The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth

Findings From the New England Children's Amalgam Trial

Jennifer Ann Soncini, DMD; Nancy Nairi Maserejian, ScD; Felicia Trachtenberg, PhD; Mary Tavares, DMD, MPH; Catherine Hayes, DMD, SM, Dr Med Sc

ABSTRACT

Background. Limited information is available from randomized clinical trials comparing the longevity of amalgam and resin-based compomer/composite restorations. The authors compared replacement rates of these types of restorations in posterior teeth during the five-year follow-up of the New England Children's Amalgam Trial.

Methods. The authors randomized children aged 6 to 10 years who had two or more posterior occlusal carious lesions into groups that received amalgam (n = 267) or compomer (primary teeth)/composite (permanent teeth) (n = 267) restorations and followed them up semiannually. They compared the longevity of restorations placed on all posterior surfaces using random effects survival analysis.

Results. The average ± standard deviation follow-up was 2.8 ± 1.4 years for primary tooth restorations and 3.4 ± 1.9 years for permanent tooth restorations. In primary teeth, the replacement rate was 5.8 percent of compomers versus 4.0 percent of amalgams ($P = .10$), with 3.0 percent versus 0.5 percent ($P = .002$), respectively, due to recurrent caries. In permanent teeth, the replacement rate was 14.9 percent of composites versus 10.8 percent of amalgams ($P = .45$), and the repair rate was 2.8 percent of composites versus 0.4 percent of amalgams ($P = .02$).

Conclusion. Although the overall difference in longevity was not statistically significant, compomer was replaced significantly more frequently owing to recurrent caries, and composite restorations required seven times as many repairs as did amalgam restorations.

Clinical Implications. Compomer/composite restorations on posterior tooth surfaces in children may require replacement or repair at higher rates than amalgam restorations, even within five years of placement.

Key Words. Dental amalgam; resin-based composites; compomers; dentition, primary; dentition, permanent; clinical trial; longevity.

JADA 2007;138(6):763-72.

Two randomized controlled clinical trials conducted in the United States and Portugal recently demonstrated the safety of dental amalgam restorations in children.[1,2] Although these studies definitively addressed decades of controversy regarding the use of mercury-containing amalgam in children, dentists may continue to seek alternatives to amalgam that are thought to be more suitable for the restoration of posterior primary teeth or esthetically preferable for permanent teeth.

In the past three decades, resin-based composite restorative materials have become a common alternative to amalgam. The American Dental Association Council on Scientific Affairs concluded that both amalgam and resin-based compomer/composite materials are safe and effective for tooth restoration.[3] However, controversy continues regarding which material is more durable.[4-6]

Amalgam and resin-based compomer/composite have vastly different physical and functional properties. Amalgam, which has

Dr. Soncini is a staff associate, The Forsyth Institute, Boston, and an assistant clinical professor, Department of Pediatric Dentistry, Boston University School of Dental Medicine.
Dr. Maserejian is a research scientist, New England Research Institutes, 9 Galen St., Watertown, Mass. 02472, e-mail "nmaserejian@neriscience.com". Address reprint requests to Dr. Maserejian.
Dr. Trachtenberg is a statistician, New England Research Institutes, Watertown, Mass.
Dr. Tavares is a senior clinical investigator, The Forsyth Institute, Boston.
Dr. Hayes is a professor and the chair, Department of Public Health and Community Service, Tufts University School of Dental Medicine, Boston.

been used in dentistry for more than 150 years, is a mixture of mercury and silver alloy powder that solidifies at mouth temperature. It is tolerant to a wide range of clinical placement conditions and moderately tolerant to the presence of moisture during placement. The biocompatibility and durability of amalgam are good-to-excellent in large load-bearing restorations, but the silver-colored material has little esthetic value, and controversy regarding its safety lingers.[7-9]

Adequate retention of amalgam in posterior primary teeth may be difficult given the tooth structure (thin enamel and dentin, shallow pits and fissures, narrow occlusal tables and enamel rods that run in the occlusal direction) compared with that of permanent teeth; thus, primary teeth in particular are thought to benefit from restoration with resin-based compomer, which may allow greater conservation of sound tooth structure than does amalgam.[10-15] Compomers, which were introduced into dentistry in the mid-1990s, are polyacid-modified resin-based composites that contain 72 percent (by weight) strontium fluorosilicate glass, with an average particle size of 2.5 micrometers.[16] The presence of both acid functional monomer and basic ionomer-type glass attracts moisture into the material, which can trigger a reaction that releases fluoride and buffers acidic environments.[17,18] In addition to its ability to release fluoride, compomer has the esthetic value of being tooth-colored and the practical value of having simple handling properties that are particularly useful in pediatric dentistry.[16,19]

For permanent teeth, dentists commonly use resin-based composites, a heterogeneous blend of organic resin and inorganic filler.[20] For example, the hybrid composite consists of 60 to 65 percent volume filler of silica and glass and a particle size of 0.6 to 1.0 µm. The high percentage of filler particles provides strength, and the small size of the filler particles enhances polishability, which generally results in improved finishing qualities compared with compomer.[21] In a 1991 report, Newman[5] ranked composite as the superior restorative material in specific circumstances, such as those in enamel sites beyond the height of contour, in nonocclusal function, in cervical abrasion and in root caries. In 2002, Fuks[7] recommended composite for small occlusal restorations, because composite placement requires less removal of sound tooth structure than does amalgam (though refurbishing is recommended[22]). Some researchers have cited marginal leakage caused by polymerization shrinkage as a problem of resin-based composites.[23,24]

