Survival analysis of amalgam restorations in long-term recall patients

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The longevity of amalgam restorations in premolars and first and second molars in long-term recall patients has been calculated by means of survival analysis. The present retrospective longitudinal study includes information from 32 patients and their records over a time period of 17 years. The data were recorded by six dentists. The estimated time of 90% survival was 7 years. After 17 years the survival estimate decreased to 78%, indicating a favorable longevity of amalgam restorations in patients taken care of in an established recall system. □ *Dental materials; longevity; restorative dentistry*

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Restorative treatment accounts for the major part of the economic resources spent on dental health care (1). Several studies have dealt with the longevity of amalgam restorations (1–11), the reasons for failure, and the quality of restorations (1, 12–16), to elucidate factors of importance for increasing their longevity. In some studies the 'real' longevity of amalgam restoration is not discussed, only the longevity of amalgam restorations that are *replaced* (1). To estimate longevity, one must take into account all amalgam restorations present (2–10) and not only those in need of replacement.

Studies of the longevity of amalgam restorations have been done on patients attending single- or limited-operator practices (2, 4, 5), patients attending many different practitioners (6), dental school patients (11), and military personnel (3).

The aim of the present longitudinal, retrospective study was to estimate the longevity of amalgam restorations in long-term recall patients, taking into account all amalgam restorations present, by using survival analysis.

Materials and methods

Four dentists working in private practices and four dentists working both as teachers at the Department of Operative Dentistry, Dental Faculty, University of Oslo, and in private practice were invited to take part in the present study. They were asked to register from the patient records the date of all kinds of filling therapy in 10 patients who had visited the dentist once a year for at least 10 years.

The dental status and information from the patient records were registered for the first patients visiting the dentist and fulfilling the criteria. One dentist did not want to take part in the study and the other seven dentists obtained information for four to eight patients. Information from one dentist was excluded owing to inadequate recordings. The final sample thus included information from 32 patients recorded by 6 dentists with information of filling therapy during the past 17 years for all patients but somewhat longer time for 12 of the patients. There was an equal sex distribution among the patients, and the range and mean of the age were 31–77 years and 55 years, respectively, for the women and 39–72 and 53 for the men.

Registration method

All amalgam restorations on facial, oral, mesial, and distal surfaces on all premolars and first and second molars were included. The longevity of the restorations present at

Table 1. Example of registration: tooth 16 was checked every year from 1970 to the final registration in 1987

Year of treatment				
1970	1975	1981	1985	1987
MOD	ODB	OD	MO	MODBL

Survival rates:
1) 5 years, OD (1970–75)
2) 6 years, OD (1975–81)
3) 15 years, MO (1970–85)
4) 6 years, OD (1981–87) censored (present at final registration)
5) 2 years, MO (1985–87) censored (present at final registration)
6) 12 years, B (1975–87) censored (present at final registration)
7) 17 years, L (1970–87) censored (present at final registration and before first registration)

the final registration (the last dental visit) or when the restorations were inserted before the first registration (the first dental visit) are included in the study and called 'censored data'.

The criteria for failure were as follows: If only one part of a double class-II restoration was removed, the survival rate was recorded for the replaced part of the restoration. If these single class-II restorations were replaced by one double class-II restoration, two survival rates were recorded: one for each of the single class-II restorations. If all surfaces of a double class-II restoration were replaced by a new double class-II, one survival rate was recorded. A restoration was considered as failed if the tooth was extracted.

An example of registration of tooth 16 in one of the patients with corresponding survival rates is demonstrated in Table 1. In 1970 a MOD restoration was inserted. In 1975 the OD part was replaced and extended buccally. A survival rate of 5 years for the OD part of the MOD restoration was recorded. In 1981 the OD part was replaced with a new OD restoration. A survival rate of 6 years was then recorded. In 1985 the MO part of the original MOD restoration, inserted in 1970, was replaced, which gave a survival rate of 15 years. In 1987 (final registration) all restorations present in the tooth were recorded (MODBL). The survival rates of 6 years (OD), 2 years (MO), 12 years (B), and 17 years (L) were then recorded (see Table 1, subsections 4, 5, 6, and 7).

