Journal of Dentistry 62 (2017) 13–17

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Longevity of 2- and 3-surface restorations in posterior teeth of 25- to 30-year-olds attending Public Dental Service—A 13-year observation

Ulla Palotie[a,*], Anna K. Eronen[b], Kimmo Vehkalahti[c], Miira M. Vehkalahti[d]

[a] City of Helsinki, Department of Social Services and Health Care, Metropolitan Area Department of Oral Special Care, P.O. BOX 6670, FI-00099 Helsinki, Finland
[b] Social Statistics, Department of Social Research, Faculty of Social Sciences, University of Helsinki, P.O. BOX 18, FI-00014 Helsinki, Finland
[c] Centre for Research Methods, Faculty of Social Sciences, University of Helsinki, P.O. BOX 18, FI-00014 Helsinki, Finland
[d] Department of Oral and Maxillofacial Diseases, Faculty of Medicine, University of Helsinki, P.O. BOX 41, FI-00014 Helsinki, Finland

ARTICLE INFO

Keywords:
Amalgam
Composite
Direct restoration
Longevity
Survival

ABSTRACT

Objectives: The aim of this patient document-based retrospective study among 25- to 30-year-old Finnish adults was to evaluate longevity of 2- and 3-surface posterior restorations according to type of tooth, size of restoration, and restorative material used.

Methods: Data were extracted from electronic patient files of the Helsinki City Public Dental Service (PDS), Finland. A total of 5542 2- and 3-surface posterior composite and amalgam restorations were followed indirectly from 2002 to 2015. Longevity of restorations was illustrated using Kaplan-Meier curves. Annual failure rates (AFRs) of the restorations were calculated separately by type of tooth, size, and material. Differences in longevity were statistically tested with log-rank tests.

Results: Composite restorations formed the majority (93%). The longest median survival times and the smallest failure rates were found for teeth in the upper jaw, for premolars, and for 2-surface restorations. Median survival time of all restorations was 9.9 years (95% CI 9.6, 10.2) and re-intervention of restorations occurred less often in the maxilla (AFR 4.0%) than in the mandible (AFR 4.7%). Median survival time of composite restorations was greater for 2-surface than for 3-surface restorations: in premolars 12.3 vs. 9.6 years ($p < 0.001$) and in molars, 9.2 vs. 6.3 years ($p < 0.001$); for molar amalgams the difference (8.0 vs. 6.3 years) was non-significant ($p = 0.38$). Median survival time of 2- and 3-surface restorations in premolars exceeded that in molars (12.0 vs. 8.7 years; $p < 0.001$).

Conclusions: Longevity of posterior composite multisurface restoration is comparable to amalgam longevity.

Clinical significance: Regarding material choices for posterior multisurface restorations, composite and amalgam perform quite similarly in molars, 3-surface restoration being challenge for both materials.

1. Introduction

The estimates of longevity of larger dental restorations vary widely depending on the study in question [1–8]. The characteristics most often associated with longevity are restoration material and extent, type of tooth and patient age. The settings range from one-dentist practices or clinic or dental schools to large Practice Based Research Network (PBRN) or insurance-based records, and the length of follow-up rarely exceeds 5 years [1]. The changing pattern of restorative materials is evident; in the Nordic countries, the use of amalgam has dramatically decreased, and in Norway is no longer permitted [9]. Globally, composite resins are in continuous development, with new filler sizes, combinations, and compounds being introduced regularly [10].

Regarding Class I and II direct restorations in posterior teeth, a review and *meta*-analysis of eight studies report a mean annual failure rate (AFR) of 1.7% for amalgam and 3.1% for composite [1], but patient ages were not available for all of the studies. A large 10-year PBRN follow-up from the Netherlands reports as a mean AFR of 5.2% for amalgam and 4.4% for composite in posterior teeth [2], but does not give AFRs by size of restoration or material separately for premolars and molars. A 12-year follow-up of a private practitioner reports an AFR of 2.41% for amalgam and 1.68% for composite [3]. A cohort study from the USA based on insurance data of over 300 000 multisurface restorations in posterior teeth reports survival as 5-year rates: 94% for amalgam and 93% for composites [4], suggesting corresponding AFR rates of 1.2% and 1.4%. Using a cross-sectional design with a questionnaire for dentists, studies from general dental practice have reported median age of 6–16 years for failed Class II amalgam

* Corresponding author.
E-mail address: ulla.palotie@fimnet.fi (U. Palotie).

http://dx.doi.org/10.1016/j.jdent.2017.05.012
Received 18 January 2017; Received in revised form 15 May 2017; Accepted 17 May 2017

restorations and 4–6 years for failed Class II composites [5–7]. A similar questionnaire study among Finnish private dentists regarding their adult patients reports a mean age of 15.5 years for failed amalgam restorations and 7 years for failed composites [8], but the longevity data were available for only half of the failed restorations, and types of tooth and restoration sizes were not specified.

