The Cost-Effectiveness of Large Amalgam and Crown Restorations Over a 10-Year Period

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Abstract

Objective: To assist clinical decision making for an individual patient or on a community level, this study was done to determine the differences in costs and effectiveness of large amalgams and crowns over 5 and 10 years when catastrophic subsequent treatment (root canal therapy or extraction) was the outcome. Methods: Administrative data for patients seen at the University of Iowa, College of Dentistry for 1,735 large amalgam and crown restorations in 1987 or 1988 were used. Annual costs and effectiveness values were calculated. Costs of initial treatment (large amalgam or crown), and future treatments were determined, averaged and discounted. The effectiveness measure was defined as the number of years a tooth remained in a state free of catastrophic subsequent treatment. Years free of catastrophic treatment were averaged, and discounted. The years free of catastrophic treatment accounted for individuals who dropped out or withdrew from the study. Results: Teeth with crowns had higher effectiveness values at a much higher cost than teeth restored with large amalgams. The cost of an addition year free of catastrophic treatment for crowns was $1,088.41 at 5 years and $500.10 at 10 years. Teeth in women had more favorable cost-effectiveness ratios than those in men, and teeth in the maxillary arch had more favorable cost-effectiveness ratios than teeth in the mandibular arch. Conclusions: Neither the large amalgam or crown restoration had both the lowest cost and the highest effectiveness. The higher incremental cost-effectiveness ratio for crowns should be considered when making treatment decisions between large amalgam and crown restorations.

Key Words: cost-effectiveness analysis, dental restoration, dental amalgam, crowns, treatment outcome, premolar, molar

Introduction

Large amalgam restorations and crowns are two of the most common procedures for restoring teeth that have been severely compromised due to a loss of tooth structure (1,2). While there is some evidence that crowns, on average, last longer than large amalgams, few studies have incorporated the significant difference in the cost between these procedures into an outcomes assessment. Incorporating the costs of alternative treatments over time into an outcome assessment is valuable information for clinical decision-making. To improve the evidence base for decision-making, cost-effectiveness analyses have been used to gain an understanding of the costs associated with various alternative treatments and the outcomes of treatment. In this study a cost-effectiveness analysis was performed to compare the outcomes and costs of posterior teeth that received a large amalgam restoration with those that received a large amalgam foundation and a crown over a ten-year period. This information is beneficial in making the most appropriate dental care decisions, not only for practitioners and their individual patients, but also for administrators planning treatment programs in such environments as community health clinics, care facilities or institutions, dental insurance companies, and state Medicaid programs.

Limited information exists regarding the long-term outcomes of posterior teeth that received large amalgam restorations compared to crowns. There are a few studies that used administrative data to evaluate outcomes of these two restorations. These studies found that teeth with crowns were significantly more likely to survive over a five- to 15-year period than teeth that only received a large amalgam (3,4). However, none of these studies incorporated the substantial difference in cost or the difference in effectiveness between these two procedures into their analysis.

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One way to incorporate differences in the cost of two treatment alternatives into an outcomes assessment is by conducting a cost-effectiveness analysis. Cost-effectiveness analysis is a quantitative tool that compares the cost of alternative treatment regimens with the expected health outcomes that are likely to result from the use of each regimen (5,6).

In dentistry, most published cost-effectiveness studies have concentrated on preventive and diagnostic methods although some have evaluated differences in the cost-effectiveness of different restorative materials (e.g., composite resins vs amalgams) (7-9). Maryniuk, Schweitzer, and Braun developed a computer model of the lifetime restorative needs of a posterior tooth and evaluated the cost-effectiveness of various strategies in the restoration of a posterior tooth with either a large (4-surface) pin amalgam or a crown (10). The longevity models, which relied on a group of dentists to provide estimates of restoration longevity, all demonstrated that the optimum treatment decision was to replace the first failed amalgam restoration with another amalgam instead of a crown. However when an amalgam restoration fails, the subsequent suitable replacement may be a crown. While the study provided some evidence based on a team of clinical dentists, it neither used actual data nor did it account for the possible extraction of the tooth as an outcome.

In this study, administrative data for patients treated at the University of Iowa, College of Dentistry were used to determine whether there was a difference in the cost-effectiveness of large amalgams and large amalgams and a crown (to be called crowns) based on 5- and 10-year costs and outcomes associated with each sampled tooth. The costs associated with both the initial placement of the restorations and subsequent treatment(s) were incorporated into the cost-effectiveness analysis. The effectiveness measure in this study was the number of years a tooth remained in a state free of catastrophic subsequent treatment (not experiencing root canal therapy or extraction).