Statistical methods

In the present study the survival analysis, the actuarial method (17) was used for statistical evaluation of the results. The actuarial estimator is similar to the Kaplan–Meier estimator but is more useful when the time axis is rough.

$$\hat{S}(t) = t^{\pi}_{i \leq t} \left(1 - \frac{m_i}{Y(t_i) - 1/2c_i}\right),$$

where m_i = the number of fillings replaced until time t_i, $Y(t_i)$ = the number of fillings at risk until the time t_i, c_i = the number of censored fillings until the time t_i, and $\hat{S}(t)$ = the cumulative survival function (actuarial estimator).

The intensity of replacements was estimated with Nelson's estimator for the integrated intensity (cumulative):

$$\hat{\Lambda}(t) = t^{\Sigma}_{i \leq t} \frac{m_i}{Y(t_i) - 1/2c_i}$$

The 95% confidence interval for the actuarial estimator was estimated in accordance with the formula:

$$\hat{S}(t) - 1.96\,\mathrm{SE}\,(\hat{S}(t)) \leq S(t) \leq \hat{S}(t) + 1.96\,\mathrm{SE}(\hat{S}(t))$$

$$\mathrm{SE}\,(\hat{S}(t)) = \hat{S}(t) \sqrt{\frac{1 - \hat{S}(t)}{Y(t_i) - 1/2c_i}}$$

Results

A total of 782 amalgam restoration were registered in 32 patients who met for dental examination/treatment every year for at least 17 years. Of these fillings 145 failed (19%), and 527 were censored during 17 years. After 17 years no restorations failed, and 110 were censored. The median survival time for the *failed* restorations was 5 years.

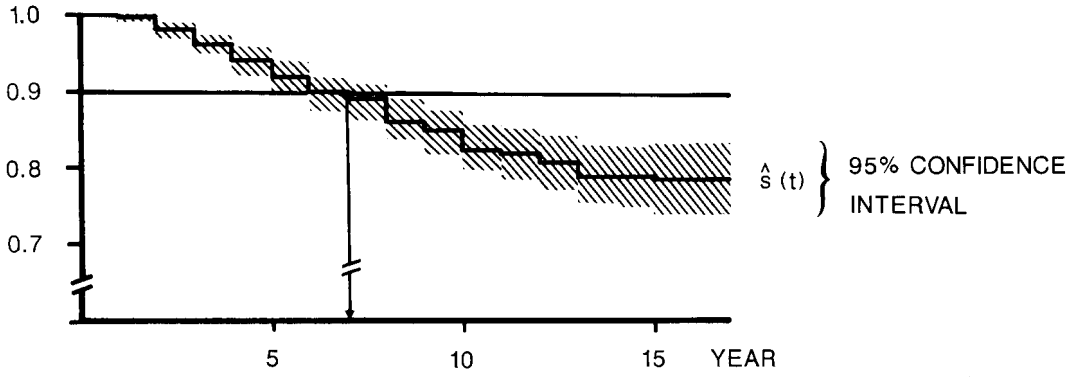

Fig. 1. Actuarial estimate, cumulative survival curve ($\hat{S}(t)$). The shaded area indicates 95% confidence intervals. The estimated time when 90% of the restorations are not replaced (indicated by a horizontal line) was 7 years. The 95% confidence interval for the time of 90% survival was estimated to be $0.876 \leq S(t) \leq 0.922$—that is, 7 ± 1 years.

The calculated survival time by the actuarial method (17), with all 782 restorations included, is presented in Fig. 1. The figure illustrates the probability of an amalgam restoration not being replaced at time (t), assuming that the filling was present the preceding time interval.

