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Variations in survival time for amalgam and resin composite restorations: a population based cohort analysis

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Objectives: To estimate the association between the restorative material used and time to further treatment across population cohorts with universal coverage for dental treatment. ***Basic research design:*** Cohort study of variation in survival time for tooth restorations over time and by restoration material used based on an Accelerated Failure Time model. ***Clinical setting:*** Primary dental care clinics. ***Participants:*** Members of Canada's First Nations and Inuit population covered by the Non-Insured Health Benefits program of Health Canada for the period April 1, 1999 to March 31, 2012. ***Intervention:*** Tooth restorations using resin composite or amalgam material. ***Main outcome:*** Survival time of restoration to further treatment. ***Results:*** Median survival time for resin composite was 51 days longer than amalgam, for restorations placed in 1999-2000. This difference was not statistically significant ($p>0.05$). Median survival times were lower for females, older subjects. Those visiting the dentist annually, and decreased monotonically over time from 11.2 and 11.3 years for resin composite and amalgam restorations respectively placed in 1999-2000 to 6.9 and 7.0 years for those placed in 2009-10. ***Conclusions:*** Resin composite restorations performed no better than amalgams over the study period, but cost considerably more. With the combination of the overall decrease in survival times for both resin composite and amalgam restorations and the increase in use of resin composite, the costs of serving Health Canada's Non-Insured Health Benefits population will rise considerably, even without any increase in the incidence of caries.

Key words: *restorative dentistry, survival time, cohort analysis, Canada, indigenous*

Introduction

The use of resin composites for direct posterior restorations is increasingly popular among clinicians and patients. Amalgam use is declining (Demarco *et al.*, 2012; Kopperud *et al.*, 2012) and is planned to eventually be phased out (UNEP, 2013). Differences in material costs and survival rates between the two approaches mean this increasing use of resin composite has implications for planning and funding public dental care programmes (Lynch and Wilson, 2013a;b).

Attempts to quantify these implications are limited by study samples based on selection and eligibility of individuals for dental programmes or insurance plans and difficulties following and recalling patients over long time periods. The Non-Insured Health Benefits (NIHB) programme of Health Canada's First Nations and Inuit Health Branch provides coverage for dental care costs without copayments for all members of Canada's First Nations and Inuit populations. Services are provided by private dentists who are remunerated by the NHIB Programme on a fee-for-service basis. Programme data therefore provide a comprehensive record of all dental care received by these population groups. The absence of copayments and the ability to seek care from any dentist means there is little reason to pay privately for care covered by the programme. NIHB programme data provide an opportunity to explore trends in restorations and further treatment on restored teeth by type of material used for the initial restoration.

Between 1999 and 2010, the annual number of posterior restorations delivered under the programme increased from 280,000 to 368,000. The number of amalgam restorations decreased by over 50%, while the number of resin composite restorations increased by over 130% during this period. Thus the proportion of restorations that were amalgam fell from 54% to 18% while expenditures on resin composite restorations increased from around 50% to over 80% of all expenditures on restorations. This shift in resources from amalgam toward resin composite was not the result of policy decisions. It is therefore important to consider whether this shift in practice style represents an efficient use of public programme resources.

The objective of this study is to estimate the association between the restorative material used and survival time of the restoration together with other possible factors affecting survival time. The implications of the findings for programme costs are also considered.

Background literature

Comparisons of resin composite and amalgam restorations in adult populations have been the subject of several clinical studies. Sunnegårdh-Grönberg *et al.* (2009) examined the longevity of all new and replacement restorations for adults (age 16 and over) delivered in Public Dental Health clinics in Västerbotten, Sweden using a retrospective analysis of all patients who attended clinics during

