The ultimate guide to restoration longevity in England and Wales. Part 1: methodology

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Key points

A large dataset, of almost 14 million restorations over 15 years, has been analysed.	The large size of the data set facilitates, not only the survival of restorations to re-intevention, but also (arguably most importantly) the time to extraction of the restored tooth.	A modified form of Kaplan-Meier statistical methodology has been employed to produce survival curves of different subgroups of restorations and teeth.

Aim It is the aim of this paper to describe the analysis of a new data set which will be interrogated in order to present data on the survival of restorations by analysis of the time to re-intervention on the restorations and time to extraction of the restored tooth, and to discuss the factors which may influence this. **Methods** A data set was established consisting of General Dental Services (GDS) patients whose birthdays were included within a set of randomly selected dates, twenty in each possible year of birth. The data consist of items obtained from the payment claims submitted by GDS dentists to the Dental Practice Board (DPB) in Eastbourne, Sussex, UK. **Results** Data for more than a million patients, including more than 26 million courses of treatment, were included in the analysis. Data down to individual tooth level are included. **Conclusion** It is concluded that the new data set will enable the analysis of the intervals between placing a restoration and re-intervention on the tooth, and, because of its size, will also make possible the analysis of time to extraction of the restored tooth.

Introduction

Restorations in the General Dental Services

Direct placement restorations comprise the largest volume of restorations placed within the National Health Service General Dental Services (GDS) in England and Wales. Satisfactory life expectancy of dental restorations is central to the achievement of patient satisfaction, and to the fostering of confidence in the dental profession, to fulfilling the rigours of clinical governance and to satisfying third party funders that they are receiving value for money.

Restoration longevity may be assessed in a variety of ways, including randomised controlled clinical trials, systematic reviews, cross-sectional analyses and cohort studies. Because of the need to keep the researchers, patients and clinicians together for the duration of such studies, the numbers of restorations and duration of the study may be limited by these factors. Another source of information, where this exists, is the analysis of data obtained from a national dental treatment database, and it could be expected that this should provide a comprehensive assessment of restoration longevity and the factors associated with this. Such databases have been used, to varying extents, by Elderton in Scotland,[1] Bogacki and co-workers in Washington State in the USA,[2] and, more recently, by Pallesen *et al.*[3] in Copenhagen, by Raedel and co-workers in Germany,[4] Palotie and colleagues in Finland,[5] and Laske and colleagues,[6] who have analysed ten-year restoration survival using a large database which has been established in The Netherlands.

A large database has also been available at the former Dental Practice Board (DPB), based in Eastbourne in the UK, now part of the Business Services Authority (BSA) of the National Health Service (NHS). Restoration survival per se has been represented by the time interval to the next restoration or other intervention upon the same tooth, with this having been used extensively in the past.[7] However, the effect of the restoration upon the survival of the tooth to extraction is another factor which should be considered, given that it may be considered that it is longevity of the tooth which is important, rather than simply the longevity of the restoration. The size of the newly established data set (*vide infra*) allows this to be assessed.[8] Analysis of this will also inform dentists and their patients in decisions on the optimum treatment for their patients, underpinned by analysis of the outcome of a given treatment in terms of the survival of the restored tooth.

The General Dental Services

In the UK, dental treatment has been available from 1948 under the auspices of the GDS, with this being administered in England and Wales by the DPB in Eastbourne, Sussex, more

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Table 1 Survival to re-intervention by type of treatment

Type of treatment	Survival (%) at				
	1 year	5 years	10 years	15 years	n
Amalgam	91	66	51	41	7,292,564
Composite resin	87	59	43	34	3,504,225
Glass-ionomer	84	53	37	28	1,592,566
Crown	93	77	63	53	1,202,005
Inlay	90	67	48	37	86,189
Veneer	90	69	52	42	66,509
Multiple types	88	59	41	30	151,990
All restorations	89	64	48	39	13,896,048

Table 2 Survival to extraction by type of treatment

Type of treatment	Survival (%) at				
	1 year	5 years	10 years	15 years	n
Amalgam	98.5	93.5	88.1	83.7	7,292,564
Composite resin	98.7	93.6	87.9	83.3	3,504,225
Glass-ionomer	97.5	89.8	82.5	77.1	1,592,566
Crown	98.7	92.4	84.5	77.4	1,202,005
Inlay	98.9	94.5	89.0	83.3	86,189
Veneer	99.7	98.4	95.7	93.0	66,396
Multiple types	98.1	91.5	83.7	77.8	151,990
All restorations	98.4	93.0	87.1	82.3	13,896,048

recently subsumed within the NHS BSA. The DPB/BSA was also concerned with probity and with the quality of work carried out within the GDS, employing a group of dental reference officers for this purpose.

