PEDIATRIC DENTISTRY/Copyright © 1988 by
The American Academy of Pediatric Dentistry
Volume 10, Number 2

The durability of primary molar restorations: III. Costs associated with placement and replacement

Nicholas J. Levering, DDS, MS Louise B. Messer, BDSc, LDS, MDSc

Abstract

As part of a large retrospective study of the durability and lifespan of 2229 restorations (1898 amalgams and 331 stainless steel crowns) in primary molars of 226 pediatric patients attending a dental school clinic, the costs associated with first placement and later replacements of the restorations were examined. Individual restoration histories were followed for up to 9 years, computerized, and restorative costs assessed retrospectively using a scale of cost units. Of 1483 first-placement amalgams, 69% did not require replacement throughout the study; 73% first replacements and 86% second replacements did not require subsequent replacement. The frequency of replacement of Class I amalgams with Class II amalgams was low (9-16%), and low for replacement with crowns (11-12%); the frequency of replacement of Class II amalgams with crowns was also low (9-18%). The majority (77%) of primary molars were maintained to either exfoliation (mean 48.2 ± 21.2 months SD) or to the end of the study (mean 50.9 ± 18.2 months) for a total investment of approximately the cost of 2 one-surface amalgams. The cost to maintain these molars for one year of good service was approximately half the cost of a one-surface amalgam. Crowned molars followed to exfoliation (mean 47.7 ± 19.2 months) or to the end of the study (mean 50.1 ± 15.2 months) required a total investment of approximately 3 times the cost of a one-surface amalgam. Overall comparisons (disregarding age of child at placement) indicated that crowns were a more costly service than amalgams and provided similar periods of good service.

Literature Review

Few studies report on the cost of placement and replacement of restorations in the permanent and primary dentitions. An early interpretation of the cost of amalgam replacements indicated a dentist in British Columbia, Canada, replaced an average of 6.6 amalgam surfaces in permanent teeth per day (Richardson and Boyd 1973). Estimating the cost per surface at $6, and with 1518 surfaces replaced per year, the total cost of replacements was $9108 — approximately 20% of his gross income. Braff (1975) studied replacement of amalgams and stainless steel crowns in primary teeth and analyzed cost in terms of the number of additional treatments required to accomplish all subsequent restorations. Because an average of 2.4 additional treatments were needed to replace amalgams vs. 1.4 treatments to replace crowns, he concluded that crowns might be more economical for the patient than amalgam. Later, utilizing California Medical Assistance fees, Braff (1982) concluded that crowns are more cost effective than multisurface amalgams and advocated crowns in primary molars requiring more than restoration of a single surface.

The present authors have used a case-historic approach (Gordon 1978; Lilienfeld and Lilienfeld 1980) to develop a data pool of first placement and replacement restorations in primary molars in order to study restoration durability, predict long range success, and quantitate costs associated with restoration placement and replacement. Observations on the durability and predictions of success for amalgams and stainless steel crowns have been reported (Levering and Messer 1988; Messer and Levering 1988); this paper reports costs associated with these restorations. The study objectives were to identify the cumulative cost of restorative procedures to maintain a restored primary molar in the mouth throughout the study period and to compare the cost of placement of a single molar restoration.

Materials and Methods

Selection Criteria

The 7 criteria used to select 226 patient records (123 males, 103 females) treated in the University of Minnesota Pediatric Dental Clinic have been described previously (Levering and Messer 1988). These records represented a data pool of 2229 first placement restorations (1898 amalgams, 331 stainless steel crowns) in primary

molars placed by dental students between 1970 and 1982. Individual histories of restored molars were recorded from the records (using both progress notes and radiographs) by arrival condition and surfaces of treatment rendered thereafter, coded, and analyzed by the Statistical Analysis System (SAS) package program. Since no statistically significant differences were seen in the frequency of occurrence of first placements and replacements among primary molar amalgams with respect to fluoride history (Levering and Messer 1988), histories of restored molars from patients with and without an optimal fluoride history were pooled.