In determining the restorative material of choice, the dentist should consider the important factor of longevity, because replacement of failed restorations is a burden to patients, practitioners and health care systems. The survival time of restorations generally is shorter in primary and young permanent dentition, with recurrent caries often cited as the most common reason for replacement.[23,25-30] For primary dentition, differences in longevity between amalgam and resin-based compomer are difficult to determine from previous studies, mainly because studies using the split-mouth design have been limited by small sample sizes, and retrospective studies using chart reviews are subject to bias by confounding factors associated with receipt of treatment.[7] In their study of restorations in young dentition, Forss and Widstrom[26] concluded that tooth-colored restorative materials may be less durable than amalgam in pediatric patients. In particular, compomer's longevity may be more compromised in technically difficult situations (such as lack of patient cooperation, difficulty in isolating the tooth).[23,28] On the other hand, studies that limited variability by using split-mouth designs showed comparable retention rates for compomer and amalgam during 24- to 36-month periods and suggested that compomer restorations had better marginal adaptation or surface texture.[31-33]

Regarding posterior permanent teeth, researchers who conducted a systematic review found insufficient evidence from well-controlled studies to establish whether amalgam and resin-based composite have comparable longevity, but they cited several retrospective studies that reported a longer survival time for amalgam.[34] A 17-year longitudinal study published in 2003 found a significantly higher survival time for extensive amalgam restorations than for extensive composite restorations.[35] Because a variety of factors are associated with placement of amalgam or composite in children, results from studies in which investigators did not control for such factors may be biased in either direction, and the studies have not addressed the issue of longevity adequately.[36,37]

ABBREVIATION KEY. NECAT: New England Children's Amalgam Trial.

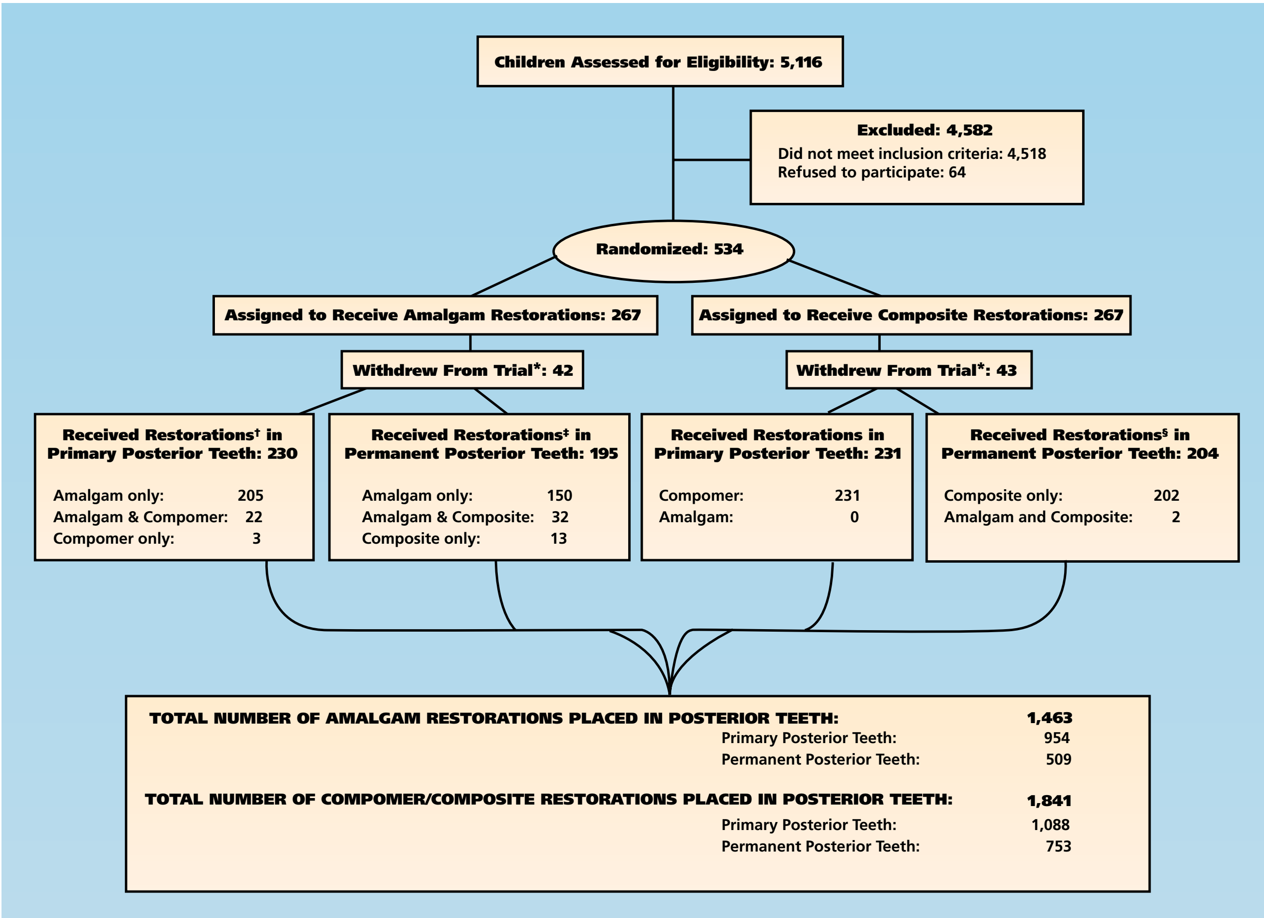

Figure 1. Randomization assignment, treatment received in posterior teeth and follow-up in the New England Children's Amalgam Trial (NECAT). *Subjects who withdrew from the trial were included in this analysis because they had undergone some follow-up before withdrawing. †Compomer was indicated by NECAT protocol and standard clinical practice guidelines for carious teeth in 24 children in the amalgam group. One participant in the amalgam group refused amalgam restorations and received compomer only. ‡Composite was indicated by NECAT protocol and standard clinical practice guidelines for carious teeth in 45 children in the amalgam group. §Two children in the composite group received amalgam restorations from out-of-study dentists.

Our objective in this article is to clarify the issue of restoration longevity by using a randomized clinical trial to compare the replacement rates of restorative material in children's posterior teeth. The New England Children's Amalgam Trial (NECAT) randomly assigned children aged 6 to 10 years to groups receiving restorations of either amalgam or resin-based compomer/composite material and prospectively followed them for approximately five years, thus providing an unbiased method to evaluate the durability of the materials.