The DPB database held data, derived from dentists' claims for payment, on dentist and patient factors such as their gender and date of birth. Individual dentists were identified by unique personal numbers within the database, while patients were identified by the combination of surname, initial, gender and date of birth. Each course of treatment was linked to the postcode at which the treatment was provided, together with the dates of acceptance, examination and completion. Detailed treatment information was provided, including specific treatment codes and the teeth which were treated. By these means, it was possible to identify, for any particular restoration or treatment, the following covariates:

1. Tooth position, individually and grouped by arch, quadrant and function (incisor, canine, premolar and molar)
2. Cavity type, as distinguished in the GDS Statement of Dental Remuneration (SDR)
3. Material type – this is confounded with cavity type above, but also distinguishes between amalgam, glass-ionomer and composite resin, as well as the different combinations of materials for crowns, veneers and inlays
4. Treatment type: tooth–specific treatments include fillings, inlays, crowns, veneers, dentures and bridges, but there are also records for other more general treatments including prophylactic and diagnostic procedures such as periodontal treatment and radiographs.
5. Additional treatment on same tooth – root filling and/or pin or screw retention
6. Those teeth with and without other treatment at the same time as the particular treatment
7. Age, gender and experience of dentist providing the treatment
8. Gender and age cohort of patient
9. Age of patient at time of acceptance for the course of treatment in which each restoration was placed
10. Patient history, determined by, for example, the median attendance interval, mean annual gross fees, and the number of different surgeries or dentists attended
11. Geographical area of surgery – and hence an indicator of the water fluoridation level in the area
12. Charge-paying status of patient at each date of attendance, including dates of initial restoration and re-intervention.

Other covariates, including the year and month of placement of the restoration, may also be identified.

DPB/BSA activity statistics

Prior to 1990, detailed treatment activity statistics were provided at the DPB by aggregation of a systematic sample of treatment records, according to a pre-specified set of aggregation tables. The detailed records themselves were not retained. However, in 1990, this system was replaced by a combination of 100% aggregate tables and a detailed sample consisting of all the treatment records relating to all patients whose dates of birth matched a randomly chosen set of birth dates, with equal numbers of dates in each year of birth. This latter sample has been retained in full, and will be referred to as the DPB's longitudinal treatment sample. An anonymised copy of this dataset has been established and is now held by UK Data Services under archive study number 7024.[8]

It is the purpose of this paper to describe the methodology used to investigate the times to re-intervention of restorations provided within the GDS in England and Wales between 1990 and 2006, and to identify the factors which may affect this. The time to extraction of the restored tooth will also be assessed.

Methods

The data

In brief, for the purpose of this work, survival of a restoration was considered to be the time interval between the date of completion of the course of treatment in which it was placed and the date of acceptance of the course of treatment when the next tooth-specific treatment was carried out on the same tooth. The nature of the re-intervention on a given tooth is available from the data, but whether this indicates failure of a restoration is not known. This is indeed a study of re-intervention, rather than of failure

