Survival analysis of metal crowns versus restorations in primary mandibular molars

Gerardo Maupomé, BDS, MSc, PhD; Juan F. Yepes, DDS, MD, MPH, MS, DrPH; Madison Galloway, DMD; Qing Tang, MAS; George J. Eckert, MAS; Timothy Downey, MS; LaQuia Vinson, DDS, MPH

ABSTRACT

Background. The effectiveness of stainless steel crowns (SSCs) versus direct restorations when placed in primary mandibular molars (teeth nos. L and S) is uncertain. The authors evaluated effectiveness by gauging longevity of treatment.

Methods. The authors obtained private dental insurance claims (2004-2016) from a national dental data warehouse. Paid insurance claims records (n = 1,323,489) included type of treating dentist, treatment placed, and patient age.

Results. Dentist specialty, type of treatment, and patient age were significant in predicting failure after the first restoration. The authors found high survival rates for all treatments (> 90%) after 5 years; however, as soon as within 3 years after treatment, SCCs had approximately 6% better survival.

Conclusions. Teeth nos. L and S first treated with SSCs

The outcomes expected from different approaches to treating carious lesions in the primary mandibular first molars have been the subject of debate.[1-3] Compared with pediatric dentists (PDs), general dentists (GDs) may be less adept at performing pulpotomies and placing stainless steel crowns (SSCs) in their pediatric patients.[4] Even with similar case manifestations, GDs may be more likely to place Class II restorations than SSCs[5]; the reverse would be many PDs' treatments of choice. The importance of these clinical issues and their cost implications is whether the results of 1 course of treatment or the other will last longer.

The existing literature provides partial guidance, but opinions predominate over evidence. Population-based studies often have been in small convenience samples. Some observations highlight limitations when treating proximal lesions in children younger than 4 years or in those whose permanent first molars have not erupted.[6,7] Generally accepted best practices are as flexible as recommending SSCs "when the restoration is expected to last longer than two years or when the patient is younger than six"[8]; such guidelines appear ambiguous. Investigators in the population-based studies have reported that SSCs are less likely to require retreatment than are multisurface amalgam restorations[7,9] and have greater longevity at 8- and 5-year follow-ups.[10-12] Although some SSCs also were deemed to fail over time, investigators in 1 of the larger-scale reviews concluded that Class II amalgam restorations had a failure rate of 26% at 5 years, whereas SSCs had only 7%.[11,12] The situation for composite restorations was generally poorer than for amalgam restorations.[13] Estimated 5-year survival rates were 68% for SSCs, 60% for amalgam restorations, and 40% for composite restorations.[13] Investigators in a 2015 Cochrane review[3] found more studies than they had for the original 2007 review; the key findings were that SCCs placed to treat carious lesions or after pulp treatment were more likely to avert

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failure or pain in the long term compared with direct restorations.

Although survival rates over fixed periods is an important first step in ascertaining the comparative effectiveness of SSCs versus that of direct restorations, various factors affect such estimates. The largest unknown is whether the population groups studied portray the diverse factors that drive a decision to restore or repeat treatment. Treatment planning decisions can be modified depending on the child's risk of developing caries, the family's socioeconomic status, caries experience in the child's parents, dietary habits, and mutans streptococci levels,[8] as well as the long-term follow-up care and compliance in home care. How to weigh those factors in clinical management is complex. Investigators in none of the studies cited explicitly incorporated diagnostic codes, stringent case definitions, or precise treatment indications.[3] Another layer of complexity arises when we examine reports in light of dentists' clinical decision making.[14]

Given the high cost of undertaking longitudinal prospective trials, we propose the second best approach to contrasting survival performances: to examine what happens in real life by using private dental insurance claims. Although secondary analysis of dental insurance claims does not afford an in-depth understanding about why some teeth were treated in a certain way whereas other teeth were treated with a different approach, it offers a description of the overall performance of the treatment courses. We chose to conduct this examination on teeth nos. L and S. Their anatomic characteristics provide a singular situation whereby the clinical training of dentists and their familiarity with placing SSCs might condition the decision to choose direct restorations over SSCs.[7] The objectives of our study were to examine the survival of SSCs or direct restorations in primary mandibular first molars (teeth nos. L and S) in a largely national census sample of private dental insurance claims; to examine whether longer survival rates were more characteristic of either treatment when undertaken by different providers, such as GDs versus PDs versus any other dental specialist; and to calculate the overall direct costs paid for dental care on teeth initially treated with either SSCs or direct restorations.