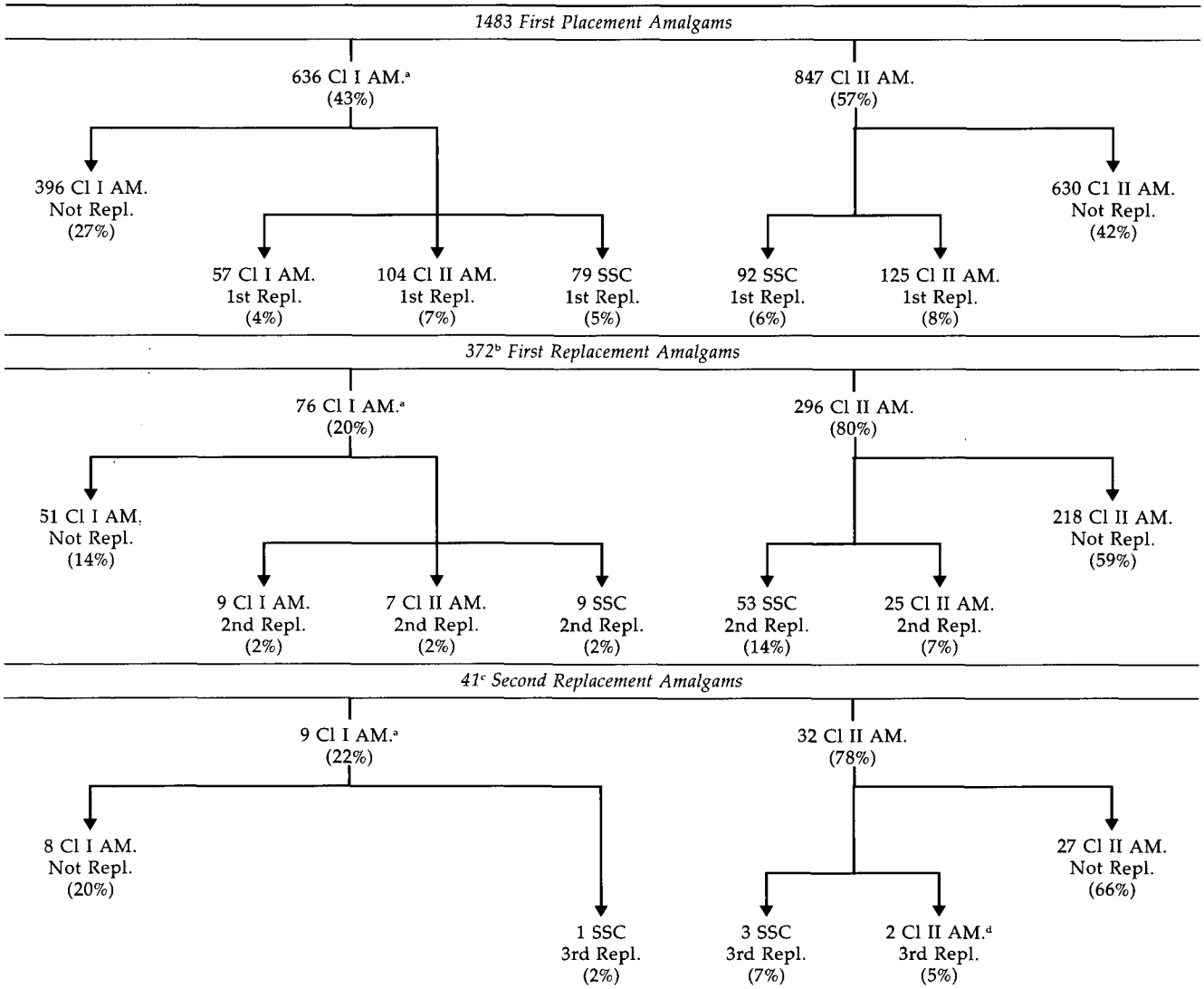
Distribution of Restorations

Amalgams and crowns were classified as first placement (initial placement), first replacement, second replacement, and third replacement (the latter terms refer to the consecutive replacement of the initial placement).

The 1898 amalgams studied comprised 1483 first placements and 415 replacements (372 first replacements plus 41 second replacements plus 2 third replacements; Table 1); the 372 first replacements included 86 amalgams replacing restorations placed by private dentists prior to the patient's commencing care at the Dental School clinic, plus 286 first replacements of 1483 first-placement amalgams placed by dental students.

The 331 crowns studied comprised 317 first placements and 14 replacements; 73 crowns were placed in association with vital pulpotomies (Table 1). The 237 first-placement crowns (79 + 92 + 9 + 53 + 1 + 3) were

TABLE 1. Distribution of 1898 Amalgam Restorations of Primary Molars with Reference to Placement and Replacement History



[a] Percentages are of total sample under consideration in each section of table.
[b] Includes replacement of 286 first placement amalgams (57 + 104 + 125 from first section above), plus 86 amalgams which replaced restorations placed by private dentists prior to the patient commencing care at the dental school clinic.
[c] Represents replacement of 41 first replacement amalgams (9 + 7 + 25 from second section above) as second replacement amalgams.
[d] Two amalgams requiring third replacement.

placed as replacements for previous amalgams; the remaining 80 crowns were first placements not replacing a previous restoration.