Tooth position in dental arch has been suggested to have an influence on restoration longevity. Re-treatment of amalgam and tooth-colored restorations in adults at a one-year follow-up was more likely in molars (7%) than in premolars (5%) in an American PBRN cohort study [11]. Also in the Netherlands the mean AFR of restorations in molars was 5.2% compared to 4.0% in premolars [2]. Some other reports have found no association between longevity of posterior restorations and type of tooth or jaw [12,13].

Based on a vast administrative database of the NHS in England and Wales in 1991–2001, comprising data on 80 000 adult patients with over 500 000 restorations, 58% of 1-surface and 49% of 2-surface posterior amalgam restorations and 43% of 3-surface (MOD) amalgams remained without intervention over a 10-year follow-up [14]. Another large study from the Washington Dental Service, with over 279 000 posterior restorations in adults followed retrospectively from 1993 to 2000 until censored or failed, reports longevity of 4.4 years for 2-surface and 4.3 years for 3-surface amalgam restorations, and for composites, 2.6 years for 2-surface and 2.1 years for 3- to 4-surface restorations [15]. A recent study from Germany analyzed health insurance data of almost 15 million restorations and reports four-year-success rates for posterior teeth being 74% for 2-surface and 68% for 3-surface restorations [16], yet the mean and median observation times remained near two years (650-700 days).

This study aimed at investigating longevity of 2- and 3-surface restorations in posterior teeth among 25- to 30-year-olds across 13 years at the Helsinki City Public Dental Service. Our working hypotheses were that longevity of restorations in premolars exceeds that in molars, longevity of 2-surface restorations exceeds that of 3-surface restorations, and no difference exists in longevity according to the restorative material of amalgam or composite.

2. Materials and methods

2.1. Background

In Finland, Public Dental Services (PDS) are available for all citizens, but more than half of adults use private services. Adults visiting public dentists pay highly subsidized fees. Both in the public and private sector, the recording of treatments is based on the official codes given by the National Institute for Health and Welfare, an agency under the Finnish Ministry of Social Affairs and Health. Filling out the patient documents is strictly regulated. In PDS, all patient documentation is recorded and stored in electronic format. The patients are identified using their personal identification number.

2.2. Ethics considerations

Our data are based on patient documents from the database of the Helsinki City PDS, the original recordings having been made at each appointment. Before providing us with the data, a PDS officer removed the identification numbers, replacing them with consecutive numbers to ensure confidentiality. The City of Helsinki Department of Social Services and Healthcare approved the study protocol.

2.3. Study design

The baseline cases were restorations of Class II or larger placed in 2002 in posterior teeth of patients aged 25–30 years visiting the Helsinki City PDS. We followed the fate of the restorations indirectly via the database as long as the patient in question continued visiting the Helsinki City PDS, but no longer than the end of 2015.

2.4. Data collection

For each restoration, we collected information about the tooth, numbered according to the ISO 3950 system, and later categorized as premolar or molar, and as upper or lower tooth. Based on the size of the restoration, we coded three types: Class II mesial (MO), Class II distal (DO), and larger (MOD). MO and DO were 2-surface restorations and MOD 3-surface ones. The restoration materials included composite, amalgam, and glass-ionomer. A further inclusion criterion was that after the placement of the restoration the patient had visited the Helsinki City PDS at least once. We recorded the dates of the placement and the re-intervention of the restoration and the patient's most recent dental visit. The patient's background data included gender, age in years, and dental indices (DMFT and DT) in 2002.

In total, the database included 6528 restorations, but for 926 restorations the patients made no further visits to the Helsinki City PDS. In addition, we considered the number of glass-ionomer restorations ($n = 60$) too small for estimating their longevity. After excluding these incompatible cases, a total of 5542 restorations remained for analyses.