METHODS

Study design and participants. NECAT was a randomized controlled trial of neuropsychological and renal effects of dental amalgams in children. Detailed descriptions of the design of NECAT have been published.[1,38] The study was approved by the institutional review boards of the New England Research Institutes, Watertown, Mass.; The Forsyth Institute, Boston; and all participating dental clinics. English-speaking children aged 6 to 10 years at baseline were eligible if they had no known prior or existing amalgam restorations, more than two posterior teeth with dental caries requiring restorations on occlusal surfaces and no clinical evidence of existing psychological, behavioral, neurological, immunosuppressive or renal disorders. We screened 5,116 children for eligibility. The screening process and baseline visits included a dental examination by a NECAT dentist, radiographs, standard preventive dental care (such as cleaning, application of fluoride and sealants), phlebotomy, urine sample, anthropometric measurements, health interviews and neuropsychological testing of the child and his or her guardian. We confirmed eligibility for 598 children and obtained parental consent and child assent for 534 children (Figure 1).

Dental treatment and clinical procedures. NECAT investigators randomized children to receive either amalgam (n = 267) or resin-based compomer/composite (n = 267) restorations at baseline and during the course of the trial. Randomization was stratified by geographical location (the study sites were urban Boston and rural Farmington, Maine) and number of teeth with caries (two to four or ≥ five carious teeth) by using randomly permuted blocks within each of the four strata. In Maine, children were seen at the nonprofit Franklin County Dental Center (Mt. Blue Health Center, Farmington). Boston clinics included three private, nonprofit community health centers (Codman Square Health Center, Dorchester; South Boston Community Health Center, South Boston; Windsor Street Health Center, Cambridge), as well as the Children's Hospital Boston and the independent Forsyth Institute. One dentist (J.A.S.) treated 97 percent of the Boston-area participants (two additional dentists treated only the seven children who attended the Children's Hospital Boston), and three dentists treated rural Maine participants during the course of the trial. Clinical variability was minimized by centralized training of all dental personnel and the use of standard pediatric dental procedures, specified in the NECAT protocol and procedures manual. NECAT provided clinics with dentists and materials; any remaining costs were billed to third-party payers.

For children assigned to the resin-based compomer/composite group, NECAT dentists placed compomer in all primary dentition and composite in all permanent dentition. For children in the amalgam group, NECAT dentists used compomer or composite in posterior dentition if required by standard clinical practice guidelines.

We scheduled a complete dental examination for each participant every six months during the five-year trial. The study dentists placed restorations continually during the course of the trial as needed, according to the assigned treatment. Restorations could cover multiple surfaces, and the dentists classified restoration size as small (one-quarter of the surfaces or less), medium (between one-quarter and one-half of the surfaces) or large (one-half of the surfaces or more). The dentists repaired restorations when teeth exhibited less than ideal marginal adaptation and/or stained margins.[39] If a restoration required replacement, the dentists categorized the reason for replacement as one of the following: new caries, recurrent caries, fracture, restoration loss or other. The dentists used the criterion of "new caries" when the carious surface was different from the one previously restored on the same tooth. The dentists recorded exact dates of dental visits, replacements, repairs and extractions.

The dentists used the same technique when placing all restorations, using rubber dams most of the time. After completely removing carious matter, the dentist acid-etched the tooth with 30 percent phosphoric acid for 20 seconds and washed it thoroughly. He or she applied a bonding agent (Optibond, Kerr, Orange, Calif.) and light-cured it for 30 seconds. The dentist then placed the restoration according to the manufacturer's indications using Dispersalloy (Dentsply/Caulk, Milford, Del.) for the amalgam restorations, Dyract (Dentsply/Caulk) for the compomer restorations and Z100 (3M ESPE, St. Paul, Minn.) for the composite restorations.

Statistical analysis. We collected data for each restoration from the date of initial placement to the date of replacement, repair, extraction, exfoliation or the child's last dental visit (whether at year 5 or before withdrawal from the trial), whichever occurred first. Because the study dentists placed restorations at the baseline dental visits as well as during follow-up visits throughout the five-year trial, the start of follow-up time could vary for each restoration. We estimated the date of exfoliation by averaging the date of the last dental visit with the primary tooth with the date of the first dental visit with the corresponding permanent tooth. Because the dentist performed dental examinations every six months and documented the status of each tooth, the date of exfoliation is accurate to within three months. We excluded from all analyses any restorations placed with no subsequent follow-up (placed at the last dental visit before withdrawal from the study, before tooth exfoliation or at the end of the trial).

The analysis for permanent teeth consisted of two main outcomes: rate of replacement and rate of repair. In the main analysis for primary teeth, we considered only the rate of replacement, as we made no repairs on restorations in primary posterior teeth. We compared rates of extraction in an additional analysis because primary teeth containing restorations in need of replacement may have been extracted if the tooth was close to exfoliation.

To evaluate whether the rate of replacement and/or repair varied by type of restoration material, we used a random effects accelerated failure time model with proportional hazards. The random effect was the participant, to account for correlations between restorations in the same mouth. The models adjusted for the following covariates when they were significant or changed the effect of the restoration material by more than 10 percent: age, sex, socioeconomic status and the number of restorations (of either type) in the mouth.

In our sensitivity analyses of primary teeth, we examined first and second primary molars separately. In sensitivity analyses of permanent teeth, we restricted the analyses to restorations that were placed at baseline and for which we had five-year follow-up data. In additional analyses, we evaluated the association between the size of the restoration and the need for replacement by adding it into the multivariate models. Here, we used only the subset of patients seen by a single dentist (J.A.S., the primary dentist in Boston) (n = 1,044 restorations in primary teeth, 875 restorations in permanent teeth), because size classification may be subjective. We used a repeated-measures logistic regression model with compound symmetric variance structure, which accounts for correlations within the same child, to compare reasons for replacement between materials.