Material and Methods

Retrospective data from The University of Iowa, College of Dentistry administrative database were used to follow posterior 'target teeth' (not including third molars) that received a large amalgam restoration (4 or 5 surfaces) in 1987 or 1988. Large amalgams where identified by using the following American Dental Association (ADA) current dental terminology codes (CDT): 02161 (four surface + alloys) and 02950 (core buildup). 'Target teeth' that received a subsequent crown on or before 365 days from the placement of the large amalgam were classified as crowns. The CDT codes used to identify crowns included: 02720, 02721, 02740, 02750, 02752, 02790, 02792, and 02810. 'Target teeth' that did not receive a subsequent crown or received a subsequent crown after 365 days were classified as large amalgams. All treatment prior to (up to 2.5 years) and following the placement of the initial large amalgam or crown was determined by evaluating the CDT codes and corresponding dates of service until the date of the patient's most recent visit. If a patient had more than one target tooth, one tooth was randomly selected for this analysis. In an effort to standardize teeth the administrative data were used to exclude from the onset: third molars, teeth with prior root canal therapy (root canal procedure codes prior to the placement of the initial large amalgam), and teeth that served as a fixed bridge abutment (abutment procedure codes following the placement of the initial large amalgam). After these exclusions, there were a total of 1,735 teeth. The costs and the effectiveness levels for teeth with large amalgams and crowns were averaged for each one year interval (interval started at date that the tooth received the large amalgam or crown) and then discounted to their present value. SAS Software Version 8.2 was used to manage the data and determine the number of teeth that experienced a catastrophic event each year. Microsoft Excel was used to calculate the cost and effectiveness values. This study was approved by the Committee for the protection of Human Subjects at the University of Iowa.

Costs. Costs for the initial placement of the large amalgam or crown plus all subsequent treatment on the 'target teeth' were calculated. Treatment fees from the ADA 2001 national fee survey were assigned to each procedure code as an indication of the societal cost of dental treatment (11). This fee survey is the most expansive and up to date report of fees charged across the United States. The ADA 2001 fees for treatment were used be-

TABLE 1
Distribution of demographic variables by restoration type

Variable	Levels	Large Amalgam		Crown		Chi squarep-value
		n	(%)	n	(%)	
		1071	(62)	664	(38)	
Age	20-34	261	(24)	98	(15)	<0.001
	35-44	223	(21)	130	(20)	
	45-54	166	(16)	115	(17)	
	55-64	187	(18)	169	(25)	
	65-74	160	(15)	127	(19)	
	75+	68	(6)	25	(4)	
Gender	Male	510	(48)	300	(45)	0.328
	Female	560	(52)	363	(56)	
Tooth type	Premolar	260	(24)	202	(30)	0.005
	Molar	811	(76)	462	(70)	
Tooth arch	Maxillary	536	(50)	366	(55)	0.040
	Mandibular	535	(50)	298	(45)	
Type of Provider	Undergraduate	757	(71)	470	(71)	0.295
	Graduate	110	(10)	55	(8)	
	Faculty	204	(19)	139	(21)	

cause they were the most current procedure fees available, and therefore were considered more meaningful for the interpretation of the results than were the actual costs at the time of the initial treatment in 1987 - 1988 (12).

Future costs were discounted to reflect the existence of time preference; dollars spent or saved in the future should not weigh as heavily as dollars spent or saved today (6). The average charges associated with having the large amalgam or crown in the year 2001 were added to the future dental treatment charges which were averaged for each one-year time interval and then discounted to present value (2001) dollars. The cumulative discounted average costs were calculated for 5- and 10-year periods. A 3% discount rate was used which is consistent with the shadow-price-of-capital approach to evaluate public investments as suggested by the US Public Health Service panel on Cost-Effectiveness in Health and Medicine (12).