Longevity of a restoration was the interval from the placement to the re-intervention if any; in case no such incident occurred, the follow-up time ended at the last visit made by the patient before the end of 2015. These intervals indicated the longevity for survivals. We calculated the intervals to an accuracy of one day.

2.5. Statistical methods

The data were prepared for analyses using Survo MM [17,18]. Descriptive statistics included Chi-squared tests for comparison of frequencies and *t*-test for comparison of mean values. Further statistical analyses were performed using R version 3.2.3 [19] and its survival package [20]. The survival curves were created using Kaplan-Meier analysis [21], and the differences in longevity according to type of tooth and size of restoration were statistically tested with log-rank tests. The R package plotrix [22] was used to refine the graphs. Pointwise confidence intervals for the survival functions were computed based on the cumulative hazard of the logarithm of the survival function [21]. The mean AFR for the restorations were calculated using the formula $(1-y)^z = 1-x$, where y stands for the mean AFR and x is the total failure rate at z years [23]. Differences in longevity were statistically tested with log-rank tests.

3. Results

At baseline, we enrolled in the follow-up a total of 5542 restorations conducted on 3051 patients in 2002. The mean age of patients was 27.6 (SD = 1.7) years, and 63% were women. The mean DMFT was 13.2 (SD = 5.5), slightly higher for men than for women (13.5 vs. 13.0; $p = 0.037$). The mean DT was 3.3 (SD = 3.1), clearly higher for men than for women (4.2 vs. 2.8; $p < 0.001$).

Sixty-one percent of the restorations enrolled were in female patients and 39% in male patients. Table 1 provides the characteristics of the restorations enrolled in the follow-up. Molar teeth predominated over premolars, and as the material, composite predominated over amalgam. Gender differences were present with regard to the type and material of the restoration.

For half of the restorations, the follow-up was longer than 6 years and for one-fourth longer than 10 years. Figs. 1–4 illustrate survivals and failures of the restorations according to selected characteristics. Median survival times were longer for any restorations in upper teeth or in premolars or for any 2-surface or any composite restorations than for those in lower teeth or molars or for 3-surface or amalgam restorations. We found no differences in survival times according to gender ($p = 0.17$, curves not shown).

Table 1
Characteristics of the restorations (n = 5542) enrolled in the follow-up at baseline.

Baseline characteristics	No. of teeth restored at baseline			p-value
	Total N = 5542	In men N = 2154	In women N = 3388	
Type of tooth (%)				0.051
Premolar	40	42	39	
Molar	60	58	61	
Jaw and type of tooth (%)				0.199
Upper premolar	29	31	28	
Lower premolar	11	11	11	
Upper molar	27	26	28	
Lower molar	33	32	33	
Teeth by jaw (%)				0.398
Upper jaw	57	57	56	
Lower jaw	43	43	44	
Type of restoration (%)				0.019
Mesio-occlusal (MO)	39	37	41	
Disto-occlusal (DO)	46	47	45	
Larger (MOD)	15	16	14	
Material of restoration (%)				< 0.001
Amalgam	7	9	6	
Composite	93	91	94	

Statistical evaluation for gender differences: Chi-squared tests.

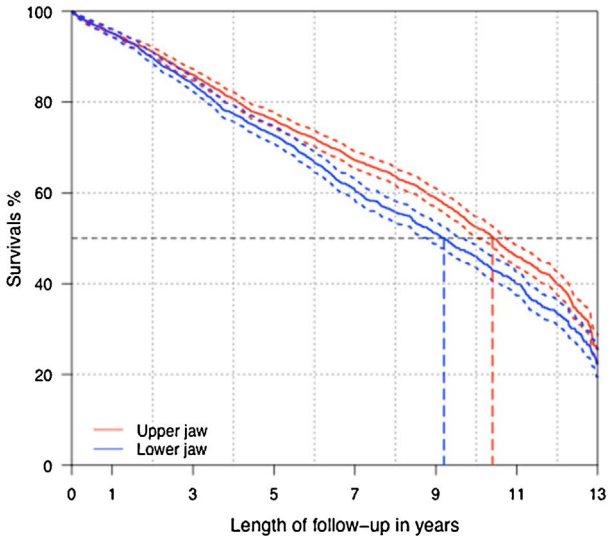

Fig. 1. Survival (%) of restorations placed in posterior teeth (n = 5542) of 25- to 30-year-olds illustrated as medians and Kaplan-Meier curves with 95% confidence intervals by jaw.