TABLE 1

Baseline characteristics of New England Children's Amalgam Trial participants (N = 534), by assigned treatment.*

CHARACTERISTIC	RESTORATION GROUP	
	Amalgam Group (n = 267)	Composite Group (n = 267)
Study Site, n (%)		
Boston	144 (53.9)	147 (55.1)
Maine	123 (46.1)	120 (44.9)
Carious Surfaces, Mean (SD†) Range	9.8 (6.9) 2-39	9.3 (6.2) 2-36
Age, Years (Mean [SD])	7.9 (1.3)	7.9 (1.4)
Sex, n (%)		
Female	131 (49.1)	156 (58.4)
Male	136 (50.9)	111 (41.6)
Race, n (%)‡		
Non-Hispanic white	165 (64.0)	158 (60.3)
Non-Hispanic black	49 (19.0)	49 (18.7)
Hispanic	15 (5.8)	23 (8.8)
Other	29 (11.2)	32 (12.2)
Household Income, n (%)		
≤ $20,000	74 (29.2)	86 (33.1)
$20,001-$40,000	113 (44.7)	109 (41.9)
> $40,000	66 (26.1)	65 (25.0)
Education of Primary Caregiver, n (%)		
< High school	34 (13.2)	38 (14.6)
High school graduate	197 (76.4)	194 (74.3)
College graduate	18 (7.9)	17 (6.5)
Postcollege degree	9 (3.5)	12 (4.6)

* For race, data were available for 520 participants; for income, 513 participants; for education, 519 participants.
† SD: Standard deviation.
‡ Race was self-reported by the parents of the children.

RESULTS

Figure 1 shows the randomization assignment and treatment received during the trial. In all, we placed 954 amalgam and 1,088 compomer restorations in posterior primary teeth among 461 children and 509 amalgam and 753 composite restorations in posterior permanent teeth among 399 children. Of the restorations placed, 36 percent were small, 51 percent were medium and 13 percent were large, with similar distributions for primary and permanent teeth, as well as for amalgam and compomer/composite restorations.

At baseline, the average age of participants was 7.9 years (with a standard deviation [SD] of 1.3 years in the amalgam group and 1.4 years in the composite group) (Table 1). The mean number of carious tooth surfaces at baseline was 9.5, of which 7.8 were in primary teeth and 1.7 in permanent teeth. Children in the two treatment groups were similar in terms of baseline characteristics, including age, race, household income, education of primary caregiver and number of carious tooth surfaces. The numbers of girls and boys were comparable in the amalgam group, but girls outnumbered boys in the composite group.

TABLE 2

Replacement of posterior restorations in the five-year New England Children's Amalgam Trial.*

RESTORATION/TOOTH TYPE	RESTORATION MATERIAL		P VALUE§
	Amalgam	Compomer†/ Composite‡	
Primary Restorations			
No. placed	954	1,088	
Total replaced, n (%)	38 (4.0)	63 (5.8)	.10
Replaced owing to recurrent caries, n (%)	5 (0.5)	33 (3.0)	.002
Permanent Restorations			
No. placed	509	753	
Total replaced, n (%)	55 (10.8)	112 (14.9)	.45
Total repaired, n (%)	2 (0.4)	21 (2.8)	.02

* Average length of follow-up = 2.8 years ± standard deviation 1.4 years for primary restorations and 3.4 ± 1.9 years for permanent restorations.
† Compomer was placed in primary teeth.
‡ Composite was placed in permanent teeth.
§ *P* values were calculated from random effects accelerated failure time models with proportional hazards. The models adjusted for age, sex, socioeconomic status and number of restorations in the mouth if statistically significant ($P < .05$) or if the estimate for restoration material changed by more than 10 percent.

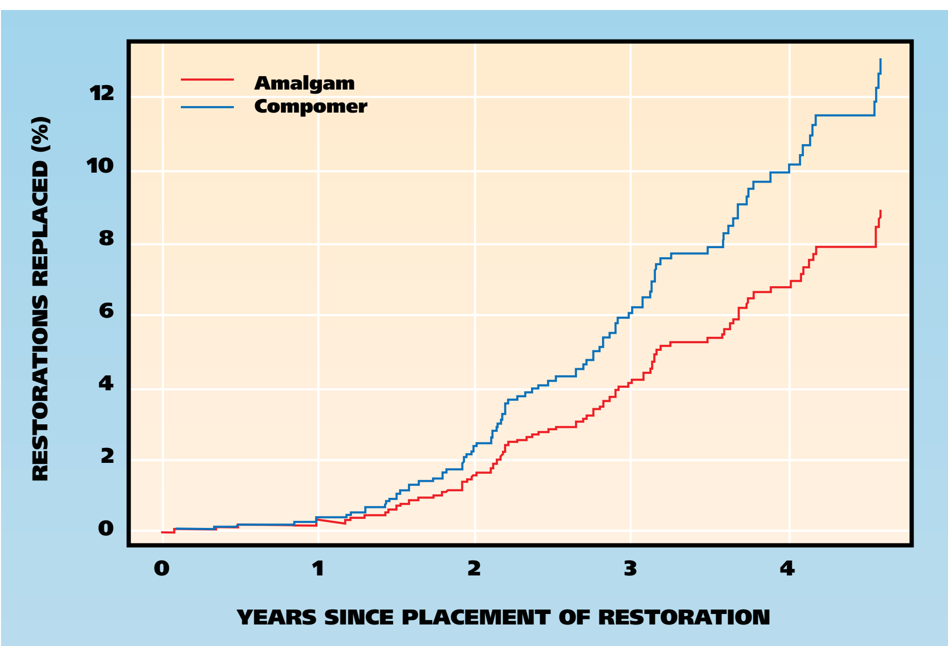

Figure 2. Restoration replacement rates in primary teeth for all restorations in the New England Children's Amalgam Trial. $P = .10$, calculated from a random effects accelerated failure time model with proportional hazards, adjusted for age and number of restorations in the mouth.