METHODS

An institutional review board at Indiana University approved the project (1508889495).

Participants and study locations. We obtained data from a commercial dental insurance data warehouse that accrues claims from more than 50 dental insurance plans and multiple carriers in the United States. The data warehouse includes a large proportion of all dental plans in the country but not all of them. We obtained deidentified nationwide data for children 18 years or younger to include length of time between first and subsequent treatments (identified by means of their Current Dental Terminology codes,[15] a standardized system for identification and billing prevalent in the American market), a unique identifying number, age in years, and dental care provider information (including whether GDs, PDs, or practitioners in any other specialty had filed the claim). The data extraction encompassed all records from May 2004 through June 2016.

Current Dental Terminology codes were primarily D2391, D2392, D2393, D2394, D2140, D2150, D2160, and D2161 for direct restorations and D2930, D2933, and D2934 for SSCs.[15] Other codes were used only for calculating costs (codes relevant to teeth nos. L and S for restorative, endodontic, and surgical procedures).

Study procedure and data sources. Analyses included only paid claims. We focused on the first billed and paid claim involving teeth nos. L and S for direct restorations (amalgam or composite) and for SSCs; any other restorative, endodontic, or extraction subsequently billed and paid for teeth nos. L and S; patient age; and the specialty of the dentist providing the first treatment.

Data transformation and statistical analysis. Data transformation followed the rationale summarized in Figure 1. Briefly, a tooth could have a dental history whereby it was healthy and was exfoliated naturally; the analytic data set would not register any claims. A tooth also could have been treated with an extraction; we did not consider that single event in the analyses. Our analyses focused on the treatment outcomes of teeth nos. L and S when they first were restored either with a direct restoration or with an SSC. We used the first observation in the data for each tooth for the type of restoration placed: SSCs or direct restorations (Class I, II, and III composite restorations or amalgam restorations). For teeth that were not treated at least a second time, we censored the follow-up time at the earlier of the last data recorded for the patient, including extractions, or age 11 years (average typical exfoliation age for teeth nos. L or S, which we assumed to be the end point of a nonextracted tooth because exfoliations were not recorded in the claims database).

We used the data set in 3 analytic approaches. First, we addressed a yes-or-no failure analysis. We fit generalized logit models to compare the effects of practitioner specialty and patient age on the distribution of the type of restoration. We included random effects to account for the correlation among patients within provider and between the 2 teeth within a patient.

Second, we used a generalized estimating equation model that incorporated type of practitioner, type of restoration, and patient age as predictor variables to estimate the odds of failure after first restoration. We used a Kaplan-Meier (product limit) estimator

ABBREVIATION KEY. **GD:** General dentist. **PD:** Pediatric dentist. **SSC:** Stainless steel crown.