Fig. 1 Survival to re-intervention by type of treatment

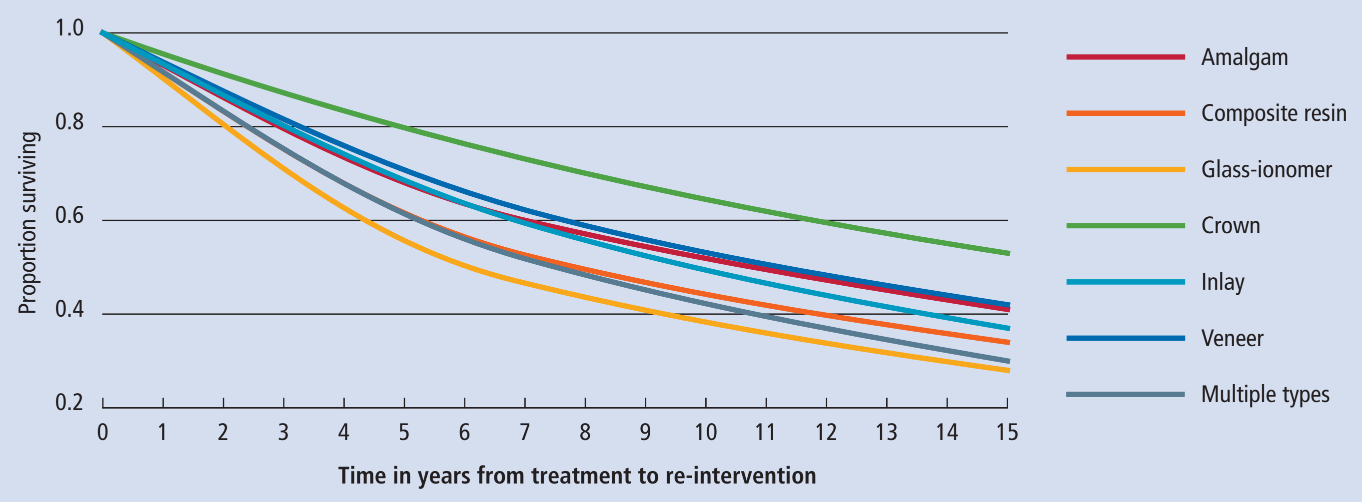
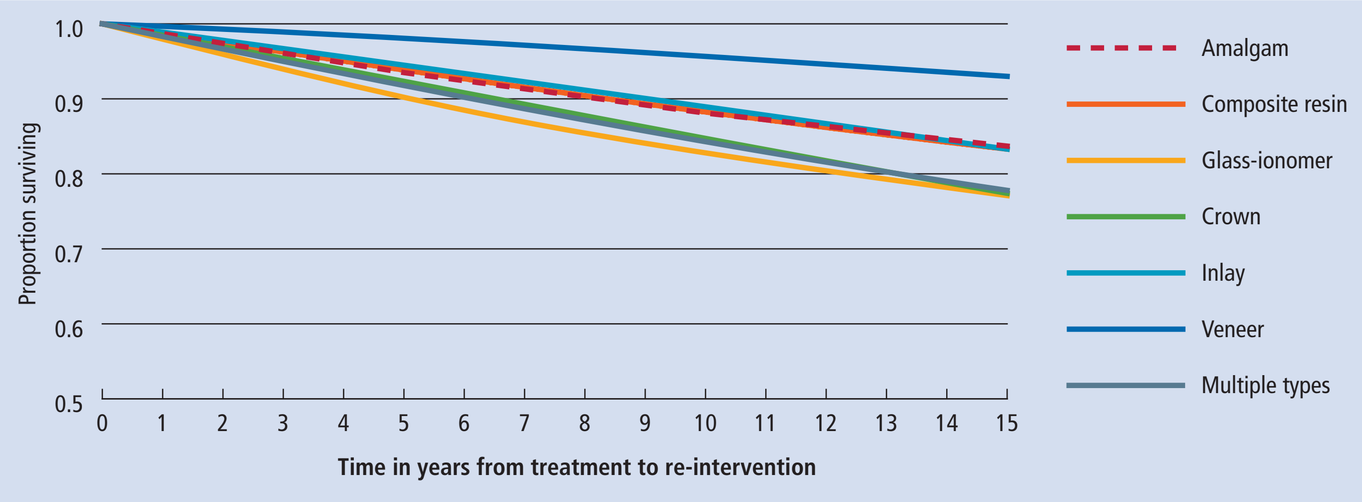


Fig. 2 Survival to extraction by type of treatment



or replacement, although the two are related. In this regard, the re-intervention on the previously restored tooth may not be directly associated with the original restoration. The interval to first re-intervention, and the type of first re-intervention, cover a wider range of circumstances, but may include occasions involving failure or replacement of the restoration as component events. In addition, the time to extraction of the restored tooth may be calculated, the authors consider that this provides an additional perspective to previous evaluations on the effect of restoration type on time to tooth loss.

The dataset held by UK Data Services under archive study number 7024[8] contains data on all dental treatment provided by the NHS GDS in England and Wales between October 1990 and March 2006 inclusive, for a large sample of patients chosen by random date of birth within each possible year of birth. Within the whole dataset there are more than three million different patient IDs and more than 26 million courses of treatment, each of which includes data down to individual tooth level, where the treatment is tooth-specific. The dataset, which was compiled at the DPB, was released to the research community by the Economic and Social Data Service in August 2012.

Types of analysis

Given the size and complexity of the data set, there is no practical limit to the total volume of analysis which may be undertaken. We have the benefit of existing published work using the more limited dataset extracted in March 2002[9–11] and the methods used to obtain these data on restoration survival have previously been described.[7] A modified version of Kaplan-Meier statistical methodology was used to plot survival curves for different subgroups within the population of patients for whom data were available.[7] Similar methodology will be used in the present work.