The average length of follow-up was 2.8 ± 1.4 years for primary tooth restorations and 3.4 ± 1.9 years for permanent tooth restorations, with a range of 0.03 to 6.3 years for both. Although this was a five-year study with dental visits every six months, children sometimes scheduled visits at longer intervals, resulting in greater than five years of follow-up. The average length of follow-up was similar for amalgam and resin-based compomer/composite restorations.

Restorations in primary teeth. *Replacement of restorations.* The percentage of restorations replaced during the trial was greater for resin-based compomers (5.8 percent) than for amalgams (4.0 percent) (Table 2). Figure 2 displays the rates of replacements for all restorations. The difference in longevity became noticeable between one and two years after placement and persisted until the end of the trial, although it failed to reach statistical significance in the random effects survival model ($P = .10$). The need for replacement increased with the number of restorations in the mouth ($P < .001$).

As expected considering the later natural exfoliation of second molars, follow-up was longer for the second molars than for the first molars (3.0 versus 2.4 years). In a sensitivity analysis restricted to first molars, we saw no difference between amalgam and compomer. In contrast, the sensitivity analysis of second molars showed a greater rate of replacement for resin-based compomer restorations compared with amalgam restorations (7.0 percent versus 3.9 percent, $P = .07$; data not shown).

Overall, reasons for replacement varied significantly with the restorative material ($P = .04$) (Table 3). Almost one-half (47 percent) of amalgam replacements were the result of new caries, whereas resin-based compomer replacements most often (52 percent) were caused by recurrent caries. Considering that recurrent caries is likely to be the most relevant reason for restoration replacement in a comparison of restorative materials and replacement rates, we conducted an exploratory subanalysis. We found that 3.0 percent of the compomer restorations were replaced owing to recurrent caries, compared with 0.5 percent of the amalgam restorations (Table 2), a sixfold increase. As seen in Figure 3, replacements due to recurrent caries were more common among compomer restorations as early as one year after placement, and this difference grew substantially through follow-up ($P = .002$).

The need for replacement did not vary with the size of the restoration. Of the amalgam restorations placed, 2.7 percent of small restorations, 5.7 percent of medium restorations and 3.6 percent of large restorations were replaced. Of the resin-based compomer restorations placed, 4.8 percent of small restorations, 7.4 percent of medium restorations and 4.2 percent of large restorations were replaced.

Extractions. Posterior teeth restored with compomers were more likely to be extracted at a later point than were those restored with amalgam (10.7 percent of compomer restorations versus 7.2 percent of amalgam restorations; data not shown). This difference was due mainly to the extraction of mandibular second molars (13.6 percent of compomers versus 3.8 percent of amalgams).

Restorations in permanent teeth. *Replacement of restorations.* Replacement was more frequent among resin-based composite restorations, with 14.9 percent of composite restorations replaced compared with 10.8 percent of amalgam restorations (Table 2). Although there was a noticeable difference in longevity two years after placement (Figure 4), this difference was not statistically significant in the random effects survival model ($P = .45$). When we restricted the analysis to

TABLE 3

Reasons for restoration replacement in the New England Children's Amalgam Trial, by restorative material.*

REASON FOR REPLACEMENT	NO. (%) OF RESTORATIONS REPLACED, BY RESTORATION/TOOTH TYPE			
	Primary Restorations		Permanent Restorations	
	Amalgam (n = 38)	Compomer (n = 63)	Amalgam (n = 55)	Composite (n = 112)
New Caries	18 (47)	13 (21)	22 (40)	37 (33)
Recurrent Caries	5 (13)	33 (52)	24 (44)	58 (52)
Fracture	4 (11)	7 (11)	3 (5)	2 (2)
Restoration Loss	10 (26)	8 (13)	1 (2)	1 (1)
Other	0 (0)	0 (0)	5 (9)	13 (12)
Missing Reason	1 (3)	2 (3)	0 (0)	1 (1)

* $P = .04$ for primary restorations and .47 for permanent restorations, for association between reasons for replacement and restorative material.

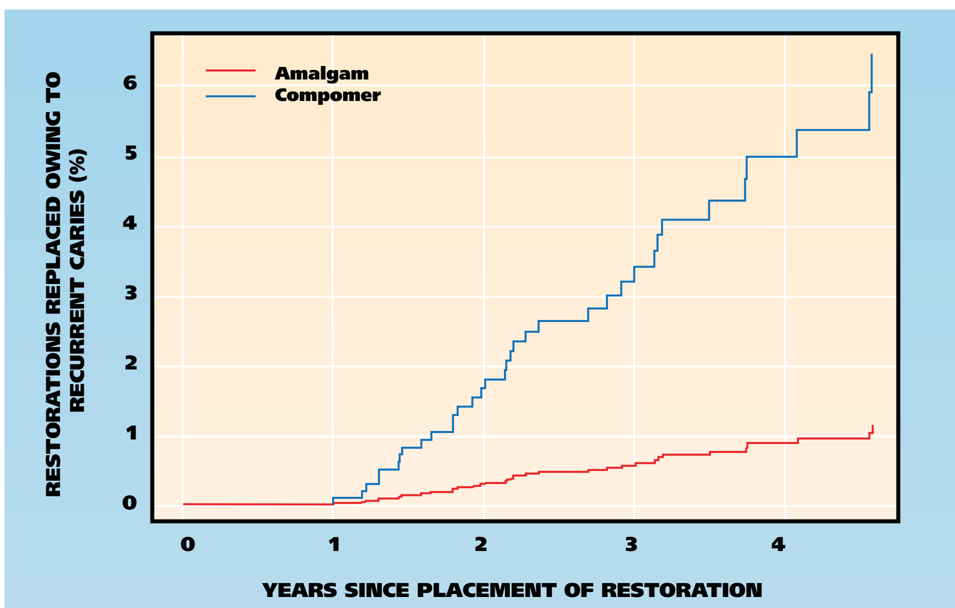

Figure 3. Restoration replacement rates due to recurrent caries in primary teeth in the New England Children's Amalgam Trial. $P = .002$, calculated from a random effects accelerated failure time model with proportional hazards, adjusted for age and number of restorations in the mouth.