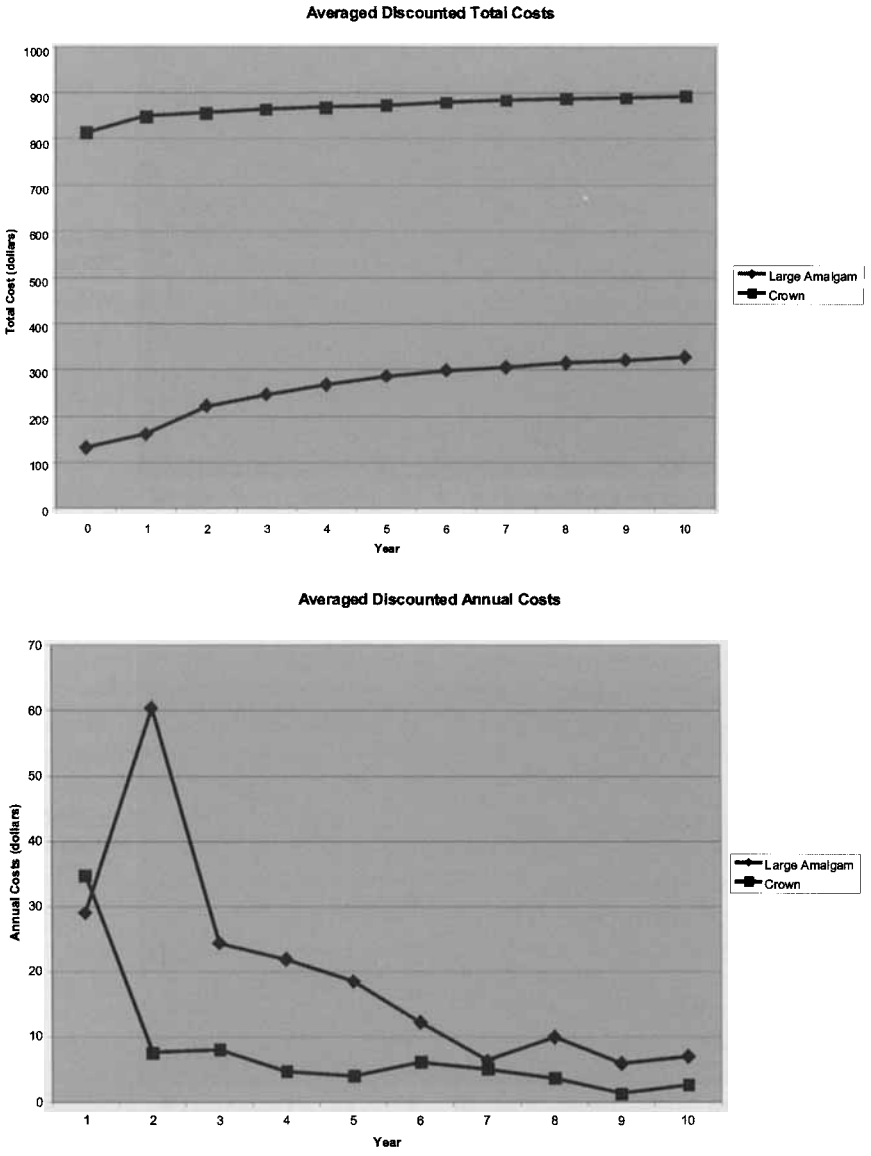
The following notation was used to discount costs:

$$P = \sum E_n (1+r)^{-n}$$

where n = 0 to 9 years, P = present value, Cn = averaged future costs at year n, and r = annual discount rate (3%) (6).

Effectiveness. In this study, effectiveness was defined as the cumulative discounted average number of years free of catastrophic treatment. Thus teeth with a large amalgam or crown were given a score of one for each year that a tooth avoided having a catastrophic treatment. A value of 0.5 was given to a tooth during the year in which the tooth experienced a catastrophic treatment, or the data were censored because the patient no longer sought care at the University of Iowa, College of Dentistry. A value of 0.5 was given with the assumption that these teeth were present, on average, for at least half of the year. In the years after the teeth received the catastrophic treatment or were censored, the effectiveness value or these teeth was a 0.