Classifications

The data can be viewed at four different levels: dentist, patient, course of treatment, and tooth. At each level an individual can be classified in relation to any particular time period, and in particular in relation to the complete data set. Apart from the classifications inherent in the raw data files (for example year of birth and gender of dentist, year of birth and gender of patient, postcode area and dates of course of treatment, mouth position of tooth), there are many classifications which can be developed from the interaction between individuals at different levels. These will now be considered in turn:

- Dentists may be classified by their mix of experience, their volume of activity, their

Table 3 Survival to re-intervention by type of tooth

Type of tooth	Survival (%) at				
	1 year	5 years	10 years	15 years	n
Upper incisor	87	60	43	34	2,062,128
Lower incisor	87	62	49	40	479,724
Upper canine	88	58	41	32	870,961
Lower canine	88	61	45	36	369,844
Upper premolar	90	66	50	41	2,018,221
Lower premolar	89	64	49	40	1,646,006
Upper molar	91	67	51	42	3,141,890
Lower molar	90	65	49	40	3,307,274
All restorations	89	64	48	39	13,896,048

Table 4 Survival to extraction by type of tooth

Type of tooth	Survival (%) at				
	1 year	5 years	10 years	15 years	n
Upper incisor	98.6	93.2	86.8	81.5	2,062,128
Lower incisor	97.9	90.6	83.6	78.9	479,724
Upper canine	98.3	91.5	83.9	77.8	870,961
Lower canine	98.4	92.0	85.6	80.2	369,844
Upper premolar	98.5	92.9	86.6	81.5	2,018,221
Lower premolar	98.6	93.7	88.4	84.1	1,646,006
Upper molar	98.3	92.9	87.0	82.3	3,141,890
Lower molar	98.4	93.6	88.4	84.2	3,307,274
All restorations	98.4	93.0	87.1	82.3	13,896,048

persistence in the dataset from one year to the next and from one area to another. They can also be assessed in terms of the mixture of patients which they treat and by measures of performance, such as longevity of restorations and loyalty of their patients

- Patients can be classified by their treatment and attendance history, and by whether they have had exemption from paying patient charges
- Courses of treatment can be classified by the treatments contained within them, as well as by the volume of treatment and the teeth treated (for example, root canal treatment of molar teeth)
- Individual teeth can be classified by their treatment history, including the incidence of multiple treatments during the same course of treatment. They may also be classified according to the treatment history of adjacent teeth or other treatments carried out in the same course of treatment.

Classification at each level can draw on the classifications of the other level with which the individual interacts – so for example, a tooth may be classified by the characteristics of the patient in whose mouth it resides, and by the characteristics of all the dentists who have treated that tooth, or indeed who have treated that patient.

Classification is therefore not an end in itself, but an essential step towards meaningful analysis. Once there is a set of classifications, it is possible to present descriptive statistics, in both graphical and numerical form, showing the relative distribution of the population with respect to those classifications and their interactions. This can be by a variety of bar charts and tables, similar to those produced in the publications of the NHS Information Centre for Health and Social Care. Prior to 2006 the DPB produced statistical reports (for example, the Digest of Statistics) which can be used to cross-validate some of the simpler descriptive analyses which can be derived from the new data set.

Kaplan-Meier survival curves

A Kaplan-Meier curve is a survival curve estimated by using a mixture of complete and incomplete life records, such as the intervals between courses derivable from the new data set. For some courses of treatment there is no subsequent course within the data set, so the interval has to be considered as censored at some time between the start of the interval and the end date of the data set, namely 31 March 2006. For the present analysis, the Cox-Regression procedure in SPSS V23 has been used, since it copes well with the large volumes of data in the full data set.

Precise evidence-based outcome measures

Previous studies have investigated the factors involved in restoration survival using a much smaller sample of circa 500,000 restorations[9–11] (compared with over thirteen million in the new data set), with the associated limitations in cases where the numbers of a given restoration type, or factor(s) influencing its survival, were small. However, given the size and, as a result, robustness of the potential analysis of the new database, it is anticipated that this will provide very precise information regarding the factors influencing survival of restorations of all types. This may be considered essential information for dentists when asking patients for their consent to treatment. It could also be considered important to inform third-party funders such as the NHS with regard to the treatments which provide optimum value for money in these times of limited financial resources.