Analysis of Costs

Actual treatment costs between 1970 and 1982 showed considerable changes in association with inflation and other factors. Therefore, in order to compute costs on an equitable basis and allow comparisons across the 12-year period without using actual dollar amounts based upon annually changing fee schedules, a scale of cost ratios was developed. This was based upon the 1983 undergraduate fee schedule of the school. Comparison with earlier and recent fee schedules for the institution showed little variation from these computed cost ratios. The cost of placement of a one-surface amalgam was arbitrarily assigned a cost unit of 1.0 and cost units (CU) for other restorative procedures were calculated proportionately (Table 2).

TABLE 2. List of Actual Costs and Relative Costs Applied Retrospectively in Computing Restorative Costs to Maintain a Restored Molar

Restoration Type	*Actual Cost[a] ($)*	*Relative Cost[b] (cost units, CU)*
One-surface amalgam	9	1.0
Two-surface amalgam	14	1.6
Three-surface amalgam	18	2.0
Stainless steel crown	22	2.4
Pulpotomy plus stainless steel crown	36	4.0

[a] Actual cost taken from the 1983 Department of Pediatric Dentistry undergraduate fee schedule.

[b] Example of computation of cost units for a two-surface amalgam: a one-surface amalgam cost $9 and was assigned a cost unit of 1.0; a two-surface amalgam cost $14; therefore the ratio is 14/9 = 1.6 cost units (CU).

The costs incurred with each placement and all subsequent replacement restorations in a molar were accumulated as cumulative cost units to restoratively maintain the tooth; the cost of recall examinations, diagnostic radiographs, prophylaxes, and topical fluorides, while all assisting in maintaining the tooth, were not included in the cumulative restorative cost. No CU were assigned to the extraction of a restored molar because this terminal procedure meant that the restored tooth was no longer maintained.

Cost Computations

The data pool was examined with respect to cost, using 3 different computations: (1) the cost to restore a molar and then restoratively maintain this tooth; (2) the cost to restore a molar with a first-placement or replacement restoration; and (3) a comparison of CU for amalgams and crowns placed during the period studied.

The cost to restore and then restoratively maintain a molar was designated as the cumulative cost unit for initial placement of one or more restorations (amalgams or crowns) and subsequent replacements as necessary, through one of 3 periods of observation (i.e., exfoliation, end of study, or extraction). To aid comparisons between groups, the cost to restoratively maintain the tooth for 1 year of good service also was computed. Good service represents the period in which a restoration was recorded as successful, i.e., no evidence in the record of the restoration being replaced (or need for replacement), or tooth extraction. One year of good service was computed by recording the CU associated with the total months of observed good service of the restoration and calculating the number of CU that would be associated with 12 months of good service, assuming the same scale of units.

In computing the cost to restore a molar with a first-placement or replacement restoration (amalgam or crown), each restoration was followed over 4 observation periods to tooth exfoliation, end of study, restoration replacement, or tooth extraction. Cost units were computed for the total months the restorations were followed, and also for 1 year of good service.

Results

Replacement Histories

Table 1 shows the replacement histories for first placement restorations. Of all first-placement amalgams followed, 69% (27% Class I plus 42% Class II) did not require replacement throughout the study; 73% first replacements (14% Class I plus 59% Class II), and 86% second replacements (20% Class I plus 66% Class II) did not require a subsequent replacement. The frequency of replacement of a first-placement Class I amalgam with a Class II amalgam was 16% (104 of 636), and 9% first-replacement Class I amalgams required replacement as Class II amalgams (7 of 76).

The frequency of replacement of Class I amalgams by crowns was similar, regardless of whether the amalgam replaced was a first placement or a later replacement. Crowns were used as replacements for 12% (79 of 636) first-placement Class I amalgams, for 12% (9 of 76) first-replacement Class I amalgams, and for 11% (1 of 9) second-replacement Class I amalgams (Table 1).

The frequency of replacement of Class II amalgams by crowns varied with the replacement history of the amalgam. Crowns were used as replacements for 11% (92 of 847) first-placement Class II amalgams, for 18% (53 of 296) first-replacement Class II amalgams, and for 9% (3 of 32) second-replacement Class II amalgams (Table 1).