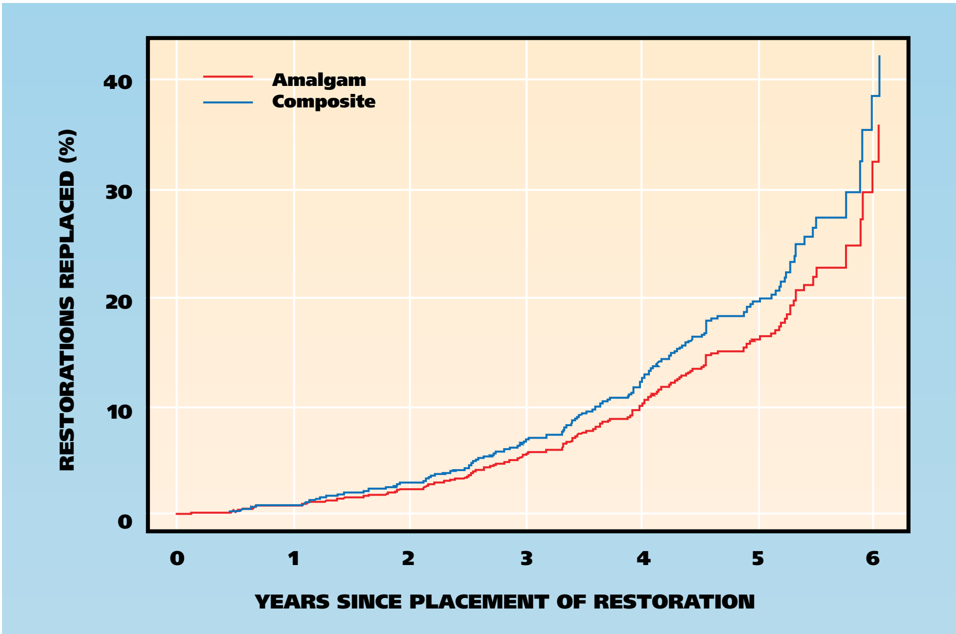

Figure 4. Restoration replacement rates in permanent teeth in the New England Children's Amalgam Trial. $P = .45$, calculated from a random effects accelerated failure time model with proportional hazards, adjusted for number of restorations in the mouth.

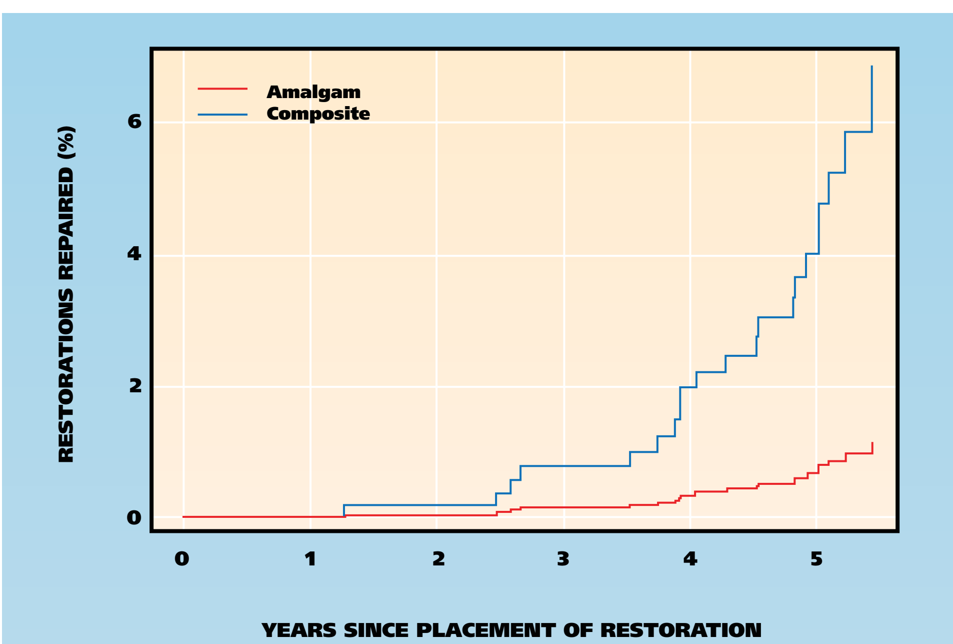

Figure 5. Restoration repair rates in permanent teeth in the New England Children's Amalgam Trial. $P = .02$, calculated from a random effects accelerated failure time model with proportional hazards.

restorations with five years of follow-up data, we found that 21.9 percent of composite restorations were replaced, compared with 15.9 percent of amalgam restorations ($P = .61$; data not shown). In both models, the need for replacement increased with the number of restorations in the mouth ($P < .001$).

Need for replacement increased significantly with the size of the restoration ($P = .04$; data not shown). Of the amalgam restorations placed, study dentists replaced 7.5 percent of small restorations, 9.6 percent of medium restorations and 14.2 percent of large restorations. Of the resin-based composite restorations placed, study dentists replaced 10.1 percent of small restorations, 11.0 percent of medium restorations and 19.8 percent of large restorations.

There were no statistically significant differences in reasons for replacement by restorative material. The most common reasons were new caries and recurrent caries (Table 3).

Repair of restorations. The percentage of repairs was significantly higher for composites (2.8 percent) than for amalgams (0.4 percent) ($P = .02$; Table 2). Figure 5 depicts the rates of repair for amalgam and composite restorations. After 2.5 years, a wide divergence that grew with increasing follow-up time is notable. Among the restorations with five years of follow-up data, repair rates were 4.0 percent versus 0.5 percent ($P = .13$; data not shown).

