

Table 2: Descriptive Statistics (120 observations).

The multivariable regression results are presented in Table 3. The reference group is amalgam restorations, two surfaces, and DDS1. Composite restorations took approximately 11 minutes longer than amalgam restoration and ART restoration took approximately 8 minutes less than amalgam restoration. This result was based on controlling for tooth type, number of surfaces, and the particular dentist performing the restoration. This difference in time and the differences in the cost of materials were the main determinants of the difference in total cost between each type of restoration. While composite restorations cost 149% of amalgam restorations, ART restorations cost 6.4% less than amalgam restorations.

Variables	Total Time		Total Cost	
	Coefficient	*z*-statistic	Coefficient	*z*-statistic
Restoration Type (reference: Amalgam)				
Composite	11.210*	13.82	149.179*	46.08
ART	-7.761*	-10.97	-6.387*	-2.49
Tooth type (reference: 1)				
2	-0.815	-0.70	-2.371	-0.84
3	-1.004	-0.84	-3.343	-1.17
4	0.296	0.25	0.200	0.07
5	-1.175	-0.95	-2.955	-1.08
6	0.287	0.24	1.308	0.50
7	-0.018	-0.02	-0.499	-0.20
Number of surfaces (reference: 2)				
3	1.740*	2.73	22.140*	12.34
Dentist (reference: 1)				
2	-1.258	-1.92	5.127*	3.26

Table 3: Multivariate Regression Results (120 observations).

Total Time estimated using ordinary least squares.

Total Cost estimated using generalized linear model with Poisson distribution and log link (all coefficients transformed to percentages: 100 (exp(parameter)-1)

All standard errors are robust to heteroscedasticity

Reference group: amalgam restorations, tooth type 1, two surfaces, and DDS1

*$p \leq .01$

Null hypothesis 1 was rejected because there were statistical differences ($p \leq 0.01$) in the average times to perform the different restorative procedures (amalgam, composite, and ART) by two clinicians after controlling for confounding factors. ART was shown to have the shortest clinical time, followed by amalgam and finally composite restorations.

Null hypothesis 2 was rejected because there were statistical differences ($p \leq 0.01$) in the average cost of the different restorative procedures performed by two clinicians after controlling for confounding factors. The total cost was determined based on the cost of clinical time and material. ART was shown to have lowest total cost, followed by amalgam and finally composite restoration.

Discussion

In this study, the selection criteria for the different treatments were equal in order to have consistent values that can be comparable to each other. This selection of restoration type was determined by each clinician without influences from the research team. The mean treatment times for amalgam restorations with two and three surfaces were 23.1 and 24.2 minutes, respectively. The mean treatment times for composite restorations with two and three surfaces were 34.1 and 35.8 minutes, respectively. The mean treatment times for ART restorations with two and three surfaces were 15.4 and 16.4 minutes, respectively. The clinical time taken to restore teeth with composite was relatively long compared to amalgam and ART. A possible explanation might be the sticky nature of the composite that resulted in some corrections and finishing having to be performed in the mouth.

Other treatment studies found that the mean treatment times was 37 minutes for standard three-surface amalgam restorations [26], 42 minutes for three-surface amalgam restorations on molars [27], and 60 minutes for extensive amalgam restorations on molars [28]. It should be mentioned that all reported treatment times for the amalgam restorations included polishing. The mean treatment time for three-surface direct composite restorations was 37 minutes [29]. When treating children with direct composite restorations and amalgam restorations, there was a clear trend for the placement time of posterior composite restorations to be greater than that for amalgam [30]. These findings agreed with the findings in our study in which amalgam restorations had shorter clinical time than composite restorations. ART clinical time in our study with a mean of 16.4 minutes for three-surface restoration was shown to be shorter than the clinical time required for amalgam and composite restorations in our study and other studies. The reason for shorter clinical time of ART probably due to the thermal expansion of glass ionomer that is similar to natural teeth and glass ionomer can be placed in a single increment [31]. This quality gives us advantage in reducing working time.

Our study also showed that the treatment cost of ART restorations were lower than those of amalgam and composite restorations. The lower cost of ART restorations provides an opportunity for vulnerable populations who cannot afford dental care to treat their dental caries. Moreover, fluoride released from glass ionomer promotes remineralization and thus helps prevent recurrent caries [31]. These factors together make of ART an acceptable and effective treatment of dental caries for vulnerable populations who lack of access and finances for dental care.

ART restoration is not only beneficial to vulnerable populations, but also would help general populations to obtain their dental care regrading to the current situation of COVID 19 in the U.S. The COVID 19 pandemic has been posing a severe negative impact on the U.S. economy. It has caused 17.8 million people unemployed as of June 2020 [32]. The jobless rate and the number of unemployment were increased by 7.6 percentage points and 12.0 million, respectively, since February, the time before the pandemic [32]. Unemployment has caused people to lose their health insurance and dental insurance which are usually provided by employers. The lack of dental insurance prevents people from accessing their dental care due to the high cost of conventional treatments. With its low cost of treatment, ART would allow the general population to continue their dental care. Moreover, the ART is minimally invasive and produces less aerosols [25]. This quality of ART helps minimizing the transmission of SAR-CoV-2 in dental facility and maintaining healthy environment for dental professionals and patients.

Limitations to this analysis include the relative costs of dentists and dental assistants. Since differences in costs are proportional to time spent performing the procedures, the lower the salaries of the dentists and the dental assistant are, the smaller the difference in cost will be between ART and amalgam restorations.

Many cost-effectiveness and cost-benefit studies have been conducted in order to guide present and future resource allocation decisions as well as the development of codes used to identify different diagnoses, treatment plans, and reimbursement. In fact, some health care decision makers have not accepted some analyses because a critical factor or issue has been omitted. For this reason, clinical translational studies must integrate different disciplines (general dentistry, public health, material sciences, pediatrics, clinical research, policy, economics) in order to cover the possible issues that decision makers consider when evaluating scientific reports related to the need for changes in the dentistry standard of care in the U.S.

A wide variety of international studies have shown that ART has very good recurrent caries prevention and acceptable retention compared with traditional amalgam restorations [26,33]. In addition, caries removal with ART is ultraconservative and retains much more tooth structure than traditional methods.

Any decision regarding the appropriate procedure to use in a given situation is based on both clinician judgment and experience. Such decisions should also consider objective evidence, such as the above findings. Compared to amalgam and composite restoration, ART can be performed faster, on average, and for a lower average cost.

For all these reasons, it is important to continue performing studies of ART in order to further illustrate the value of changing the standard of care in the US. This cost analysis is a pilot study that can help in the design of future studies with larger sample sizes that can be used by policy makers who lead the development of new rules for standards of care in pediatric dentistry and for efficient planning in dental practice. This pilot study could have potential impacts in dental practice, patient management policies, and public health.

Conclusions

- Relative to amalgam and composite restoration, ART was the shortest clinical procedure.
- ART was a cost-effective procedure that should be studied further as a candidate for inclusion in the US standard of care for pediatric dentistry.

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