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a two-week period. The median survival of replaced restorations was 16 years for amalgam compared to 6 years for resin composite**.** Roumanas (2010) analyzed the dental records of 2,780 military recruits in the US between 1997 and 2005. At the initial exam, 964 (15.2%) of the amalgam restorations and 199 (17.4%) of the resin composites required replacement and were excluded from further analysis. Of the sound restorations, 14.2% of the amalgam and 16.7% of the resin composite restorations required replacement during the 3 to 4 year follow up. In a study of restorations placed by US military dentists, Laccabue *et al.* (2014) used a Cox proportional hazards model to estimate replacement rates by type of restoration. The rate of replacement for all restorations in the sample was 5.7% during the average 2.8-year follow up. Risk of replacement was similar for resin composite and amalgam. Opdam *et al.* (2007) also reported similar survival rates for the different materials in a dental practice based study. Kopperud *et al.* (2012) used a practice-based study to assess the survival time of 4,030 Class II restorations placed in 1,873 patients (median age 15 years). After an average follow-up period of 4.6 years, 27.2% of restorations were not available for evaluation owing to patient drop-out. Among those remaining, the failure rates were higher among resin composites (12.4%) than amalgams (7.1%). However, these findings are limited by the high drop-out rate.

In a review of longitudinal, controlled studies and retrospective cross section studies of posterior restorations, Hickel and Manhart (2001) found similar annual failure rates for the respective materials. However, a recent Cochrane review Rasines Alcaraz et al., (2014) reported that resin composites were almost twice as likely to fail compared to amalgam restorations, although the authors noted that the quality of the evidence was low to moderate.

These studies were conducted in a range of settings on relatively small and often specific populations for restorations placed at a particular point in time. Moreover, one study that estimated survival time used a retrospective analysis based on attendance at clinic during a particular time period (Sunnegårdh-Grönberg *et al.*, 2009). Hence, the sample was highly selective, rendering the findings subject to bias. We consider whether the same differences in survival time occur in a non-selected population that were covered by the NIHB programme of Health Canada and whether survival times by type of restorative material are independent of the time when the original restoration was inserted. The research questions to be addressed are:

1. What is the difference in estimated median survival time between resin composite and amalgams restorations among the population covered by the NIHB programme?
2. Do the estimated median survival times for amalgam and resin composite restorations differ across cohorts of restorations?
3. Are the estimated median survival times comparable with those reported in the literature?
4. What are the effects of patient age, gender, region of residence (province/territory), tooth location, and regular vs. non-regular attender on the estimated median survival times?

Methods

We estimated an equation for the determinants of restoration survival time, measured by time between original placement and further treatment on the same tooth surface, in terms of the type of restoration, year of original restoration, the location (province/territory) of the service, tooth type (premolar, first, second and third molar), the subject's age group (at original restoration) and gender, and whether the subject attended a dentist at least once each year throughout the study period. We included interaction terms between restoration type and each of the six control variables to test for variation in the association between restoration type and survival time. Restoration survival time was estimated using the Accelerated Failure Time (AFT) model based on a lognormal distribution for survival time using maximum likelihood methodology. Patel *et al.* (2006) showed that the AFT model is more general than more traditional proportional hazards models because it is not restricted by the assumption of proportional hazards. Results from a proportional hazards model are specific to the length of follow up studied. Consequently the AFT model is especially suitable for analyzing "*interventions that delay or accelerate the onset of an event rather than reduce or increase the overall proportion of subjects who observe the event through time*" (p213). The AFT approach uses time-to-event data, irrespective of whether hazards are proportional and hence incorporates proportional hazards as a special case. Unlike the hazard ratio, the results using the AFT model are easier to interpret, once they are translated into expected changes to the median time to event. Several alternative parametric as well as proportional hazards models were also used to fit the data to consider whether our model choice affected the results.

Data were provided by the NIHB Programme on dental care delivered by five-year age groups between April 1, 1999 to March 31, 2012. No patients or providers could be identified from the data, and the Dalhousie University Ethics Board approved the study. We followed up all posterior teeth that received an amalgam or resin composite restoration during the first 11 years of this period (i.e., up to and including year 2009-10). To allow a reasonable time to detect retreatment, there was a minimum two–year follow up for all restorations. Individuals who died during the study period were removed by NIHB before providing the data for the analysis. There is no reason to believe this would affect the comparison between amalgam and composite resin. We determined that the AFT model provided a better fit to the data than proportional hazards models based on the log likelihood statistic.