Cumulative Cost to Maintain Restored Molars

Table 3 (next page) shows the distribution of 1246 restored molars followed to exfoliation, end of study, or extraction (but excludes the 73 molars treated with

pulpotomies). The majority (79%) of molars studied were restored with amalgam only (285 + 669 + 28/1246); 11% with amalgam followed by crown (38 + 100 + 5/1246); and 10% with crowns only (28 + 80 + 13/1246). The majority of molars (68%) were followed to the end of the study when they were still providing good service; 28% were followed to exfoliation; only 4% required extraction. Extracted molars were followed for briefer periods (range of means 30.4-43.4 months) than those followed to exfoliation (47.7-66.8 months) or end of study (50.1-62.5 months).

TABLE 3. Cumulative Cost in Cost Units to Maintain 1246 Primary Restored Molars During the Period Studied

Period of Observation of Molar After First Placement of Restoration	*Restorative Approach*	*No. Primary Molars (% total)*	*Total Months Molar Followed (mean ± SD)*	*Total Cost to Maintain Molar (in CU)*[a] *For Total Months Followed (mean ± SD)*	*For One Year of Good Service*[b] *(mean ± SD)*
To tooth exfoliation	Amalgam(s) only	285 (23)	48.2 ± 21.2	2.1 ± 1.2	0.6 ± 0.4
	Amalgam(s), then crown(s)	38 (3)	66.8 15.9	4.9 1.1	0.9 0.4
	Crown(s) only	28 (2)	47.7 19.2	2.9 0.7	0.9 0.6
	Subtotal	351 (28)			
To end of study	Amalgam(s) only	669 (54)	50.9 18.2	2.0 1.1	0.6 0.4
	Amalgam(s), then crown(s)	100 (8)	62.5 16.8	4.8 1.2	1.0 0.4
	Crown(s) only	80 (6)	50.1 15.2	2.9 0.8	0.8 0.4
	Subtotal	849 (68)			
To tooth extraction	Amalgam(s) only	28 (2)	30.4 20.1	2.2 0.8	1.2 0.7
	Amalgam(s), then crown(s)	5 (0.4)	43.4 20.3	5.6 0	2.0 1.3
	Crown(s) only	13 (1)	31.6 ± 16.7	3.7 ± 1.1	1.9 ± 1.2
	Subtotal	46 (4)			
	Total	1246 (100)			

[a] Refer to Table 2 for definition of cost units.
[b] One year good service defined as the period of success in which a restoration was recorded as successful, i.e., there was no evidence in the record of the restoration being replaced or needing replacement.

The mean numbers of CU required to restoratively maintain molars for the total months followed, to either exfoliation or end of study, were similar for each of the 3 approaches (Table 3). The similarity in standard deviations indicated similar ranges of individual observations in each group. Amalgam was the most economical approach (2.1 ± 1.2 CU and 2.0 ± 1.1 CU); amalgam replaced by a crown was the most costly (4.9 ± 1.1 CU and 4.8 ± 1.2 CU). Restorative approaches which failed to maintain the tooth and later resulted in molar extraction were associated with the highest costs, particularly for those treated with amalgam later replaced with a crown (5.6 ± 0 CU).

Similar trends were also seen in the mean cost units required to restoratively maintain a molar for one year of good service (Table 3). Molars followed to either exfoliation or to end of the study required similar mean cost units for each of the 3 approaches. Restorative approaches which failed to maintain the tooth and later resulted in molar extraction were associated with the highest costs, but those treated with amalgam followed by a crown were similar to the crown-only approach (2.0 ± 1.3 CU vs. 1.9 ± 1.2 CU).

Cost of Amalgam Restorations

The data pool of 1898 amalgams was examined to determine the cost of amalgam placements (first placements and replacements) over the 4 observation periods (Table 4, next page). The majority (78%) of amalgams followed were first placements (283 + 713 + 30 + 457/1898) and 22% were replacement amalgams (103 + 196 + 7 + 109/1898). The majority of amalgams were followed either to the end of study (48%) or to replacement (30%), and a total of 22% were followed to either tooth exfoliation or tooth extraction. The longest periods of good service were seen for first-placement amalgams in teeth followed either to exfoliation (42.3 ± 20.9 months) or to the end of study (47.4 ± 18.3 months), and replacement amalgams in these 2 groups provided similar periods of good service (31.3 ± 16.6 months vs. 31.4 ± 17.6 months). First-placement amalgams in molars followed to either tooth extraction or amalgam replacement provided shorter periods of good service (22.5 ± 19.5 months and 24.7 ± 16.3 months), and replacement amalgams in these 2 groups also gave brief periods of service (17.4 ± 23.1 months and 20.6 ± 12.4 months). The widely differing standard deviations for the latter periods indicated wide ranges of individual observations in each group.