FIGURE 1
Cumulative and annual costs for teeth with large amalgams and crowns over a 10-year period a) cumulative (totaled) - averaged, and discounted b) annual - averaged, and discounted



For each year the average effectiveness value (En) was calculated for teeth with a large amalgam or crown using the formula:

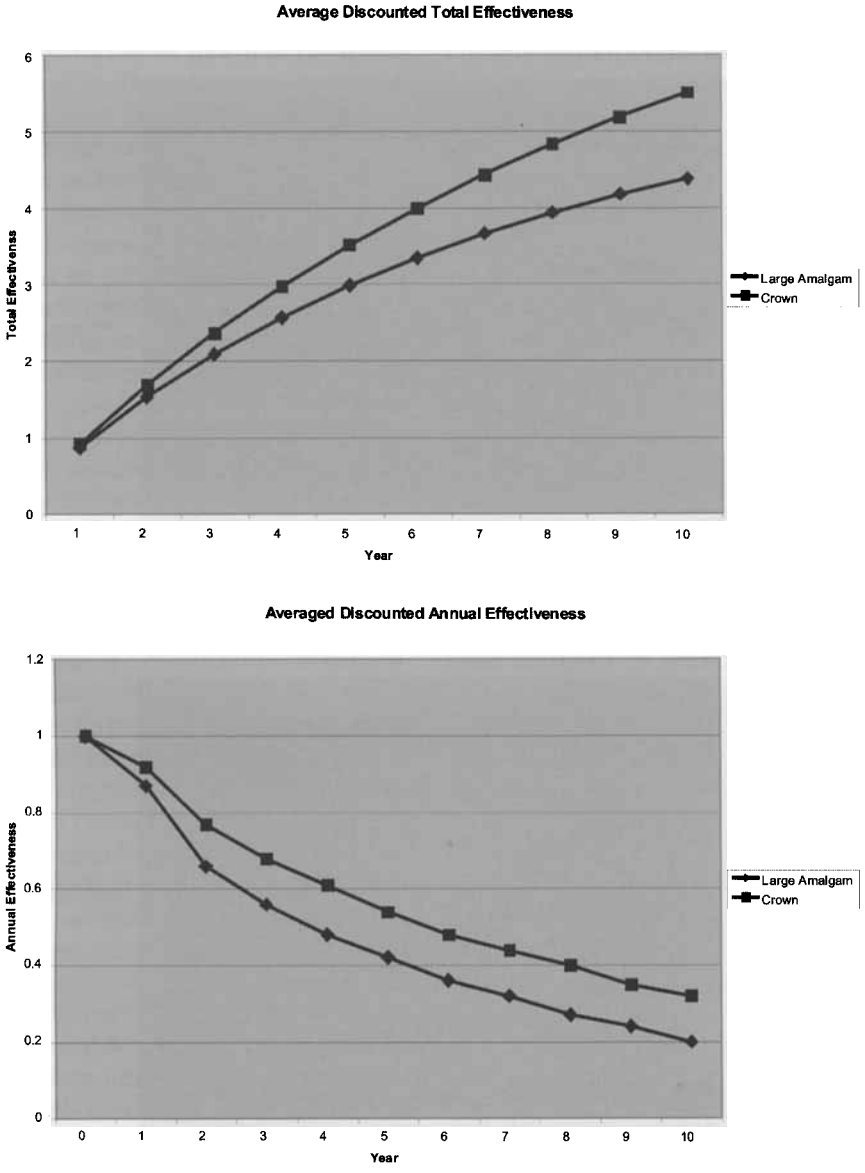
$$E_n = \left(X_n * 1 + Y_n * 0.5\right) / N_n$$

where: Xn equals number of large amalgams or crowns without catastrophic treatment in year n; Yn equals number of large amalgams or crowns with catastrophic treatment or censored during year n; and Nn equals number of teeth with large amalgam or crowns present at the beginning of year n. Beyond the first year, the effectiveness value was discounted and calculated in a similar manner to costs using the formula:

$$P = \sum E_n (1+r)^{-n}$$

where n = 0 to 9 years, P = present value, En = average effectiveness value at year n, and r = annual discount rate (3%) (6). For the first year free of catastrophic treatment a tooth received an effectiveness value of 1, for each additional year free of catastrophic treatment the effectiveness value was discounted by 3%. For the second year free of catastrophic treat-

FIGURE 2
Cumulative and annual effectiveness a) cumulative (totaled) averaged, and discounted b) annual – averaged and discounted



ment the tooth received an effectiveness value of .97 and a cumulative value of 1.97 (effectiveness value for year 1 plus the effectiveness value for year 2). For each year the effectiveness was discounted and averaged at the individual tooth level. Overall effectiveness values were totaled at 5 and 10 years. Conceivably the maximum effectiveness value for a tooth free of catastrophic treatment at 5 years and 10 years could be 4.72 and 8.79 respectively.