Survival of restorations in England and Wales

By the means described above, it is possible to produce precise information regarding the survival of restorations and all the known factors which may influence this, for use in the dental surgery for informing patients.

For this preliminary paper, overall survival curves, and the corresponding tables of survival at one, five, ten and 15 years, have been produced, covering variation by treatment type, tooth type and patient age, since previous work indicates that these are important factors affecting restoration survival. Kaplan-Meier charts have also been prepared showing the variation by year of acceptance for each restoration course of treatment, to test the stability of the data over time. Additionally, for the figures in the tables for survival, the corresponding

Fig. 3 Survival to re-intervention by type of tooth

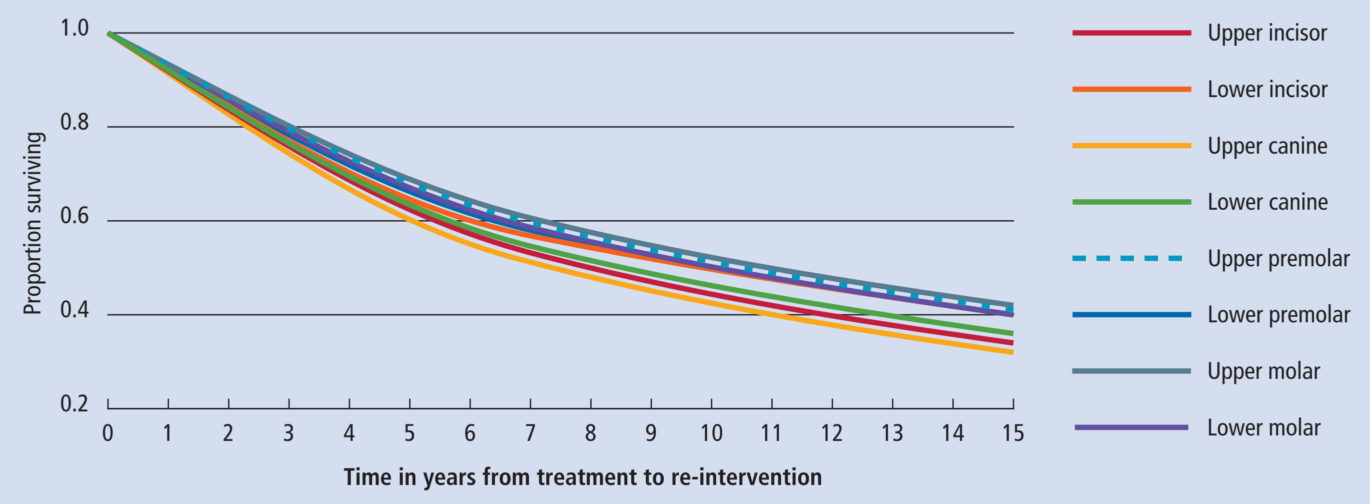
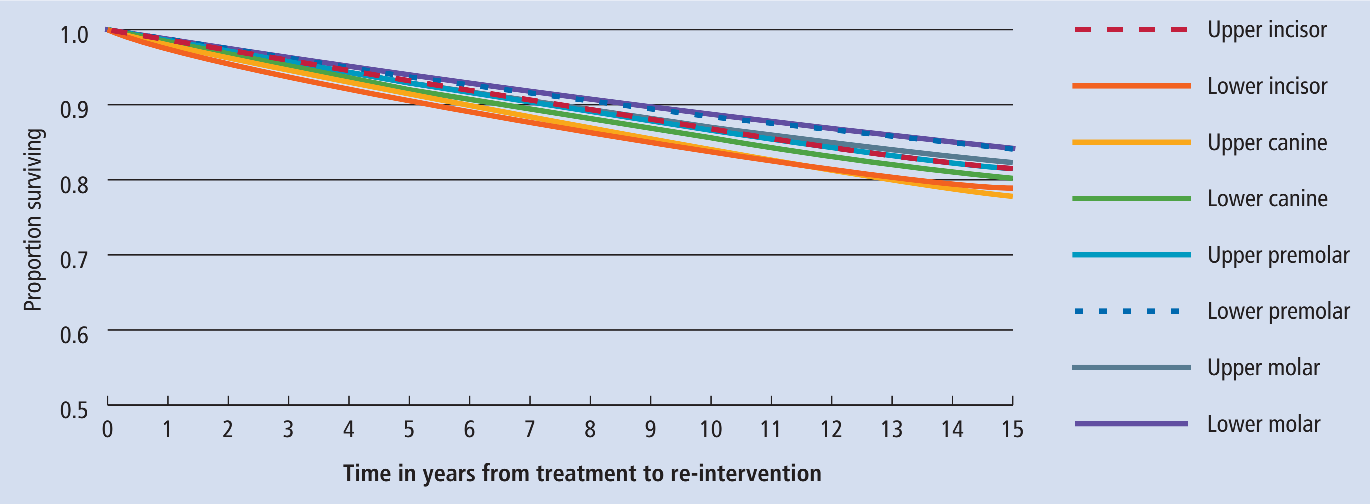


Fig. 4 Survival to extraction by type of tooth



standard errors (as generated by the standard SPSS software) have been calculated.