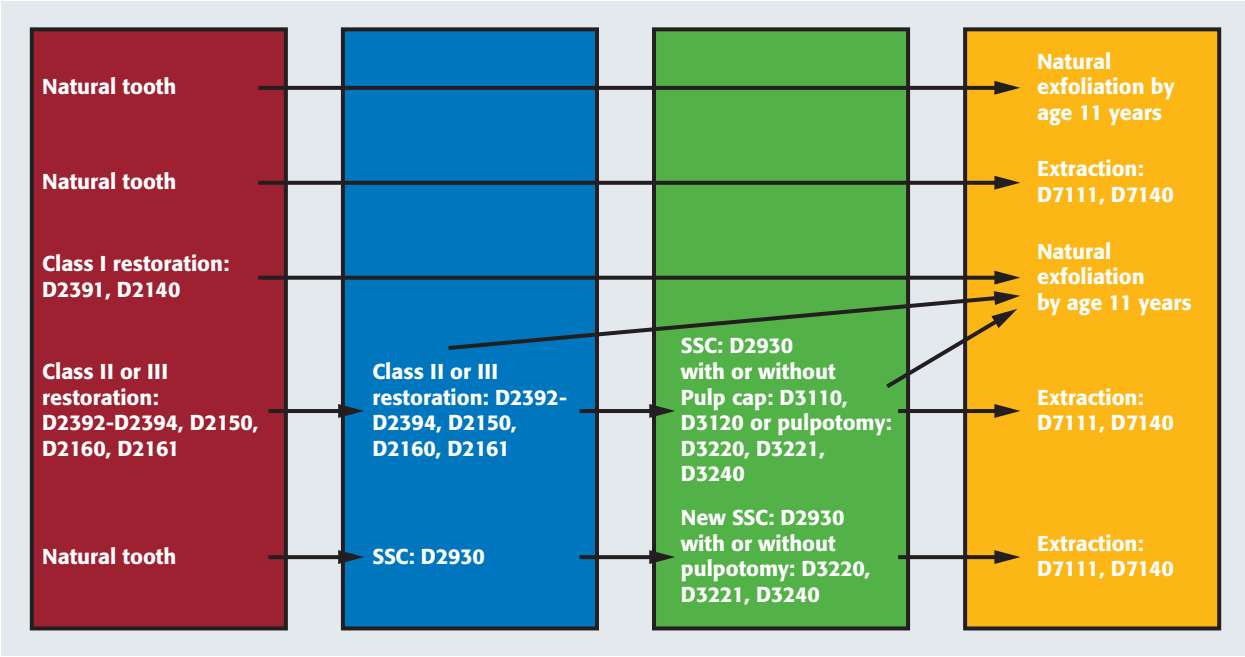

Figure 1. Diagram depicting the sequence and hierarchy of the order of treatment progression for a tooth according to Current Dental Terminology codes. SSC: Stainless steel crown. *Source: American Dental Association.*[15]

to estimate the survival rate after the teeth received their first restoration. This method took into account the right-censored data, which occurs if a patient did not receive the second restoration before age 11 years. We performed log-rank tests to compare the survival distribution between types of restorations or among types of practitioners. We also analyzed the data set with Cox regression models, which account for the nesting of patients within providers and teeth within patients; the results were similar to those of the Kaplan-Meier tests. We report only the latter.

The data allowed us to account for all procedures performed on the same tooth and paid by a dental plan. Because of the complexity of teeth nos. L and S being treated with direct restorations or SSCs more than once and in any order and by different practitioners, these results depict the categorizations pertaining to the first treatment on a given tooth. In the survival curves, we classified failure as the first instance in which an additional procedure was performed on the same tooth. The survival curves do not account for multiple failures.

Third, we calculated the overall costs of the treatments undertaken on each tooth throughout its dental history. We made no adjustments to values for any given year (first in 2004 or last in 2016) or for inflation. We discarded any claims billed and paid that did not make clinical sense. Using 2-sample *t* tests, we compared overall costs for teeth that were first treated using SSCs with those for teeth that were first treated using direct restorations. We analyzed data by using software (SAS, Version 9.4, SAS Institute).

RESULTS

Basic results. The data included 1,323,489 records specific to teeth nos. L and S in the 12 years making up the data set. Records pertained to 750,859 unique patients and to 106,252 unique providers. Of these, GDs provided the first treatment in 62.9% (446,906 of 710,633) of the cases, and PDs provided first treatment in 35.0% of the cases (248,456 out of 710,633); all other specialties combined billed and were paid only 2.1%.