Table 2 presents details of survivals and failures of the restorations. Median survival time was 1.2 years longer for upper than lower teeth. By type of tooth, the difference was 3.3 years for all restorations and within composite restorations, 3.2 years in favor of premolars. Both for premolars and molars, median survival time of composite restorations was almost 3 years longer for 2-surface restorations than for 3-surface restorations. All of these differences were significant ($p < 0.001$). With regard to molar teeth, median survival times by size of restoration were fairly similar regardless of the material. For amalgam restorations in molars, we found no differences ($p = 0.38$) in median survival times for 2- and 3-surface restorations because of the wide 95% confidence intervals for both medians; the corresponding difference for molar composites was obvious in favor of 2-surface restorations ($p < 0.001$). The overall AFR across 13 years was 4.3%, being smallest for 2-surface composite restorations in premolars and greatest for 3-surface composite restorations in molars (Table 2).

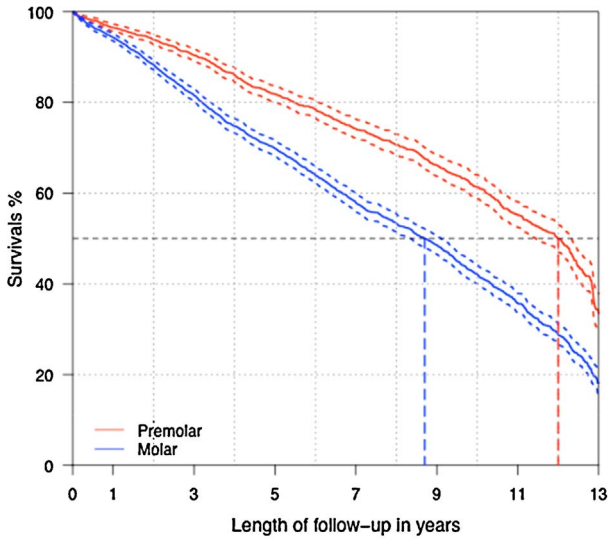

Fig. 2. Survival (%) of restorations placed in posterior teeth (n = 5542) of 25- to 30-year-olds illustrated as medians and Kaplan-Meier curves with 95% confidence intervals by type of tooth.

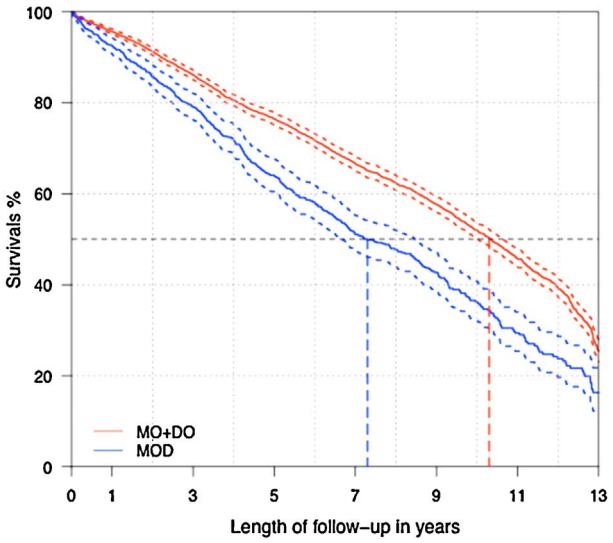

Fig. 3. Survival (%) of restorations placed in posterior teeth (n = 5542) of 25- to 30-year-olds illustrated as medians and Kaplan-Meier curves with 95% confidence intervals by size of restoration.

4. Discussion

We evaluated longevity of 2- and 3-surface posterior restorations among 25- to 30-year-olds attending the Helsinki City PDS. Our results give a broad picture of longevity and AFR of restorations, allowing comparisons also with studies restricted to certain types of restorations. As we expected, longevity of restorations was greater in premolars than in molars and for 2-surface restorations than for 3-surface restorations. Regarding longevity by material, composite and amalgam restorations in molars had fairly similar longevity, as we had hypothesized.