The mean costs of placement of the first amalgam (Table 4) followed through the 4 observation periods for the total months observed were similar (ranging from 1.3 to 1.5 CU); the mean cost of replacement amalgams was slightly higher (ranging from 1.4 to 1.6 CU). First-placement amalgams followed to tooth exfoliation, end of study, or to tooth extraction all exhibited similar costs for 1 year of good service (0.5 ± 0.4 CU to 0.6 ± 0.3 CU). Mean costs of replacement amalgams followed to tooth exfoliation or end of study were similar (0.9 ± 0.4 CU), as were the mean costs for replacement amalgams followed to tooth extraction or further replacement (1.4 ± 1.5 vs. 1.4 ± 1.3 CU).

Cost of Stainless Steel Crowns

The data pool of 331 crowns was examined to determine the cost of crown placements followed through the 4 observation periods (Table 5). Of all crowns, only 4% required replacement and 96% first placements were followed to exfoliation (25%), end of study (62%), or tooth extraction (8%). Regardless of pulpal therapy, the longest periods of good service were seen for crowns followed to exfoliation (35.4 ± 17.8 months and 38.1 ± 18.0 months) and to end of study (37.0 ± 16.5 months and 40.5 ± 18.1 months). Briefer periods of service were seen for crowns followed to replacement (24.0 ± 17.0 months and 15.7 ± 11.9 months) and to tooth extraction (25.0 ± 15.2 months and 26.3 ± 18.5 months). For crowned molars (with or without pulpotomies) followed to exfoliation, end of study, or extraction, the total costs of these restorations for the months of good service observed reflect the costs of a single placement of the restorations, because none were replaced. Regardless of pulpal therapy, crowns followed to exfoliation or end of study showed the lowest costs for 1 year of good service (1.2 ± 0.8 CU and 1.0 ± 1.6 CU), while those followed to extraction or replacement were much higher (2.0 ± 1.9 CU and 2.4 ± 2.1 CU), particularly with a pulpotomy (3.3 ± 2.5 CU).

TABLE 4. Comparison of Costs as Cost Units for 1898 Amalgam Restorations in Primary Molars

Period of Observation of Molar After First Placement of Restoration	*Amalgam Placement*	*No. Amalgams (% total)*	*Total Months of Good Service (mean ± SD)*	*Total Cost of Amalgam (in cost units)[a]*	
				For Total Months Followed (mean ± SD)	*For One Year of Good Service[b] (mean ± SD)*
To tooth exfoliation	First placement	283 (15)	42.3 ± 20.9	1.4 ± 0.3	0.6 ± 0.4
	Replacement	103 (5)	31.3 16.6	1.5 0.2	0.9 0.4
	Subtotal	386 (20)			
To end of study	First placement	713 (38)	47.4 18.3	1.3 0.3	0.5 0.4
	Replacement	196 (10)	31.4 17.6	1.5 0.3	0.9 0.4
	Subtotal	909 (48)			
To tooth extraction	First placement	30 (2)	22.5 19.5	1.5 0.3	0.6 0.3
	Replacement	7 (0.4)	17.4 23.1	1.6 0	1.4 1.5
	Subtotal	37 (2)			
To amalgam replacement	First placement	457 (24)	24.7 16.3	1.3 0.3	1.1 1.3
	Replacement	109 (6)	20.6 ± 12.4	1.4 ± 0.3	1.4 ± 1.3
	Subtotal	566 (30)			
	Total	1898 (100)			

[a] Refer to Table 2 for definition of cost units.
[b] One year good service defined as the period of success in which a restoration was recorded as successful, i.e., there was no evidence in the record of the restoration being replaced or needing replacement.