Mean (standard deviation) age for children first receiving a restoration was 6.5 (1.9) years; for SSCs, it was 5.8 (1.7) years. Claims paid for children 4 years or younger (117,732 of 710,633; 16.6% of the total) were the smaller group and then increased to reach a peak at ages 5 years (128,793 out of 710,633; 18.1%) and 6 years (138,772 out of 710,633; 19.5%). Claims for later ages continued to decrease. We did not estimate survival rates or costs for data from study participants older than 11 years.

Generalized estimating equation model to estimate odds of failure after first treatment. Type of practitioners, type of treatment (SSCs or direct restorations), and patient age were significant in predicting the odds of failure after the first treatment ($P < .0001$). The odds of failure for treatments provided by GDs and other practitioners were higher than for treatments performed by

PDs. The odds for direct restorations were higher than for SSCs. The odds decreased as age increased.

Survival analysis between time of first treatment and time of second treatment, across all dentists. We calculated Kaplan-Meier survival curves for the length of time after first treatment until occurrence of end point (second treatment or extraction) for direct restorations and SSCs (Figure 2). For GDs, PDs, and other practitioners, the survival rates for SSCs were significantly higher than those for direct restorations ($P < .0001$).

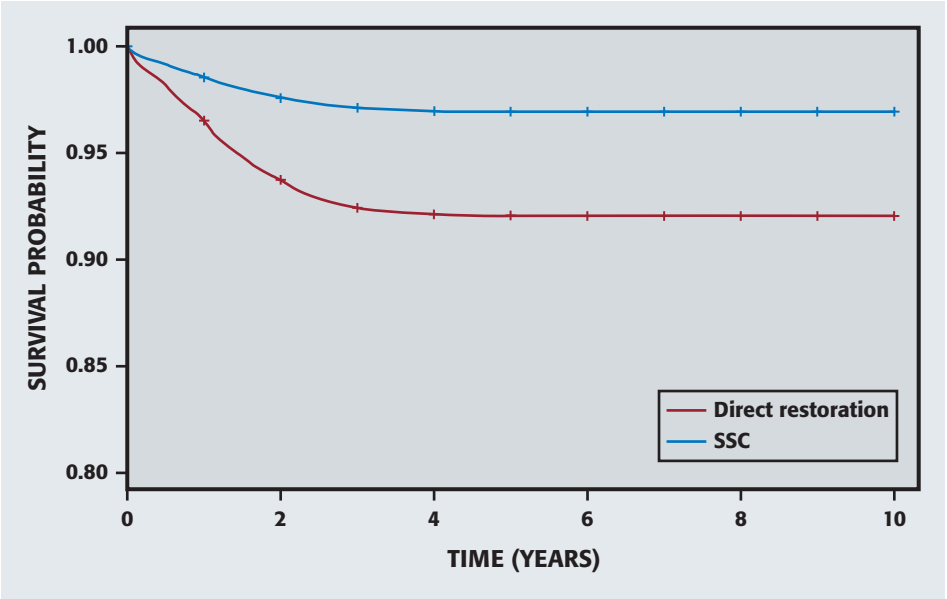

Figure 2. Kaplan-Meier survival curves for direct restorations and stainless steel crowns (SSCs) for teeth nos. L and S for all dentists, regardless of whether they were specialists or general dentists. Although both restoration types had a survival rate of greater than 90%, SSCs lasted longer than direct restorations (log-rank test, $P < .001$).

Survival analysis between first treatment and second treatment, among dentists according to specialty. We calculated Kaplan-Meier survival curves for the length of time after first treatment until occurrence of end point (second treatment or extraction) for GDs, PDs, and other practitioners for direct restorations (Figure 3) and for SSCs (Figure 4). For teeth that received the same type of first treatment, the survival rate was significantly different across practitioners (log-rank test for both, $P < .0001$), but it was always greater than 90% after 2 years of follow-up. Treatments provided by PDs had the highest survival rate for direct restorations and SSCs ($P < .001$). Direct restorations placed by GDs had higher survival rates than did those placed by other specialists ($P < .001$), but survival rates for SSCs did not differ between GDs and other specialists ($P = .67$).