Results

2,661,846 restorations (791,723 amalgam and 1,870,123 resin composite) were recorded in the data with the share of resin composites increasing rapidly over the study period (46% in 1999-2000 to 82% in 2009-10). Table 1 provides the estimated coefficients and exponentiated coefficients with 95% confidence intervals for restoration survival time. The exponentiated intercept represents the median survival time for restorations with reference level values for each variable. Hence, the estimated median survival time for amalgam restorations, placed in 1999-2000, on premolar teeth, in females under 35 who were residents of Alberta and non-regular attenders to the dentist was 12.7 years.

Table 1. Estimated coefficients and 95% confidence (Exp), exponentiated coefficiants (Exp.coeff) intervals for the determinants of median survival time

	Resin composite				Interactions with resin composite			
Variable	*Coef.*	*95% CI*	*Exp. Coeff.*	*95% CI*	*Coef.*	*95% CI*	*Exp. Coeff.*	*95% CI*
Intercept	2.54	2.53, 2.55	12.65	12.51, 12.80				
Resin composite	0.01	-0.01, 0.03	1.01	0.10, 1.03				
Cohort 1 (2000-2001)	-0.05	-0.06, -0.04	0.96	0.94, 0.97	0.01	-0.00, 0.03	1.01	1.00, 1.03
Cohort 2 (2001-2002)	-0.09	-0.10, -0.08	0.92	0.91, 0.93	0.04	0.02, 0.05	1.04	1.02, 1.05
Cohort 3 (2002-2003)	-0.11	-0.12, -0.10	0.90	0.89, 0.91	0.04	0.03, 0.06	1.05	1.03, 1.06
Cohort 4 (2003-2004)	-0.13	-0.14, -0.12	0.88	0.87, 0.89	0.02	0.01, 0.04	1.02	1.01, 1.04
Cohort 5 (2004-2005)	-0.15	-0.16, -0.14	0.86	0.85, 0.87	0.01	-0.01, 0.03	1.01	1.00, 1.03
Cohort 6 (2005-2006)	-0.17	-0.19, -0.16	0.84	0.83, 0.85	-0.00	-0.02, 0.01	1.00	0.98, 1.01
Cohort 7 (2006-2007)	-0.25	-0.26, -0.24	0.78	0.77, 0.79	0.03	0.01, 0.04	1.03	1.01, 1.04
Cohort 8 (2007-2008)	-0.30	-0.32, -0.29	0.74	0.73, 0.75	0.00	-0.01, 0.02	1.00	0.99, 1.02
Cohort 9 (2008-2009)	-0.34	-0.36, -0.33	0.71	0.70, 0.72	-0.03	-0.04, -0.01	0.98	0.96, 0.99
Cohort 10 (2009-2010)	-0.41	-0.43, -0.39	0.66	0.65, 0.68	-0.03	-0.05, -0.01	0.97	0.96, 0.99
Atlantic	-0.04	-0.06, -0.02	0.96	0.95, 0.98	0.05	0.03, 0.07	1.05	1.03, 1.07
Manitoba	0.13	0.12, 0.15	1.14	1.13, 1.16	-0.03	-0.04, -0.02	0.97	0.96, 0.99
Nunavut	-0.48	-0.52, -0.4	0.62	0.60, 0.64	0.04	-0.00, 0.07	1.04	1.00, 1.08
NW Territories	-0.33	-0.35, -0.31	0.72	0.70, 0.74	0.05	0.02, 0.07	1.05	1.02, 1.07
Ontario	-0.08	-0.09, -0.07	0.92	0.92, 0.93	0.00	-0.01, 0.01	1.00	0.99, 1.01
British Columbia	-0.03	-0.04, -0.03	0.97	0.96, 0.98	0.01	-0.00, 0.02	1.01	1.00, 1.02
Quebec	-0.27	-0.28, -0.26	0.77	0.76, 0.77	0.12	0.11, 0.14	1.13	1.12, 1.15
Saskatchewan	-0.13	-0.14, -0.12	0.88	0.87, 0.89	-0.01	-0.02, 0.01	0.99	0.98, 1.01
Yukon	-0.16	-0.20, -0.11	0.86	0.82, 0.90	-0.02	-0.07, 0.03	0.98	0.93, 1.03
First molar	-0.09	-0.09, -0.08	0.92	0.91, 0.93	-0.03	-0.04, -0.02	0.97	0.96, 0.98
Second molar	0.02	0.02, 0.03	1.03	1.02, 1.03	-0.01	-0.02, 0.00	0.99	0.99, 1.00
Third molar	0.06	0.04, 0.07	1.06	1.04, 1.08	0.03	0.01, 0.05	1.03	1.01, 1.05
Regular attender	-0.47	-0.48, -0.46	0.63	0.62, 0.63	0.00	-0.01, 0.02	1.00	0.99, 1.02
Age 35+	-0.32	-0.33, -0.31	0.73	0.72, 0.73	0.02	0.01, 0.03	1.02	1.01, 1.03
Male	0.11	0.10, 0.11	1.11	1.10, 1.12	-0.02	-0.02, -0.01	0.99	0.98, 0.99