Cost-effectiveness ratios. The large amalgams and crowns were compared by calculating the incremental cost–effectiveness ratio (C/E). The C/E is calculated by taking the difference in the groups' costs divided by the difference in their effectiveness ($\Delta C/\Delta E$). The C/E is the incremental cost of obtaining a unit health effect from a given intervention when compared with an alternative (12).

Sensitivity analysis. A one-way sensitivity analysis was completed by changing the discount rate from 3 percent to 0 percent and 5 percent. The purpose of the sensitivity analysis was to examine the robustness of the estimated C/E result over a range of alternative values for uncertain parameters (5,6).

Inflation. Cost are reported in 2001 dollars, based on 2001 ADA fee estimates. Future costs were not inflated, for it is assumed that all costs inflate at the same rate which is the same rate as inflation in general (6).

Results

Of the 1735 teeth, 62% were large amalgams with the remainder defined as crowns. Table 1 displays the distribution of demographic and tooth characteristics for each type of restoration. Patients with large amalgams were slightly younger. Teeth with crowns were more likely to be premolars and to be in the maxillary arch. There was no significant difference in gender or the type of provider placing the different restorations.

The cumulative and annual costs and effectiveness for teeth with large amalgams and crowns at each yearly increment over a period of ten years are displayed in Figures 1 and 2. The initial average cost for teeth with crowns was $814.74, while the initial average cost assigned to the teeth with large amalgams was $132.14. Figure 1a indicates the cumulative costs, including the initial restoration over the ten-year period. Cumulative, average, discounted costs for teeth with crowns rose to $893.31 and $328.20 for teeth with large amalgams.

Figure 1b shows the annual, average, discounted costs following the cost of the initial restoration. In year one, annual costs associated with crowned teeth were higher but declined significantly and remained lower than the costs for teeth with large amalgams over the ten-year period. Costs for teeth with large amalgams peaked in year two and declined significantly up until year seven when they approached the annual costs for crowned teeth and remained relatively low for years seven through ten.

For both large amalgams and crowns the effectiveness measure, years free of a catastrophic treatment, was similar in year one (Figure 2). Over time, the increase in the cumu-

Table 2
Averaged and discounted costs at 5 and 10 years for all teeth, teeth in men and women, and teeth in the maxillary and mandibular arch

	5 Years - averaged and discounted		10 Years - averaged and discounted	
	Large Amalgam	Crown	Large Amalgam	Crown
All Teeth – Large Amalgam (n=1071), Crown (n=664)				
Cost($)	286.46	874.20	328.20	893.31
Effectiveness	2.99	3.53	4.39	5.52
C/E	1,088.41		500.10	
Men – Large Amalgam (n=510), Crown (n=300)				
Cost($)	294.07	870.82	328.01	901.38
Effectiveness	3.02	3.44	4.34	5.27
C/E	1,373.21		616.53	
Women – Large Amalgam (n=560), Crown (n=363)				
Cost	279.81	873.41	328.72	883.11
Effectiveness	2.99	3.60	4.46	5.72
C/E	973.11		439.99	
Maxillary – Large Amalgam (n=535), Crown (n=298)				
Cost	278.61	854.92	319.30	872.81
Effectiveness	3.05	3.70	4.46	5.90
C/E	886.63		384.38	
Mandibular – Large Amalgam (n=536), Crown (n=366)				
Cost	294.29	889.90	337.07	910.01
Effectiveness	2.93	3.40	4.32	5.21
C/E	1267.26		643.75	

Table 3
Sensitivity analysis

	5 Years - averaged		10 Years - averaged	
	Large Amalgam	Crown	Large Amalgam	Crown
0 % Discount - All Teeth				
Cost	294.11	875.88	345.09	899.01
Effectiveness	3.14	3.72	4.84	6.15
C/E	1003.05		422.84	
5 % Discount - All Teeth				
Cost	281.79	873.18	318.47	890.07
Effectiveness	2.90	3.42	4.13	5.16
C/E	1137.29		554.95	

lative, discounted effectiveness for crowned teeth was greater than for teeth with a large amalgam (Figure 2a). The average annual effectiveness scores, not including the initial placement of the restorations, declined for both large amalgams and crowns; however the effectiveness of the teeth with large amalgams declined at a faster rate (Figure 2b).