TABLE 5. Comparison of Costs as Cost Units for 331 Stainless Steel Crowns in Primary Molars With and Without a Pulpotomy as Pulpal Therapy

Period of Observation of Molar After First Placement of Restoration	*Pulpal Therapy of Molar*	*No. Crowns (% total)*	*Total Months of Good Service (mean ± SD)*	*Total Cost of Crown (in cost units)[a]*	
				For Total Months Followed (mean ± SD)	*For One Year of Good Service[b] (mean ± SD)*
To tooth exfoliation	No pulpotomy	66 (20)	35.4 ± 17.8	2.4 ± 0	1.2 ± 0.8
	Pulpotomy[c]	18 (5)	38.1 18.0	4.0 0	1.2 1.2
	Subtotal	84 (25)			
To end of study	No pulpotomy	172 (52)	37.0 16.5	2.4 0	1.0 1.6
	Pulpotomy	35 (10)	40.5 18.1	4.0 0	0.9 0.4
	Subtotal	207 (62)			
To tooth extraction	No pulpotomy	10 (3)	25.0 15.2	2.4 0	2.0 1.9
	Pulpotomy	16 (5)	26.3 18.5	4.0 0	2.2 2.4
	Subtotal	26 (8)			
To crown replacement	No pulpotomy	10 (3)	24.0 17.0	4.8 0	2.4 2.1
	Pulpotomy	4 (1)	15.7 ± 11.9	6.4 ± 0	3.3 ± 2.5
	Subtotal	14 (4)			
	Total	331 (100)			

[a] Refer to Table 2 for definition of cost units.
[b] One year good service defined as the period of success in which a restoration was recorded as successful, i.e., there was no evidence in the record of the restoration being replaced or needing replacement.
[c] Pulpotomy was a one-step formocresol pulpotomy performed on a vital tooth in accordance with traditional procedures and standard armamentarium.

Comparison of Costs of Amalgams and Crowns

In order to examine the relative cost effectiveness of amalgams vs. crowns, the data pool of 1898 amalgams was compared with the subset of 258 crowns placed on molars where a pulpotomy was not required (in no instance was pulpal therapy rendered in conjunction with an amalgam restoration). This data collation assumes that a choice of restorative material between amalgam and crown is possible, but that a crown is the restoration

of choice when a pulpotomy is performed. Combining these data (Table 6), the majority of restorations were followed to the end of the study (50%) or to replacement (27%). Based on mean numbers of months, amalgams provided slightly longer periods of good service than crowns for those restorations followed to tooth exfoliation (39.4 ± 20.4 months vs. 35.4 ± 17.8 months) or to end of study (44.4 ± 19.3 months vs. 37.0 ± 16.5 months), but crowns provided slightly longer service than amalgams for those restorations followed to tooth extraction (25.0 ± 15.2 months vs. 21.6 ± 20.0 months) or to replacement (24.0 ± 17.0 months vs. 23.9 ± 15.7 months). Over the total months followed and regardless of the observation period, a crown was a more costly restoration than an amalgam (costing approximately 1.7-fold more if observed to tooth exfoliation, end of study, or to tooth extraction), and costing 3.7-fold more if requiring replacement. For all observation periods, the relative cost of a crown vs. an amalgam for 1 year of good service was approximately twofold.

TABLE 6. Comparison of Costs as Cost Units for 1898 Amalgam Restorations and 258 Stainless Steel Crowns in Primary Molars Without a Pulpotomy as Pulpal Therapy

Period of Observation of Molar After First Placement of Restoration	*Restorations Placed*	*No. Restorations (% total)*	*Total Months of Good Service (mean ± SD)*	*Total Cost of Restoration (in CU)*[a] *For Total Months Followed (mean ± SD)*	*Total Cost of Restoration (in CU)*[a] *For One Year of Good Service*[b] *(mean ± SD)*
To tooth exfoliation	Amalgams[c]	386 (18)	39.4 ± 20.4	1.4 ± 0.3	0.7 ± 0.7
	Stainless steel crowns[d]	66 (3)	35.4 17.8	2.4 0	1.2 0.8
	Subtotal	452 (21)			
To end of study	Amalgams	909 (42)	44.4 19.3	1.4 0.3	0.5 0.6
	Stainless steel crowns	172 (8)	37.0 16.5	2.4 0	1.0 1.6
	Subtotal	1081 (50)			
To tooth extraction	Amalgams	37 (2)	21.6 20.0	1.5 0.3	0.8 1.4
	Stainless steel crowns	10 (0.4)	25.0 15.2	2.4 0	2.0 1.9
	Subtotal	47 (2)			
To restoration replacement	Amalgams	566 (26)	23.9 15.7	1.3 0.3	1.2 1.2
	Stainless steel crowns	10 (0.4)	24.0 ± 17.0	4.8 ± 0	2.4 ± 2.1
	Subtotal	576 (27)			
	Total	2156 (100)			

[a] Refer to Table 2 for definition of cost units.
[b] One year good service defined as the period of success in which a restoration was recorded as successful, i.e., there was no evidence in the record of the restoration being replaced or needing replacement.
[c] Refers to all first placement and replacement amalgams.
[d] Refers to stainless steel crowns which were not associated with a formocresol pulpotomy.