Cost analyses. The mean (standard deviation) overall cost of a tooth first treated with direct restorations (n = 589,840) was $98.68 (58.50; median, $88.00; maximum, $1,726.60). These overall costs over a tooth's life of treatments were lower ($P < .0001$) than were the overall costs of a tooth first treated with SSCs (n = 120,793), which was $170.63 (80.31; median, $158.50; maximum, $1,408.00).

DISCUSSION

To our knowledge, this is the first large-scale study of paid dental claims depicting the dental history of direct restorations and SSCs on teeth nos. L and S. Because this is a health services research project incorporating a nationwide sample of data from private dental insurers, we are able to provide a 12-year perspective of treatment trends and the cost effect for that specific segment of the US dental market. We could not account for publicly funded, out-of-pocket, or donated dental care in our study because there is no registry depicting such segments of the market that would complement our data.

SSCs appear to be superior to direct restorations in the short term. This feature does not mean that they may not be superior in the longer term; it means that our research framework was more solid by limiting the appraisal to assigning a track to teeth (direct restorations or SSCs) as signified by the first paid claim. Results of a yes-or-no failure analysis indicated that age of the child was a significant factor predicting failure, which is not surprising because age differentially would affect decisions to treat teeth nos. L or S with direct restorations or SSCs.[8,11] Age is an inherent issue in gauging clinical performance in pediatric dental care because of teeth having a prespecified life expectancy. Results of an extensive yet dated review showed SSCs lasted longer than did multisurface amalgam restorations.[10] The obvious question is whether treatment and retreatment had equal probabilities of taking place. In our study, we depicted what happened in real life and was paid for by private dental insurance plans.

Our results help confirm those of a prior report undertaken in a small sample that showed survival rates greater than 90% for SSCs evaluated within 4.5 years compared with results for amalgam.[9] Investigators in another small-sample study found that SSCs had the highest survival rate followed by amalgam, composite,

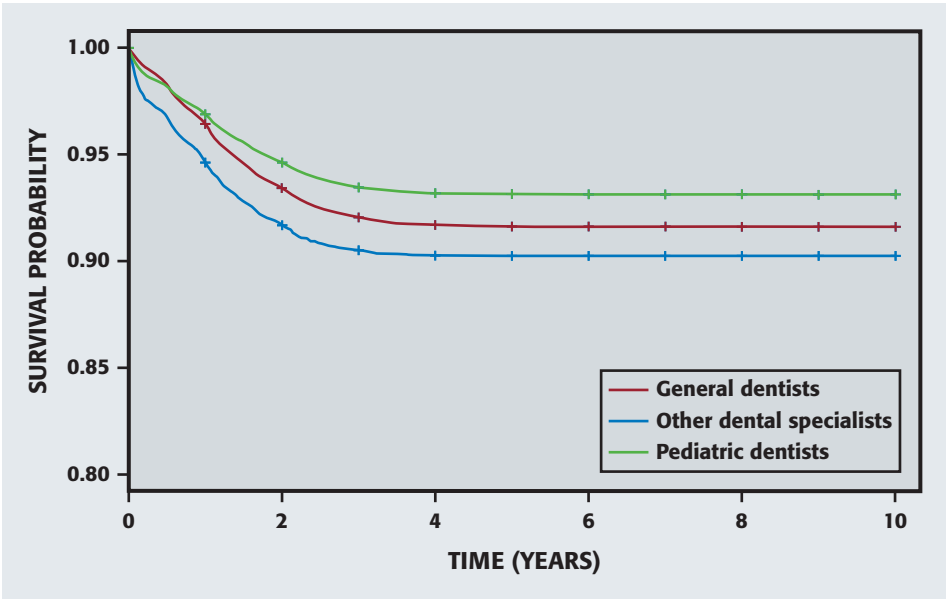

Figure 3. Kaplan-Meier survival curves for direct restorations for teeth nos. L and S placed by general dentists, pediatric dentists, and other dental specialists. Survival was longest for those placed by pediatric dentists, followed by those placed by general dentists and then those placed by other dental specialists (log-rank test, all $P < .0001$).