DISCUSSION

This article presents data from one of the first two randomized clinical trials comparing amalgam and resin-based compomer/composite restorations in children.[1,2,38] NECAT not only demonstrated the safety of amalgam but also provided, for the first time, unbiased comparisons to address additional questions such as the one posed here regarding restoration longevity. During the course of the five-year trial, compomer/composite restorations consistently required more replacement or repair than did amalgam restorations. Compomers were seven times as likely to require replacement because of recurrent caries, and composites were seven times as likely to require repair. These statistically significant findings support previous reports showing that amalgam restorations have greater longevity than do resin-based materials.[23,26,28,30,40,41]

Although the difference in replacement rates between amalgam and composites was not statistically significant itself, the widening gap between materials in the survival analysis curves and the significant difference in repair rates suggest that with longer follow-up, differences in replacement rates could become significant. Studies show that the strength of a repaired composite tends to be substantially compromised, compared with the original restoration.[42-44] Although it is accepted clinical practice that composite restorations are more amenable to repair, whereas amalgam restorations more often are replaced, this practice alone cannot explain the striking difference in the rate of repairs in our study. In NECAT, the study dentists repaired composite restorations primarily because of marginal defects (as noted by J.A.S.), whereas they repaired amalgams only rarely. Regardless of the reason, the fact that composites more frequently required repair is a substantial disadvantage, because each repair requires time and materials and, therefore, increases the cost of dental care.

It is possible that primary teeth with restorations in need of replacement were extracted, rather than the restoration replaced, if the tooth was close to exfoliation. We did not record reasons for extractions, thereby limiting our ability to analyze the need for replacement. However, the finding that extracted teeth were more likely to have been restored with compomer than with amalgam provides additional evidence of a lower longevity for resin-based compomer, because the actual difference in replacement between compomer and amalgam may be greater than what we observed.

An evaluation of the reasons for replacement provides insight into the suitability of restorative materials. For example, our finding that compomer was replaced most often because of recurrent caries suggests that compomer may not be ideal for restorations in posterior primary teeth. Compomer shrinks, which may compromise the restoration and facilitate recurrence of caries.[45] In addition, compomers and composites are especially technique-sensitive and thus may be more difficult to place in young or uncooperative children.[19,26,30] The finding that most amalgam replacements in primary teeth were necessitated by new caries suggests both an advantage (that is, recurrent caries was not much of an issue), as well as a disadvantage (in that amalgams must be replaced often to facilitate restoration of new caries). Thus, the advantages and disadvantages of each material can be weighed by considering the reasons for differences in longevity, as well as the observed differences in replacement rates.

Our results are consistent with previous reports suggesting that the longevity of amalgam is higher than that of resin-based compomer in primary teeth[26] and composite in permanent teeth.[30,40] However, other studies failed to find differences in longevity for restorations in primary dentition, and some noted potential advantages of compomer over amalgam, such as improved marginal adaptation.[31-33] The lack of a clear consensus on the issue of longevity from previous studies results from varied clinical methods and materials, limited sample sizes and follow-up, and the potential for confounding. In our study, the randomization of treatment ensured that children would be balanced in terms of factors that may be related to longevity of restorations. We also minimized clinical variability by using mainly one dentist at the Boston study site and just three at the Maine site. However, the use of only one type of compomer and one type of composite may limit our ability to generalize to all compomer/composite materials. Similarly, longer follow-up would have improved our ability to assess the longevity of materials in permanent teeth. Future studies of restoration longevity in children's dentition should include children younger than 6 years to allow for maximal follow-up time of restorative materials in primary teeth as well.

CONCLUSION

Longevity is an important consideration in a determination of which restorative material to use. In posterior primary teeth, we found that resin-based compomer restorations had greater replacement rates than did amalgam restorations, but the difference was statistically significant only among replacements due to recurrent caries. In posterior permanent teeth, we found that resin-based composite restorations had significantly higher repair rates, yet not significantly greater replacement rates, than did amalgam restorations.

These findings from a randomized clinical trial in New England are the first to document, without bias, that compomer/composite restorations in pediatric patients may require more procedures than do amalgam restorations to maintain their integrity. In addition to longevity, dentists should consider the diagnosis, ease of material placement, oral hygiene, risk profile for future caries, esthetic demands and financial considerations in weighing advantages and disadvantages of compomer, composite and amalgam restorative materials. ■

The research described in this article was supported by a cooperative agreement (U01 DE11886) between the New England Research Institutes, Watertown, Mass., and the National Institute of Dental and Craniofacial Research, Bethesda, Md.

The research described in this article is registered with the U.S. National Institutes of Health as "Health Effects of Dental Amalgams in Children," identifier NCT00065988, "www.clinicaltrials.gov/ct/show/NCT00065988?order=1".