$Loglik_{(model)}$= -3,180,996 $Loglik_{(intercept\ only)}$= -3,224,107; Chi sq= 86,222 on 51 degrees of freedom, p<0.0001; Number of Newton-Raphson Iterations: 4; n=467,750

The exponentiated coefficients for each variable indicate the estimated percentage change in survival time for that variable compared to its reference value, while holding all other variables at the reference level. For example, the exponentiated coefficient for resin composite is 1.01 (Table 1 column 4) implying that the median survival time for resin composite was 1% (or 51 days) longer than amalgam with all other variables at baseline values, (i.e., restorations placed in 1999-2000, on premolar teeth, in females who were residents of Alberta and non-regular attenders to the dentist). This difference was not statistically significant (p>0.05). The estimated coefficients for all the other variables were statistically significant with coefficients for individual variables indicating median survival times that were lower for females, older subjects and subjects visiting the dentist annually (holding other variables at the reference values). Interactions between the restorative material type and the other variables were included to identify heterogeneity in the statistical associations (i.e., was strength of the association between a variable and survival time significantly associated with the type of restoration?). Estimated interactions with restoration material were significant for age group and gender, but not for the attendance pattern. The estimated longer survival for males was less for resin composite restorations. Age was dichotomized given the large number of factors and levels for each factor. Separate analysis using all 19 age groups indicated that the 30 to 34 age-group to be the best cut-off point for combining age groups into two levels, as indicated by change in the sign of the parameter. Subjects aged 35+ were found to have shorter restoration survival times, with the age difference in survival being significantly less for resin composites. For the non-binary variables (year, province, tooth type), the interactions with restoration type were significant for some variable levels. In particular, the difference in survival times between subjects in Quebec, North West Territories and the Atlantic provinces (compared to Alberta) were significantly greater for resin composites compared to amalgam, other things equal. The opposite was the case for subjects in Manitoba (compared to subjects in Alberta). Compared to Alberta residents with baseline categories of all variables including amalgam restorations, the median survival time for residents of Manitoba with resin composite (and all other variables at baseline) was 14% (1 year and 323 days) longer, based on the exponentiated sum of the constant term (2.53), the resin term (0.01), the Manitoba term (0.13) and the Manitoba-resin interaction term (-0.03). All other provinces had shorter median survival times ranging from 3% (137 days) less in Atlantic Canada to 38% (4 years and 274 days) less in Nunavut at baseline values. The estimated coefficients for the cohort variables show that restoration survival time decreased monotonically over time with median survival time being 4.55% (208 days) less for restorations placed in 2000-01, but 34% (4 years and 93 days) less for restorations placed in 2009-10 than for those placed in 1999-2000 with all other variables at baseline levels. For restorations placed in 1999-2000, median survival time was 11.2 years and 11.34 years for resin composite and amalgam restorations respectively.