In detail, we found that restorations had fewer failures in premolars (AFR 3.1%) than in molars (AFR 5.2%). This finding is consistent with the American and the Dutch PBRN studies [2,11]. Some other investigations have, however, found no variation by type of tooth despite large numbers of observations, analyzed using multilevel Cox regression and univariate modeling [12,13]. Regarding longevity by size of restoration, we found that 2-surface restorations survived longer than 3-surface restorations, which is supported by previous studies

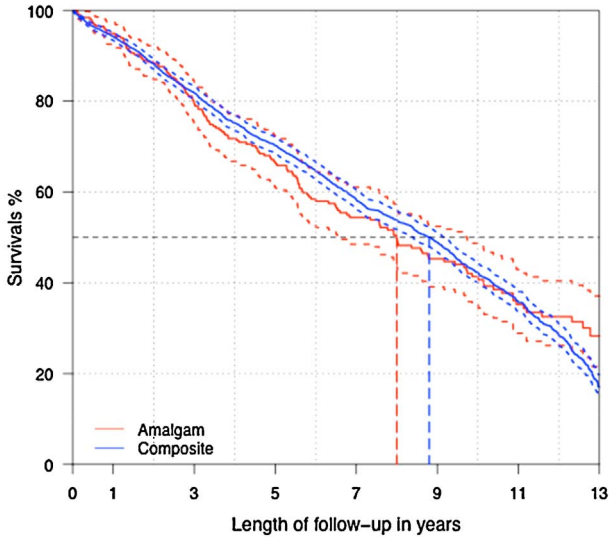

Fig. 4. Survival (%) of restorations placed in molar teeth (n = 3326) of 25- to 30-year-olds illustrated as medians and Kaplan-Meier curves with 95% confidence intervals by material.

Table 2
Median survival time and mean annual failure rate (AFR%) for restorations in posterior teeth of 25- to 30-year-olds across a 13-year observation. MO = mesio-occlusal; DO = disto-occlusal; MOD = 3-surface restoration.

Characteristics of restorations	Baseline n	Survival time (years) Median	95%CI	Mean AFR% in 13 years
All restorations	5542	9.9	9.6, 10.2	4.3
Upper jaw	3141	10.4	10.0, 10.7	4.0
Lower jaw	2401	9.2	8.8, 9.6	4.7
Premolars	2216	12.0	11.4, 12.3	3.1
Molars	3326	8.7	8.4, 9.1	5.2
Composite restorations				
All teeth	5169	10.0	9.7, 10.3	4.2
Premolars	2180	12.0	11.5, 12.3	3.1
Molars	2989	8.8	8.4, 9.2	5.2
Premolar composites				
MO + DO	1816	12.3	12.0, 12.5	2.9
MOD	364	9.6	8.6, 10.6	4.3
Molar composites				
MO + DO	2594	9.2	8.8, 9.5	5.0
MOD	395	6.3	5.3, 7.0	7.1
Molar amalgams				
MO + DO	267	8.0	6.8, 9.8	4.7
MOD	70	6.3	4.7, 10.0	5.2

Statistical evaluation: medians based on Kaplan-Meier analysis; AFR% based on the formula $(1-y)^z = 1-x$, where y stands for the mean AFR and x is the total failure rate at z years.

[2,14,15]. In the earlier studies, however, findings for premolars and molars by size of restoration have rarely been presented separately. Generally, longevity of restorations in anterior teeth, premolars, and molars as well as longevity of 1-, 2-, and 3-surface restorations in posterior teeth are mostly reported together [1,5,7,8], even though restorations covering multiple surfaces have a shorter lifespan and are more likely to need re-intervention than single-surface restorations [14,24,25].

In our study, the median longevity of all posterior 2- and 3-surface restorations was 9.9 years, which is considered satisfactory (mean AFR 4.3% at 13 years) compared with results from the PBRN investigation in the Netherlands among 26- to 45-year-olds (mean AFR 4.5%, including both anterior and posterior restorations) [2]. In line, an administrative study from England and Wales involving half a million direct restorations and all types of teeth reported a 50% survival at 10 years [26]. Notably, their study contained no composite restorations in molars.

A new and unexpected finding in our study was that restoration longevity in the upper jaw clearly exceeded that in the lower jaw. As far as we know, such a marked difference in posterior restoration longevity between upper and lower jaws has not been reported earlier. At least from a cariological viewpoint, posterior teeth in both jaws are equal [27]; our findings thus warrant further research. Lucarotti et al. [14] have reported a small but significant difference in favor of restorations in the lower jaw, but as discussed earlier, they combined all types of teeth, including anterior teeth, and their data included no composites in molars.