The cumulative, average, discounted cost and effectiveness were higher for crowned teeth at both 5 and 10 years (Table 2). Although the cumulative effectiveness was higher for crowned teeth, the overall C/E at 5 and 10 years was higher for crowned teeth. Over a 5-year time horizon when crowned teeth were compared with teeth that had a large amalgam, the cost of an additional one year free of catastrophic treatment was $1,088.41 for teeth with a crown. Due to the longevity of crowned teeth with less catastrophic treatment, this cost was reduced to $500.10 at 10 years.

Teeth in men had higher C/Es than teeth in women at both 5 and 10 years (Table 2). For men over a five-year period, the cost for crowned teeth to have an additional year free of catastrophic treatment was $1,373.21. This was much higher than the cost for women, which was $973.11. Over a ten-year period the C/Es for men and women were closer, $616.53 for teeth in men, and $439.99 for teeth in women.

There were also differences in arch type, with higher C/Es for teeth in the mandibular arch. Over a 5-year horizon the cost for crowned teeth in the mandibular arch to avoid one additional year of catastrophic treatment was $1,267.26, while for maxillary teeth the ratio was $380.00 less ($886.63). The difference in the C/Es at 10 years remained large, $644 in the mandible and $384 in the maxillary arch.

The results of changing the discount rate in the sensitivity analysis are shown in Table 3. Changing the discount rate to either 0 or 5% did not drastically change the C/Es and the significant reduction in the C/E found when going from a five- to ten-year time horizon remained.

Discussion

Tooth and restoration longevity, costs, and health consequences are important to consider when comparing alternative treatments for a tooth requiring an extensive restoration. When comparing treatment alternatives, the ideal treatment alternative is one that has both the lowest cost and the highest effectiveness, resulting in a negative C/E. Although prior research has shown that crowns have better long-term outcomes, in this study, over a period of 10 years when evaluating the cost-effectiveness of the two alternative restorations for a catastrophic outcome, neither restoration was an ideal treatment alternative. Crowned teeth had higher effectiveness, but at a much higher cost. When comparing the cost-effectiveness of teeth with crowns or large amalgams, the teeth with large amalgams had a lower or more favorable C/E at both 5 and 10 years. At 5 years when compared to teeth with a large amalgam, the cost of an additional one year free of catastrophic treatment was

$1,088.41 for teeth with a crown. On the other hand, although the initial cost of crowns is quite high this was diminished at 10-years due to the high effectiveness value of crowns. At 10-years when compared to teeth with a large amalgam, the cost of one additional year free of catastrophic treatment was reduced to $550.10. Five- and ten-year time periods were selected for this study. However, longer time periods would provide data to determine if there is a continuous reduction in the differences in cost-effectiveness ratios between teeth with large amalgams and crowns.

The results were sensitive to differences in gender and arch type. Women had overall lower C/Es mostly due to having effectiveness values that were higher than those for men. Overall the most favorable value was found for teeth with a large amalgam in women with a cost of $328.72 and an effectiveness of 4.46 at 10 years, while the least favorable value was found for teeth with a crown in men with a cost of $870.82 and an effectiveness value of 3.44 at 5 years. There have been a few studies that have reported better outcomes for women. In one study comparing all restoration types, Mahmood and Smales (13), reported that restoration survival was superior in female patients. In evaluating Class I and II amalgam restorations Gruythuysen et al. (14), found that 20% of the study restorations were replaced in males, while 16% were replaced in females. Women access dental care differently and react to health promotion in a more positive manner than men (15). Women are known to access more medical and dental health care and to seek care more frequently for both acute and chronic problems. In addition, gender differences in dental service utilization have consistently been reported, with women having had dental checkups more frequently than men (16). Having dental checkups may act as a preventive measure, increasing the longevity of restorations through more frequent routine maintenance. These cost and utilization factors may be important to program administrators developing treatment programs that target women.

The difference in maxillary and mandibular teeth is much clearer. Mandibular teeth had both higher costs and lower effectiveness values, therefore resulting in higher cost-effectiveness ratios. The most favorable value was for maxillary teeth with a large amalgam at 10 years with a cost of $319.30 and effectiveness of 4.46, while crowned teeth in the mandibular arch at 5 years had the least favorable value with a cost of $889.90 and an effectiveness value of 3.40. One study has reported lower restoration survival rates in the mandibular arch (17) while no articles have reported lower survival rates in the maxillary arch. Mandibular molars may be at higher risk for experiencing catastrophic treatment such as extraction. Longitudinal studies of older individuals have reported that of all teeth, mandibular molars experience the highest rate of tooth loss (18-20). To assist individual and community based clinical decision-making, more research is needed to determine if there is a clear distinction between the outcomes of different restorations by arch.