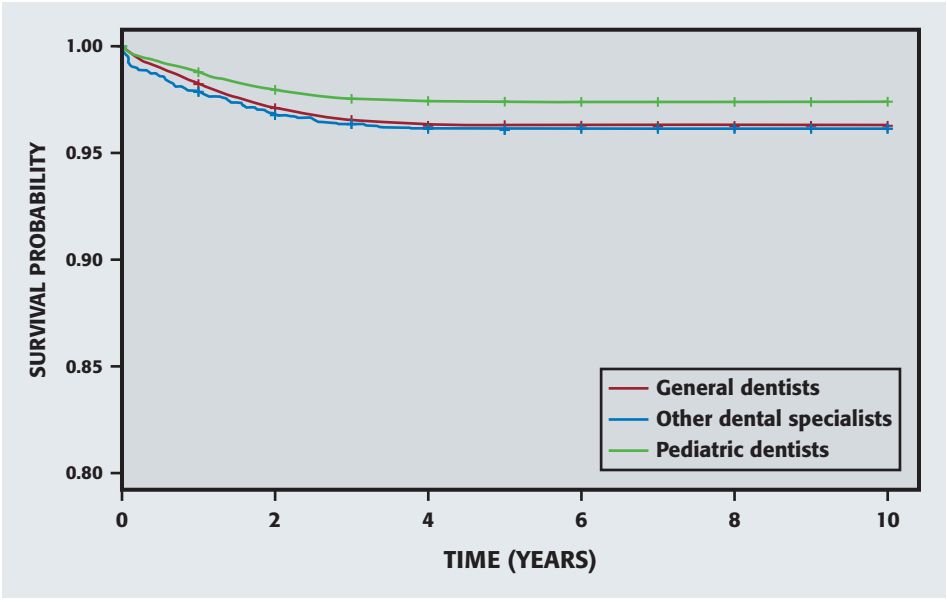

Figure 4. Kaplan-Meier survival curves for teeth nos. L and S with stainless steel crowns placed by general dentists, pediatric dentists, and other dental specialists. Survival was longest for those placed by pediatric dentists (log-rank test, $P < .001$); however, those placed by general dentists and those placed by other dental specialists were not different ($P = .67$).

and glass ionomer restorations.[13] In our study, we found high survival rates for all treatments (> 90%) after 5 years; however, as soon as 3 years after treatment, SCCs had approximately 6% better survival.

The difference in survival was clear and statistically significant, but it was also small. A better definition of what profiles of patients would benefit the most at what ages from placing (and replacing) SSCs or direct restorations remains to be established in a more finely grained contrast.

A salient issue is why some primary mandibular first molars are restored with direct restorations and others are restored with SSCs. One immediate scenario to consider is whether the skill set needed to place either one differs among clinicians or whether the clinical expertise drivers weigh differently on nonclinical considerations. The financial gain for SSCs or restorations is not remarkably different, so it does not appear to be a major driver; our research is not tailored to address this issue. Actual payments in a census sample obviate many such considerations because we safely can assume that we do not hypothesize why dentists did something but actually examine what it is they (106,252 dentists) did. Our findings showed that treatment courses undertaken by PDs had lower failure rates with either type of treatment compared with results for GDs or other practitioners. We propose that PDs may have lower failure rates with direct restorations because of the criteria they typically use to plan a direct restoration instead of an SSC. As previously discussed regarding amalgam restorations, some of the demonstrated limitations for proximal

lesions include placing amalgam restorations in children younger than 4 years or those whose permanent first molars have not yet erupted, as well as in children at high risk of developing caries.[6,7] We suggest PDs may be trained to recognize these conditions more readily and are thus more likely to provide an SSC in these cases. GDs also may recognize these conditions just as effectively, but perhaps because of a low level of comfort in providing SSCs, they opt instead to provide a direct restoration. In dental education, training for non-PDs is rather sparse as far as SSCs are concerned.[16-18] Coupled with the fact that the GD pool was much larger than the PD pool, direct restorations were 3 times more common than SSCs as first treatment.