After 17 years the probability of an amalgam restoration not being replaced was as high as 78%. The estimated time of 90% survival (the estimated time when the probability of the restorations not being replaced is 90%) is indicated with a horizontal line on Fig. 1, indicating a survival time of 7 years. The 95% confidence interval for the estimated time of 90% survival was ±1 year.

The Nelson plot (Fig. 2) shows the integrated intensity, indicating a constant intensity the first 13 years of restorations being removed. After 13 years the intensity declined dramatically.

Discussion

The patients selected to take part in the present study were meant to represent the population of long-term, urban recall patients. The sample of dentists may, however, have affected the results because four of the dentists were working at a dental school in addition to their private practices.

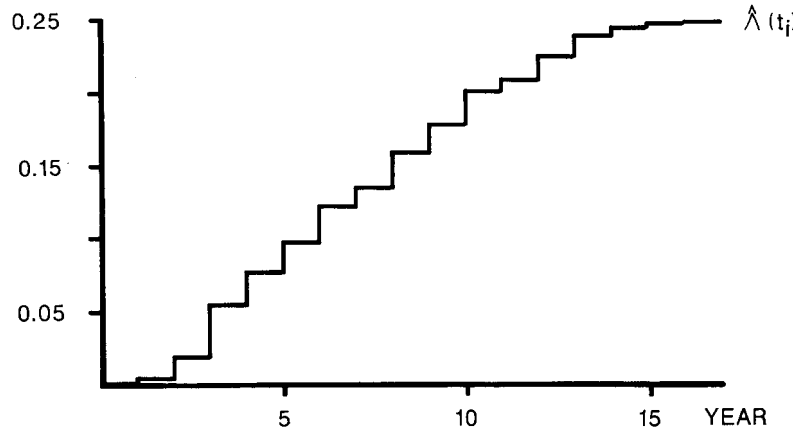

Fig. 2. Nelson's estimate of the integrated intensity (cumulative) ($\hat{\Lambda}(t_i)$). The integrated intensity indicates a declining intensity after 13 years.

The results from this study probably indicated the survival of good-quality amalgam restorations in the most motivated patients.

In most studies on longevity of amalgam restorations the criteria for failure of a restoration were fulfilled when *any of the surfaces* of the restoration were replaced or when the tooth was extracted (2, 5, 7, 8). Such a criterion may underestimate the survival time. If only one part of a double class-II restoration was replaced, we have separated the restoration in two parts with regard to survival time. It was then possible to follow the partial filling independent of the rest of the filling (Table 1). This criterion may have contributed to the higher survival time in the present study.

Previous studies have demonstrated that single-surface restorations last longer than multisurface restorations (8). The fact that we have included facial and oral restorations may also have contributed to the present high survival time. Any comparison between studies must be made with great caution owing to the two factors discussed above and owing to differences in patient categories and sample size, the length of the follow-up period, and different levels of censored data (18). A possible variation in the criteria for replacement among the dentists may also be considered. The study designs of the other studies of regularly attending patients are quite different from that of the present study. However, the median survival time in a study from England (7) was 7 years for MO, DO, and MOD amalgam restoration. The estimated time of 90% survival was as low as 2 years.

A decrease in dental caries among children (21) and adults (22) has been registered during the past 15 years. This may increase the duration of amalgam restorations in later studies, since almost 60% of amalgam restorations are reported to have failed because of recurrent caries (13, 14). Some recent investigations report a lower failure rate of amalgam restorations due to recurrent caries (19, 20). This may confirm the effect of the caries reduction. However, the present study demonstrated a favorable survival time: a probability that 78% of the amalgam restorations would not be replaced after 17 years. The selected group of patients in this study were probably most favorable with regard to longevity of amalgam restorations with a very low mean number of replaced fillings during 17 years (4.5).

When estimating the cost of reparative dentistry, survival analyses are necessary and should be included in public dental health systems for the purpose of evaluating filling therapy.

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