The results were not sensitive to changing the discount rate to either 0 or 5%. Thus, the basic conclusions do not change when the discounting rate is varied. This increased the confidence in the conclusions and that the results were not sensitive to changes in the discount rate parameters tested (6).

The results of this study support other studies that indicated that crowns survive longer than large amalgams. When factoring costs into the equation, this study also supports the longevity models created by Maryniuk et al. (10) which demonstrated that the optimum treatment decision is to replace the first failed amalgam restoration with another amalgam, instead of with a crown. By evaluating both the longevity (effectiveness) and costs of the teeth restored with large amalgams or crowns one has more information when deciding between the alternative restorations. This information is important to not only the providers and the recipients of the treatment, but also to those planning treatment programs or financing the reimbursement for the procedure.

The use of retrospective data without randomization of subjects limits the interpretation of the results because there may be an inherent bias. In this study conducted at a dental school, many patients may not have insurance and teeth at greater risk of short term failure may have been more likely to be treated with an amalgam than a crown, following a wait and see approach. Therefore it is likely that teeth at highest risk for a catastrophic event received a large amalgam instead of a crown, and the results in this study for large amalgams may be conservative. If teeth had been randomized, it might be expected that even more teeth with crowns would have failed.

In using the retrospective data for this study assumptions were made in the analysis process. It was assumed that if a crown was initially treatment planned for the target tooth, it received a crown within 365 days of receiving the large amalgam. Due to academic schedules and student rotations it is conceivable that it took more than 365 days for a tooth to receive a crown, therefore mis-categorizing some teeth in the wrong restoration group. However, chart reviews were completed and generally supported this assumption, but it was not always clear why a crown was placed. Although these details were not captured, there is an overall understanding of both the costs and outcomes. The use of diagnostic codes would help in reducing the number of assumptions that were made. This study relied on the assumption that over the 10-year period all intended treatment was captured while patients sought care at the University of Iowa, College of Dentistry.

An effectiveness measure of 1 was used for no catastrophic event during the year and declined to .5 in the year catastrophic treatment occurred, or the year the patient dropped out of

the study. Receipt of catastrophic treatment was chosen as the outcome in this study since the tooth is in a compromised state which often requires complex treatment decisions to be made by patients and clinicians. However, using a different, less extreme measure of effectiveness, something other than receipt of catastrophic treatment, may have produced different results. The use of catastrophic treatment as the outcome in this study could also have introduced a bias against teeth with large amalgams since they have a higher rate of failure.

This analysis used information about patients treated in a dental school. This care may or may not be representative of care in a private or community practice setting. More information about the treatment planning process for the initial restoration such as level of insurance coverage for crowns would also have strengthened the analysis. Lastly, as with using all administrative data for research, the data is being used for a purpose other than originally attended and can introduce error into the analysis (e.g., miscoding of procedures).

Since this analysis only included treatment costs, the results do not provide a complete societal or patient view. It would be beneficial to do a similar study from the perspective of the patient by including such parameters as patient time, patients' value of time, travel expenses, patients' value of different health states, and patient preference for type of treatment. Additionally, a complete societal view including all social investments, such as the costs associated with the loss of patient productivity, would be useful. Many patients, especially in community dental clinics, may not be able to afford a large amalgam or crown and may choose instead to have the tooth extracted. Therefore a similar study from a societal view using different outcomes, such as patient's ability to function, would be useful information for administrators planning dental treatment programs.

Although this study has limitations, it does provide an understanding of the costs and outcomes of large amalgams and crowns. Neither restoration, large amalgam or crown, appeared to be the "ideal" restorative alternative for neither had both the lowest cost and the highest effectiveness. Yet the information in this study can be used along with other factors to determine whether lower costs are worth lower effectiveness, or the additional costs are worth the additional effectiveness. This knowledge is valuable during discussions regarding treatment alternatives, not only among patients and practitioners, but also among others such as insurers, legislators, government officials, and administrators of community dental programs. To facilitate these discussions, further outcome and economic research is needed to address non dental-school practices including private practices and community based dental programs.

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