Even when GDs and other practitioners placed SSCs, the SSCs' survival curve closely resembled that of PDs. Given the data sources we used, we cannot accurately establish the precise reasons for differences within the same treatments.

One obvious factor in the clinical pathway is whether all primary mandibular molars challenge the clinician with the same constellation of clinical factors so that management decisions are just as likely to follow either route. However, it is commonly thought that SSCs or direct restorations are planned for different clinical scenarios.[2,8,11] The larger 2015 Cochrane systematic review[3] pointed that out because of a lack of detail on the extent of carious lesions. One of the major contributions to the topic is that we confidently may assume that a census sample ought to depict all interpretations of clinical information (correctly undertaken or not, according to best practices or not). There was 1 indication that SSCs and direct restorations were prescribed differentially according to clinical manifestation: the overall costs of the treatments paid for each tooth first treated with an SSC and for each tooth first treated with a direct restoration. The accumulated costs for the former were approximately 70% higher than for teeth first treated with direct restorations. One reason is that teeth receiving endodontic treatment likely receive SSCs.[19] The variation in such cumulative experiences was large; the maximum costs were high, which reasonably can be ascribed to rare outliers. If only 1 tooth hit the cumulative cost, that would pull the cost ceiling away from the median cost. Our findings shed new light on the cost comparisons between direct restorations and SSCs; past reports have offered disparate results.[20-22]

Although we offer a large-scale survival analysis study, there are some important design limitations. This is a secondary data analysis representing a large proportion of the market, but the records are not a universal collection of claims. We decided to omit the detailed survival history of cases in which multiple procedures were performed on the same tooth over time; not all those services were billed and paid to the same dentist, and not even the same type of dentist may have provided the treatments. Total costs were the summation of costs as of the time they were paid. We did not adjust for inflation, so the differences in adjusted total costs were likely to be larger than the directly calculated total costs. Finally, the structure of the data and confidentiality clauses did not allow us to follow teeth across dental plans; therefore, we were circumscribed to survival estimates for as long as the employer, subscriber, and child remained in the same dental plan. We supported the tenets of survival analysis by assembling a large data set and focusing our analysis plan on the interval between the first and the second treatments per tooth.

CONCLUSIONS

Teeth nos. L and S first treated with SSCs lasted longer without new treatment compared with teeth first treated with direct restorations. The difference was small. Teeth treated by PDs had better survival profiles than did teeth treated by GDs or practitioners in all other specialties. Overall dental care costs of teeth first treated with SSCs were considerably higher than were comparable costs in teeth first treated with direct restorations. ■

Dr. Maupomé is a professor, Indiana University Network Science Institute, Indiana University, 415 Lansing St., Indianapolis, IN 46077, e-mail gmaupome@iu.edu. Address correspondence to Dr. Maupomé.

Dr. Yepes is an associate professor, School of Dentistry and Riley Hospital for Children, Indiana University, Indianapolis, IN.

Dr. Galloway is a pediatric dental resident, School of Dentistry and Riley Hospital for Children, Indiana University, Indianapolis, IN.

Ms. Tang is a biostatistician, Department of Biostatistics, Indiana University School of Medicine, Indianapolis, IN.

Mr. Eckert is a supervisor biostatistician, Department of Biostatistics, Indiana University School of Medicine, Indianapolis, IN.

Mr. Downey is a chief analytics officer, P&R Dental Strategies, Hamilton, NJ.

Dr. Vinson is an assistant professor, School of Dentistry and Riley Hospital for Children, Indiana University, Indianapolis, IN.

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