Our data were extracted from the electronic documents of the oral healthcare register of the Helsinki City PDS. In Finland, the public authorities maintain meticulous record-keeping practices, including the patient's diagnosis and treatments [28]. Patient documentation at the Helsinki City PDS has been in electronic form since 2001 and the codes for treatments are unified, adding reliability to our results. Our data allowed observation by type of tooth, size of restoration, and filling material used. Since children and adolescents can visit the Helsinki City PDS free of charge, many of them continue regular dental visits in subsidized dental care in adulthood. In Helsinki PDS, adults comprised 55% of patients in 2003 [29]. However, adults are not enrolled in the PDS recall system and if patients visit a private practitioner, no data about these treatments are available. Nevertheless, our follow-up lasted 13 years, which is significantly longer than in most longevity studies. Furthermore, dentists at the Helsinki City PDS made clinical treatment decisions similar to those of the PBRN and were unaware of the forthcoming evaluation. The data of over 5500 posterior restorations for the selected age groups cover all 2- and 3-surface restorations placed in posterior teeth in 2002 and thus strengthen the validity of our findings. Our method of following restorations indirectly reflects well everyday dental practice.

A patient's gender seems to have no impact on the longevity of restorations [26], but the patient's age certainly plays a role, reflecting at least the developmental phase of the dentition and the size of the restoration. Some reports have found the longevity of restorations to be shorter the older the patient [2,12,13]. To control for the age confounder in our study, a narrow age group of 25- to 30-year-olds was chosen to represent a homogeneous group of patients, in contrast to adolescents who might be more prone to caries and restorative therapy or older adults who often have previous restorative treatment needing maintenance [8,30].

Restorative treatment, particularly with a direct technique, is one of the most common treatments in dental care for adults in Finland; 60% of patients report having restorative treatment at their last series of dental visits [31]. In Western countries, people's lifespan is increasing which, together with increasing number of teeth retained, may result in a greater restorative "burden" in the near future. Even a slight increase in the longevity of restorations could lead to considerable savings in treatment costs [32].

In the Nordic countries, the choice of material has shifted from the relatively inexpensive amalgam to more costly composite, increasing dental expenditures [33]. Composite resins are suitable for direct minimal intervention approaches in posterior teeth [34], but both composite and amalgam in multisurface posterior restorations seem to have limitations [1]. Use of amalgam is already restricted in some countries for environmental reasons [35], and a statement from the Minamata convention will probably decrease amalgam usage [36]. In Finland, the phasing down of amalgam has been continuing for some time already [8]. In our study, amalgam restorations formed a clear minority, and therefore, the results of amalgam longevity should be interpreted with caution.

Unfortunately, we had no information regarding the dentist's background, e.g. continuing education, this being one of the limitations

of our study. Previous research has shown that dentist-related factors affect restoration longevity and treatment practices [7,10,13]. Laske et al. [2] have even discussed different dentist profiles: proactive and reactive types and their influence on decision-making. In our study, dentist-related factors could not be analyzed due to privacy protection of employee personal information at the Helsinki City PDS. According to human resource management at the Helsinki City PDS, however, all dentists have mandatory continuing education during working hours twice a year and a five-day voluntary updating education every year.

Investigation of longevity of 2- and 3-surface posterior restorations especially in adults has proved to be challenging. Scientific articles reporting findings on longevity are based on widely variable study settings and different ways of presenting results, hindering direct comparisons [37]. For future purposes, dentist-related factors underlying re-intervention of multisurface restorations should be investigated. Knowing better the factors behind failures could have a serious impact on longevity of restorations. A current care guideline for posterior restorations could be beneficial in treatment planning.

5. Conclusion

Within the limitations of this research, we conclude that satisfactory longevity of 2- and 3-surface posterior restorations is achievable in everyday dental practice. Longevity of posterior composite multisurface restoration is comparable to amalgam longevity.

Acknowledgements

The authors acknowledge the Helsinki City PDS for handing their data at disposal. Tuomo Maisala is thanked for picking out the cases and Marjut Grainger for invaluable help with data cleaning. This study was financially supported by a personal grant to Ulla Palotie from the Finnish Dental Society Apollonia.