Discussion

To date, this study appears to be the most comprehensive examination of the relative costs of restorations in the primary dentition, taking into consideration the lifespan of individual restorations. It is important to recognize that in this study of 2229 molar restorations, individual restorations were not separated on the basis of age of child at first placement of the restoration as was done in earlier examinations of the data pool (Levering and Messer 1988; Messer and Levering 1988). Care must be taken in extrapolating these findings to other pediatric dental populations, since the present population was biased in favor of children having many restorations (4 or more primary molars restored with amalgam and/or less than 4 molars with crowns were required). In particular, the findings may not be applicable to an individual child with a single restoration.

The frequency of replacement of restorations in this study is lower than that reported by Braff (1975, 1982). In addition, this study shows a steady increase (69, 73, 86%) in the likelihood of a replacement restoration being successful. The low frequency of conversion of Class I amalgams to Class II amalgams (affecting 16% of first-placement Class I amalgams, and 9% of first-replacement Class I amalgams) and crowns (affecting 12% of first-placement Class I amalgams, 12% of first-replacement Class I amalgams, and 11% of second-replacement Class II amalgams), was an unexpected finding. This was attributed in part to the efficacy of fluoride measures in use (65% of patient sample had optimal fluoride histories (Levering and Messer 1988), and also to the decline in caries observed nationally for the years coincident with this study, (U.S. Department of Health and Human Services 1981).

The use of a cost ratio, instead of actual dollars, has allowed a retrospective comparison of costs without incorporating the limitations of a single-fee schedule. The assigning of unity to a one-surface amalgam provides a realistic baseline for comparisons in future prospective studies, because in an era of declining caries and declining complexity of restorations (i.e., fewer two-surface and three-surface restorations) the one-surface restoration is becoming a more predominant type of restoration.

This study employs the concept of time for which the restoration provided good service. This is a very conservative approach to quantitating the lifespan of a restoration, because the months recorded include the lifespan of restorations currently in the mouth and deemed to be still providing good service at the end of the study. This latter group included 48% (N = 909) of all amalgams observed and 62% (N = 207) of all crowns; these restorations were all still giving good service at the end of the study and their final months of service were unknown.

The concept of CU to maintain a tooth or restoration for 1 year of good service was developed to allow comparisons between different types of restorations when teeth were followed for different periods of time. Such comparisons showed that amalgam was the most economical restoration, and amalgam replaced by a crown was the most costly approach. The majority of molars (77% of total) were maintained to either exfoliation or end of the study (mean 48.2 ± 21.2 months and 50.9 ± 18.2 months), for a total investment of approximately the cost of 2 one-surface amalgams (2.1 ± 1.2 CU or 2.0 ± 1.1 CU). The cost to maintain these molars for 1 year of good service was approximately half the cost of a one-surface amalgam (0.6 ± 0.4 CU). In contrast, molars restored with crowns only and followed for similar periods of time to exfoliation or end of study (47.7 ± 19.2 months and 50.1 ± 15.2 months), required a total investment of almost 3 times the cost of a one-surface amalgam (2.9 ± 0.7 CU or 2.9 ± 0.8 CU). These concepts of service can be used in both retrospective and future prospective studies of treatment outcomes, e.g., with new restorative materials.

The characteristics noted for replacement restorations fulfill expectations. The total months of good service of replacement amalgams were expected to be fewer than that of first-placement amalgams because the available observation period was shorter. In addition, the majority of replacements were still providing good service at the end of the study, so the reported months of good service are necessarily conservative. For the total months followed, and for 1 year of good service. replacement amalgams cost more than first-placement amalgams. This is also as expected because the majority of replacement restorations involved more surfaces than those being replaced. Replacement of steel crowns was not a common occurrence in this study. For 96% of crowned molars, the crown or crown plus pulpotomy was a terminal restorative approach.