These survival times fell to 9.4 (resin composite) and 9.6 (amalgam) years for restorations placed in 2004-05 and to 6.9 (resin composite) and 7.0 (amalgam) years for those placed in 2009-10. Compared to premolars, survival time was 8% less for first molars, but 2.5% more for second molars, and 6% more for third molars. Median survival times were less for regular attenders compared to non-regular attenders by 37% (4 years and 230 days), less for patients aged >35 than for younger patients by 27% (3y 138d), but 11% (1y 137d) more for males than females.

The difference in estimated median survival time between year of placement was found to be greater for resin composites for years 2001-2 to 2003-4 (compared to 1999-2000), but the survival time advantage for more recent cohorts (2008-9 and 2009-10) compared to 1999-2000 restorations, favoured amalgam restorations. The difference in median survival time between first molars (compared to premolars) was significantly less for resin composites than amalgam restorations, but the opposite effect was found for third molars (compared to premolars).

Using alternative model specifications did not affect the direction and magnitude of the estimated parameters. Given that the hazard functions were non-monotonic, rising to a maximum between the second and fourth years of observation and then decreasing over the remaining years, the AFT model provided the best fit as confirmed by the log-likelihood goodness-of-fit statistic. In particular, proportional hazards assumptions were violated for several variables such as region, regular versus non-regular attendance, and age groups.

Discussion

In this study, we estimated the determinants of median survival time using a cohort approach and an AFT model focusing attention on the association between survival time and restoration material. For restorations placed in 1999-2000, the median survival time was 11.2 years and 11.3 years for resin composite and amalgam restorations respectively. These survival times fell to 6.9 (resin composite) and 7.0 (amalgam) years for those placed in 2009-10. Using retrospective records of when the original restoration was placed and the type of restoration, Sunnegårdh-Grönberg *et al.*, (2009) estimated survival time based on restorations needing treatment over a two week period in 2006 among attending patients. Hence, the original restorations were placed at different times but were not necessarily representative of all restorations placed at those different times. The authors found that the median survival time of replaced restorations was 16 years for amalgam compared to 6 years for resin composite restorations. The 6 year survival for resin composite restorations is similar to the most recent 2009-10 resin composite predicted survival in the present study; however, the Sunnegårdh-Grönberg *et al.* study design was unable to consider changes in the median survival times over time. Based on the outcomes for one restoration per member among the members of an insurance plan, Bogacki *et al*. (2002) estimated restoration survival time over an 8 year period using proportional hazards. Restorations on other teeth were excluded to maintain independence in the restoration data. The data were censored for restorations that received larger restorations, crown or endodontic treatment, or received no further treatment at the end of the follow up or the discontinuation of insurance coverage. They estimated that on average resin composites had a 16.4% greater risk of failure, but were unable to consider changes in this relative risk over time. They also noted that a change in the dentist had a significant negative effect on the survival of both types of restorative material. Lucarotti *et al.* (2005) used a Kaplan-Meir proportional hazards approach adjusted for the probability of the individual re-attending to estimate survival time in a random sample of adult patients receiving restorations in the UK National Health Service between 1991 and 2001. At that time, the NHS did not cover resin composite restorations for load-bearing surfaces of posterior teeth, but the median survival time for a two surface amalgam restoration was 31% longer than the for a resin composite. Resin composite materials and their placement techniques have changed since this study whose design did not support analyzing change in survival over time, nor did it cover any treatment provided outside of the NHS.

Our estimated median survival time at reference category values of all variables did not differ significantly by the restorative material type. This may have been because of the more recent study period used, the comprehensive data base used (which removed any risk of patient selection), or the relaxation of the underlying assumptions of proportional hazards analytical methods. Despite improvements in materials and their placement techniques, after controlling for restoration material we found median survival time decreased across 'cohorts' of restorations. Notably, the survival time for restorations placed in 2009-10 was less than two thirds the duration (6.9 for resin composite and 7.0 years for amalgam) of restorations placed a decade earlier. This variation between cohorts was much greater than the (non-significant) variation between restorative materials (amalgam vs. resin composite).