References

[1] V. Moraschini, C.K. Fai, R.M. Alto, G.O. Dos Santos, Amalgam and resin composite longevity of posterior restorations: a systematic review and meta-analysis, J. Dent. 43 (9) (2015) 1043–1050.
[2] M. Laske, N.J. Opdam, E.M. Bronkhorst, J.C. Braspenning, M.C. Huysmans, Longevity of direct restorations in Dutch dental practices. Descriptive study out of a practice based research network, J. Dent. 46 (2016) 12–17.
[3] N.J. Opdam, E.M. Bronkhorst, B.A. Loomans, M.C. Huysmans, 12-year survival of composite vs. amalgam restorations, J. Dent. Res. 89 (10) (2010) 1063–1067.
[4] R.E. Bogacki, R.J. Hunt, M. del Aguila, W.R. Smith, Survival analysis of posterior restorations using an insurance claims database, Oper. Dent. 27 (5) (2002) 488–492.
[5] I.A. Mjör, The reasons for replacement and the age of failed restorations in general dental practice, Acta Odontol. Scand. 55 (1) (1997) 58–63.
[6] F.J. Burke, S.W. Cheung, I.A. Mjör, N.H. Wilson, Restoration longevity and analysis of reasons for the placement and replacement of restorations provided by vocational dental practitioners and their trainers in the United Kingdom, Quintessence Int. 30 (4) (1999) 234–242.
[7] K. Sunnegårdh-Grönberg, J.W. van Dijken, U. Funegård, A. Lindberg, M. Nilsson, Selection of dental materials and longevity of replaced restorations in Public Dental Health clinics in northern Sweden, J. Dent. 37 (9) (2009) 673–678.
[8] H. Forss, E. Widström, Reasons for restorative therapy and the longevity of restorations in adults, Acta Odontol. Scand. 62 (2) (2004) 82–86.
[9] S.E. Kopperud, F. Staxrud, I. Espelid, A. Bjørg Tveit, The post-amalgam era: norwegian dentists' experiences with composite resins and repair of defective amalgam restorations, Int. J. Environ. Res. Public Health 13 (2016) 441, http://dx.doi.org/10.3390/ijerph13040441.
[10] F.F. Demarco, M.B. Correa, M.S. Cenci, R.R. Moraes, N.J. Opdam, Longevity of posterior composite restorations: not only a matter of materials, Dent. Mater. 28 (1) (2012) 87–101, http://dx.doi.org/10.1016/j.dental.2011.09.003.
[11] V.V. Gordan, J.L. Riley, D.B. Rindal, V. Qvist, J.L. Fellows, D.A. Dilbone, et al., Repair or replacement of restorations: a prospective cohort study by dentists in the National Dental Practice-Based Research Network, J. Am. Dent Assoc. 146 (12) (2015) 895–903.
[12] S.E. Kopperud, A.B. Tveit, T. Gaarden, L. Sandvik, I. Espelid, Longevity of posterior dental restorations and reasons for failure, Eur. J. Oral Sci. 120 (6) (2012) 539–548.
[13] M.S. McCracken, V.V. Gordan, M.S. Litaker, E. Funkhouser, J.L. Fellows, D.G. Shamp, et al., A 24-month evaluation of amalgam and resin-based composite restorations: findings from the national dental practice-based research network, J. Am. Dent. Assoc. 144 (6) (2013) 583–593.
[14] P.S. Lucarotti, R.L. Holder, F.J. Burke, Outcome of direct restorations placed within the general dental services in England and Wales (Part 1): variation by type of restoration and re-intervention, J. Dent. 33 (10) (2005) 805–815.
[15] M.N. Coppola, Y.A. Ozcan, R. Bogacki, Evaluation of performance of dental providers on posterior restorations: does experience matter? A data envelopment analysis (DEA) approach, J. Med. Syst. 27 (5) (2003) 445–456.
[16] M. Raedel, A. Hartmann, H.-W. Priess, S. Bohm, S. Samietz, I. Konstantinidis, M.H. Walter, Re-interventions after restoring teeth—mining an insurance database, J. Dent. 57 (2017) 14–19.
[17] S. Mustonen, Survo – an Integrated Environment for Statistical Computing and Related Areas, Survo Systems, Helsinki, 1992 www.survo.fi/books/1992/Survo_Book_1992_with_comments.pdf (Accessed 14 January 2017).
[18] S. Mustonen, Survo MM. –an Environment for Creative Processing of Text and Numerical Data, (2017) www.survo.fi/english , 2001 (Accessed 14 January 2017).