The overall comparisons made in this study between crowns and amalgams indicate that crowns are a more costly service than amalgam and provide similar periods of good service. It is speculated that the greater durability and economy of crowns over amalgams reported in previous literature (Braff 1975, 1982) were related to the high frequency of replacement of simple amalgams with more complex amalgams, which contributed to an apparent superiority of crowns. This was not the case in the present study, where the rate of replacement of one-surface amalgams with multisurface restorations was low. In addition, the periods of service achieved by both crowns and amalgams were longer than those reported previously (Braff 1975, 1982). The examination of the data pool in this part of the study did not take age of child at placement into consideration. In a previous publication in this series (Messer and Levering 1988), we reported on the significance of age of the child at time of crown placement, indicating the superior durability of crowns over Class II amalgams placed in children younger than 4 years, and predicting a success rate approximately twice that of Class II amalgams, for each year up to 10 years of service. In the light of the present observations, age at restoration placement becomes an increasingly important factor and the dentist may with justification allow that to be an overriding factor in his choice of a restorative material for the molar with caries on more than one surface.

Conclusions

Based on the retrospective application of a cost-ratio scale to amalgam and stainless steel crown restorations placed by dental students in primary molars, and disregarding age of child at placement of restoration, the following conclusions are drawn:

1. The frequency of replacement of Class I amalgams by Class II amalgams or stainless steel crowns was low.
2. Amalgam was the most economical approach to restoring a molar, and amalgam followed by a crown was the most costly approach.
3. Amalgam and stainless steel crowns provided similar periods of good service.

This study was supported in part by the American Fund for Dental Health/WD Kellogg Foundation, the Basic Research Support Grant (NIH), and the Minnesota Mining and Manufacturing Company (3M), St. Paul, Minnesota. It also formed part of a thesis completed by Dr. Levering in partial fulfillment of the requirements for the master's degree at the University of Minnesota. Special thanks are extended to Mr. Gary Tabbert and Dr. Ken Kotnour of the 3M Company for their assistance with computerization and statistical interpretation of the data.

Dr. Levering is chairman, pedodontics, Ehrling Bergquist Regional Hospital, Offutt AFB, Nebraska, and Dr. Messer is a professor, pediatric dentistry, and director, Postdoctoral Research Training Program in Dental Caries (NIDR), University of Minnesota School of Dentistry. Reprint requests should be sent to: Dr. Louise B. Messer, 6-150 Moos Health Sciences Tower, Dept. of Pediatric Dentistry, 515 Delaware St., S.E., Minneapolis, MN 55455.

Braff MH: A comparison between stainless steel crowns and multi-

surface amalgams in primary molars. J Dent Child 42:474-78, 1975.

Braff MH: Cost effectiveness of stainless steel crowns vs. multisurface amalgam restorations in the posterior primary dentition. J Pedod 6:244-49, 1982.

Gordon JE: Epidemiological insights on malnutrition. J Clin Nutr 31: 2340-44, 1978.

Levering NJ, Messer LB: The durability of primary molar restorations. I. Observations and predictions of success of amalgams. Pediatr Dent 10:74-80,1988.

Lilienfeld AM, Lilienfeld DE: Foundations of Epidemiology, 2nd ed. New York; Oxford University Press, 1980 chapter 8.

Messer LB, Levering NJ: The durability of primary molar restorations. II. Observations and predictions of success of stainless steel crowns. Pediatr Dent 10:81-85, 1988.

Richardson AS, Boyd MA: Replacement of silver amalgam restorations by 50 dentists during 246 working days. J Can Dent Assoc 39:556-59, 1973.

U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, National Institute of Dental Research: The prevalence of dental caries in United States children, 1979-1980. National Caries Program, NIH pub no 82-2245, 1981.

Salivary functions

Saliva is about 99.4% water and is secreted at a rate of about 60 cc per hour. This is about 2-3 pints or 1500 cc in a 24-hour period.

Recent studies have shown that saliva performs more functions than previously thought. Saliva:

1. Moistens the mucous membrane of the mouth
2. Moistens and lubricates food, permitting it to be more easily swallowed
3. Chemically changes insoluble foods into soluble sugars
4. Holds taste-producing substances in solution and brings them in contact with taste buds
5. Dilutes salts and acids, thereby protecting the mucosa
6. Provides a cleansing action on teeth, gums, and mucosa
7. Forms a salivary coating on teeth, mucosa, and oral prosthetic appliances, known as the acquired pellicle
8. Controls the growth of oral microorganisms
9. Regulates the adherence of microorganisms to oral and prosthetic surfaces through salivary flushing
10. Modulates the mineralization or demineralization of enamel by the calcium-phosphate equilibrium at the tooth surface.

Dr. Cornelius T. Geary
Wisconsin Dental Journal, September 1987