It is important to recognize that survival time was measured by the number of years between year of restoration placement in a tooth surface and the year when further treatment of that same surface occurred. Any individual who died during the study period was removed from the data set prior to the data being provided by FNIHB. However, there is no reason to believe that any such deaths occurred disproportionately by type of restoration and hence this should not affect the comparison between restorations. We did not have information on the dates of original restoration or further treatment within the respective years. However, there is no reason why the distribution of interventions within a year should differ by restoration type, so this should not bias the comparisons. We were unable to determine the reason for further treatment from the data set provided by FNIHB. Hence, some restorations may have been replaced even though they were still acceptable and had not failed. Thus the significant reduction in survival across cohorts may reflect the changing practices of dentists or the wishes of the patient as opposed to mechanical failures or caries associated with either type of restorative material. Similarly we were unable to determine whether resin composite restorations were more likely to be placed in more conservative cavities than amalgams restorations.

The fee-for-service method of payment continued throughout the study period. Although fee levels changed over time and differed between provinces, the relative levels of amalgam and resin composite fees remained the same. However, the number of dentists providing services under the programme increased from 13,230 to 14,247 over the study period. This might indicate increasing competition among providers to maintain workloads and the replacement of serviceable amalgams with tooth coloured resin composites at the request of the patient.

The data set had several other constraints that gave rise to limitations. First, the aggregate data structure assumes that incidents of further treatment are independent. However, further treatments might be clustered among particular subjects or providers. Frailty models (Hougaard, 1995) could be used to account for any such effects, although this requires access to patient-level data. Second, survival time was measured as a step function, based on the year of further treatment. The use of quarterly or monthly data would be preferred given that under the AFT model, survival time can take any positive time within a continuum [0,T] where T is the end of the study. Moreover, the cohort nature of the data meant that time of follow up for treated teeth varied across the period of the study. Finally, the data were based on the numbers of teeth as opposed to the numbers of surfaces restored, although any further treatment of the treated surface was used to measure ‘failures’. It may be that the survival time for composite resins decreases as more larger multi-surface restorations are being placed.

The findings have implications for program costs. No survival time advantage was found for resin composite. This implies that amalgam (2009-10 mean cost per restoration $91.49) could have been substituted for resin composites (2009-10 mean cost per restoration $131.42) in placing restorations without loss of survival time. This would save an estimated $11.8 million per annum (297,369 resin composite restorations x $39.93 saving per restoration) which represents over 25% of the 2009-10 NIHB expenditure on restorations. Alternatively this $11.8 million could be seen as the cost of any cosmetic benefits, reducing risks associated with the use of amalgam, and the promotion of *minimally invasive dentistry.* Although the recently introduced bulk-fill resin composite materials may be placed more quickly than conventional resin composite materials, this has not been reflected in the fee levels paid to dentists and so would not change the relative costs to the program of the two approaches.

This potential cost saving from amalgam is conservative because it is based on the survival times of resin composite and amalgam being the same (as observed across the study period). However, given that more recent ‘cohorts’ appear to show a survival benefit in favour of amalgam, resin composite restorations placed in 2009-10 might be expected to receive further treatment much sooner than amalgam restorations placed in the same year. Should the observed trend of an increasing use of resin composite restorations continue, this would further add to the cost of the programme. For example, if all 2009-10 restorations had been resin composites, the cost of the programme would have increased by $2.8 million and the expected incidence of further treatment in future years would also be greater.

Conclusion

In terms of survival time, resin composite restorations perform no better than amalgams, but they cost considerably more. There is a recent trend for resin composites to fail earlier than amalgam restorations, but more long-term data are required to determine why this is occurring. If this trend continues and the survival time continues to fall, the costs of serving the Health Canada’s client population are likely to continue to rise considerably, even without increases in the incidence of caries.

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