[19] R Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria, 2016 https://www.R-project.org (Accessed 14 January 2017).
[20] T. Therneau, A Package for Survival Analysis in S. Version. 2.38, (2017) http://CRAN.R-project.org/package=survival , 2015 (Accessed 14 January 2017).
[21] J.P. Klein, M.L. Moeschberger, Survival Analysis Techniques for Censored and Truncated Data, Second edition, Springer, New York, 2003 pp. 92–94, 105.
[22] J. Lemon, Plotrix: a package in the red light district of R, R-News 6 (4) (2006) 8–12.
[23] N.J. Opdam, B.A. Loomans, F.J. Roeters, E.M. Bronkhorst, Five-year clinical performance of posterior resin composite restorations placed by dental students, J. Dent. 32 (5) (2004) 379–383.
[24] M. Laccabue, R.L. Ahlf, J.W. Simecek, Frequency of restoration replacement in posterior teeth for U.S. Navy and Marine Corps personnel, Oper. Dent. 39 (1) (2014) 43–49.
[25] N.J. Opdam, F.H. van de Sande, E. Bronkhorst, M.S. Cenci, P. Bottenberg, U. Pallesen, et al., Longevity of posterior composite restorations: a systematic review and meta-analysis, J. Dent. Res. 93 (10) (2014) 943–949.
[26] F.J. Burke, P.S. Lucarotti, How long do direct restorations placed within the general dental services in England and Wales survive? Br. Dent. J. 206 (1) (2008) E2, http://dx.doi.org/10.1038/sj.bdj.2008.1042.
[27] P.A. Batchelor, A. Sheiham, Grouping of tooth surfaces by susceptibility to caries: a study in 5–16 year-old children, BMC Oral Health 4 (2) (2004), http://dx.doi.org/10.1186/1472-6831-4-2.
[28] Ministry of Social Affairs and Health, Government Decree on the Drawing up of Patient Documents and on Keeping Them and Other Material Related to Treatment 99/2001, (2001) http://www.finlex.fi/en/laki/kaannokset/1992/en19920785.pdf (Accessed 14 January 2017).
[29] E. Widström, A.-M. Nihtilä, Dental treatment of adults at PDS in big and medium size cities [In Finnish], Yhteiskuntapolitiikka 69 (4) (2004) 393–400 https://www.julkari.fi/handle/10024/100487 (Accessed 11 March 2017).
[30] H.J. Kroeze, A.J. Plasschaert, M.A. van't Hof, G.J. Truin, Prevalence and need for replacement of amalgam and composite restorations in Dutch adults, J. Dent. Res. 69 (6) (1990) 1270–1274.
[31] Oral Health in the Finnish Adult Population. Health 2000 Survey, in: L. Suominen-Taipale, A. Nordblad, M. Vehkalahti, A. Aromaa (Eds.), Publications of the National Public Health Institute B, Hakapaino, Helsinki, 200825/2008. http://www.julkari.fi/bitstream/handle/10024/103030/2008b25.pdf (Accessed 14 January 2017).
[32] P. Kanzow, A. Wiegand, Falk Schwendicke, Cost-effectiveness of repairing versus replacing composite or amalgam restorations, J. Dent. 54 (2016) 41–47.
[33] T. Beazoglou, S. Eklund, D. Heffley, J. Meiers, L.-J. Brown, H. Bailit, Economic impact of regulating the use of amalgam restorations, Public Health Rep. 122 (5) (2007) 657–663.
[34] C.D. Lynch, N.J. Opdam, R. Hickel, P.A. Brunton, S. Gurgan, A. Kakaboura, et al., Guidance on posterior resin composites: academy of operative dentistry – European section, J. Dent. 42 (4) (2014) 377–383.
[35] F.J. Burke, Amalgam to tooth-coloured materials–implications for clinical practice and dental education: governmental restrictions and amalgam-usage survey results, J. Dent. 32 (5) (2004) 343–350.
[36] T.K. Mackey, J.T. Contreras, B.A. Liang, The Minamata Convention on Mercury: attempting to address the global controversy of dental amalgam use and mercury waste disposal, Sci. Total Environ. 472 (2014) 125–129.
[37] N.J. Opdam, E.M. Bronkhorst, M.S. Cenci, M.C. Huysmans, N.H. Wilson, Age of failed restorations: a deceptive longevity parameter, J. Dent. 39 (3) (2011) 225–230.