1. Bellinger DC, Trachtenberg F, Barregard L, et al. Neuropsychological and renal effects of dental amalgam in children: a randomized clinical trial. JAMA 2006;295(15):1775-83.
2. DeRouen TA, Martin MD, Leroux BG, et al. Neurobehavioral effects of dental amalgam in children: a randomized clinical trial. JAMA 2006;295(15):1784-92.
3. ADA Council on Scientific Affairs. Direct and indirect restorative materials. JADA 2003;134(4):463-72.
4. Coppola MN, Ozcan YA, Bogacki R. Evaluation of performance of dental providers on posterior restorations: does experience matter? A data envelopment analysis (DEA) approach. J Med Syst 2003;27(5):445-56.
5. Newman SM. Amalgam alternatives: what can compete? JADA 1991;122(8):67-71.
6. Rosenstiel SF, Land MF, Rashid RG. Dentists' molar restoration choices and longevity: a web-based survey. J Prosthet Dent 2004;91(4):363-7.
7. Fuks AB. The use of amalgam in pediatric dentistry. Pediatr Dent 2002;24(5):448-55.
8. Needleman HL. Mercury in dental amalgam: a neurotoxic risk? JAMA 2006;295(15):1835-6.
9. Osborne JW, Summitt JB, Roberts HW. The use of dental amalgam in pediatric dentistry: review of the literature. Pediatr Dent 2002;24(5):439-47.
10. Mathewson RJ, Primosch RE, Sanger RG, Robertson D. Fundamentals of dentistry for children. Chicago: Quintessence; 1982.
11. Demirci M, Ersev H, Ucok M. Clinical evaluation of a polyacid-modified resin composite (Dyract) in Class III cavities: three-year results. Oper Dent 2002;27(3):223-30.
12. Gross LC, Griffen AL, Casamassimo PS. Compomers as Class II restorations in primary molars. Pediatr Dent 2001;23(1):24-7.
13. Hse KM, Wei SH. Clinical evaluation of compomer in primary teeth: 1-year results. JADA 1997;128(8):1088-96.
14. Roeters JJ, Frankenmolen F, Burgersdijk RC, Peters TC. Clinical evaluation of Dyract in primary molars: 3-year results. Am J Dent 1998;11(3):143-8.
15. Tran LA, Messer LB. Clinicians' choices of restorative materials for children. Aust Dent J 2003;48(4):221-32.
16. Nicholson JW. Polyacid-modified composite resins ('compomers') and their use in clinical dentistry. Dent Mater 2007;23(5):615-22. Epub 2006 Jun 21.
17. Cildir SK, Sandalli N. Fluoride release/uptake of glass-ionomer cements and polyacid-modified composite resins. Dent Mater J 2005;24(1):92-7.
18. Peng D, Smales RJ, Yip HK, Shu M. In vitro fluoride release from aesthetic restorative materials following recharging with APF gel. Aust Dent J 2000;45(3):198-203.
19. Dental caries and restorative paediatric dentistry. In: Cameron A, Widmer R, eds. Handbook of pediatric dentistry. 2nd ed. New York City: Mosby; 2003:44-70.
20. ADA Division of Science, ADA Council on Scientific Affairs. Resin-based composites. JADA 2003;134(4):510-2.
21. Moore BK, Avery DR. Dental materials. In: McDonald RE, Avery DR, Dean JA, eds. Dentistry for the child and adolescent. St. Louis: Mosby; 2004:333-52.
22. Mjör IA, Gordan VV. Failure, repair, refurbishing and longevity of restorations. Oper Dent 2002;27(5):528-34.
23. Burgess JO, Walker R, Davidson JM. Posterior resin-based composite: review of the literature. Pediatr Dent 2002;24(5):465-79.
24. Estafan D, Agosta C. Eliminating microleakage from the composite resin system. Gen Dent 2003;51(6):506-9.
25. Burke FJ, Wilson NH, Cheung SW, Mjör IA. Influence of patient factors on age of restorations at failure and reasons for their placement and replacement. J Dent 2001;29(5):317-24.
26. Forss H, Widstrom E. The post-amalgam era: a selection of materials and their longevity in the primary and young permanent dentitions. Int J Paediatr Dent 2003;13(3):158-64.
27. Friedl KH, Hiller KA, Schmalz G. Placement and replacement of amalgam restorations in Germany. Oper Dent 1994;19(6):228-32.
28. Mjör IA, Dahl JE, Moorhead JE. Placement and replacement of restorations in primary teeth. Acta Odontol Scand 2002;60(1):25-8.
29. Qvist J, Qvist V, Mjör IA. Placement and longevity of amalgam restorations in Denmark. Acta Odontol Scand 1990;48(5):297-303.
30. Qvist V, Thylstrup A, Mjör IA. Restorative treatment pattern and longevity of amalgam restorations in Denmark. Acta Odontol Scand 1986;44(6):343-9.
31. Duggal MS, Toumba KJ, Sharma NK. Clinical performance of a compomer and amalgam for the interproximal restoration of primary molars: a 24-month evaluation. Br Dent J 2002;193(6):339-42.
32. Kavvadia K, Kakaboura A, Vanderas AP, Papagiannoulis L. Clinical evaluation of a compomer and an amalgam primary teeth Class II restorations: a 2-year comparative study. Pediatr Dent 2004;26(3):245-50.
33. Marks LA, Weerheijm KL, van Amerongen WE, Groen HJ, Martens LC. Dyract versus Tytin Class II restorations in primary molars: 36 months evaluation. Caries Res 1999;33(5):387-92.
34. Downer MC, Azli NA, Bedi R, Moles DR, Setchell DJ. How long do routine dental restorations last? A systematic review. Br Dent J 1999;187(8):432-9.
35. Van Nieuwenhuysen JP, D'Hoore W, Carvalho J, Qvist V. Long-term evaluation of extensive restorations in permanent teeth. J Dent 2003;31(6):395-405.
36. Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001;3(1):45-64.
37. Hickel R, Manhart J, Garcia-Godoy F. Clinical results and new developments of direct posterior restorations. Am J Dent 2000;13(special number):41D-54D.
38. Children's Amalgam Trial Study Group. The Children's Amalgam Trial: design and methods. Control Clin Trials 2003;24(6):795-814.
39. Gordan VV, Shen C, Riley J 3rd, Mjör IA. Two-year clinical evaluation of repair versus replacement of composite restorations. J Esthet Restor Dent 2006;18(3):144-53.
40. Palotie U, Vehkalahti M. Reasons for replacement and the age of failed restorations in posterior teeth of young Finnish adults. Acta Odontol Scand 2002;60(6):325-9.
41. Qvist V, Laurberg L, Poulsen A, Teglers PT. Eight-year study on conventional glass ionomer and amalgam restorations in primary teeth. Acta Odontol Scand 2004;62(1):37-45.
42. Shen C, Mondragon E, Gordan VV, Mjör IA. The effect of mechanical undercuts on the strength of composite repair. JADA 2004;135(10):1406-12.
43. Soderholm KJ, Roberts MJ. Variables influencing the repair strength of dental composites. Scand J Dent Res 1991;99(2):173-80.
44. Swift EJ Jr, Cloe BC, Boyer DB. Effect of a silane coupling agent on composite repair strengths. Am J Dent 1994;7(4):200-2.
45. Chen HY, Manhart J, Kunzelmann KH, Hickel R. Polymerization contraction stress in light-cured compomer restorative materials. Dent Mater 2003;19(7):597-602.