Bearing in mind that different anatomical types of teeth have differing functions, the authors considered it appropriate that, alongside papers presenting overall findings within each type of restoration, separate papers will deal specifically with molars, premolars, canines and incisor teeth, given the different anatomies and functions of these teeth.

This series of papers will therefore comprise the following:

1. Four papers on survival of restorations by material type: amalgam, glass-ionomer (GI) and resin composite direct restorations, and crowns. In each case, factors peculiar to the type of restoration, as well as more general factors, will be considered, and separate analyses conducted of time to re-intervention and time to extraction. It should, however, be borne in mind that only amalgam is used as a material for restoration of cavities in loadbearing situations in posterior teeth, while GI and resin composite are not
2. Four more papers, each considering a different tooth type (incisor, canine, premolar and molar), again looking at the influence of different factors and with separate analyses of time to re-intervention and time to extraction.

This series of papers will utilise the methodology described earlier in this paper.

Results

After restricting the data to that for adults, permanent teeth, and courses which started before 31 March 2006, a total of 13,896,048 tooth restorations comprised the data on which the charts and tables are based.

Tables 1 and 2 give the estimated proportions surviving for one, five, ten and 15 years, subdivided by type of restoration, for survival to re-intervention and to extraction, respectively. Figures 1 and 2 present the corresponding Kaplan-Meier survival curves. In the tables, n is the total number of cases contributing to the analysis, and excludes any censored before the earliest event for the stratum. The only such cases in these analyses are the small number (113) of veneers placed in the last five days of the observation period, since the earliest recorded extraction of a veneered tooth occurred six days after the veneer was placed. This is why the components in Table 2 do not sum up to the total number of cases contributing to the overall survival curve.

Tables 3 and 4 give the corresponding figures subdivided by type of tooth, including whether the tooth is in the upper or lower jaw, with Figures 3 and 4 giving the corresponding Kaplan-Meier survival curves.

Table 5 Survival to re-intervention by patient age

Patient age	Survival (%) at				
	1 year	5 years	10 years	15 years	n
18 or 19	94	73	57	46	366,043
20 to 29	93	71	55	45	2,643,425
30 to 39	91	68	52	43	3,254,169
40 to 49	89	64	49	39	2,847,732
50 to 59	87	60	45	35	2,222,482
60 to 69	85	55	39	31	1,518,314
70 to 79	83	50	35	26	812,916
80 or over	82	48	33	26	230,967
All Restorations	89	64	48	39	13,896,048

Table 6 Survival to extraction by patient age

Patient age	Survival (%) at				
	1 year	5 years	10 years	15 years	n
18 or 19	99.5	97.1	93.8	90.6	366,043
20 to 29	99.3	96.2	92.2	88.7	2,643,425
30 to 39	98.9	95.2	90.6	86.5	3,254,169
40 to 49	98.6	93.6	87.8	82.9	2,847,732
50 to 59	98.0	91.4	84.0	77.9	2,222,482
60 to 69	97.3	88.4	79.4	72.2	1,518,314
70 to 79	96.5	84.9	73.3	64.8	812,916
80 or over	95.5	81.0	67.2	58.0	230,967
All restorations	98.4	93.0	87.1	82.3	13,896,048

Similarly, Tables 5 and 6, and Figures 5 and 6, give the breakdown by patient age. It should be noted that the uppermost (age 80 or over) and lowest (age 18 or 19), represent a small proportion of the population, with particular characteristics.

Concerning the standard errors, with few exceptions, these are all well below one percentage point, even for fifteen-year survival. The main exception is patients aged 80 or over, where for survival without re-intervention after fifteen years the standard error is 0.826 of a percentage point and for extraction it is 0.947 of a percentage point. This reflects not only the relatively small number of cases in that age group (230,967), but more importantly, the small proportion of that age group where the patient himself (or more likely herself) survives for fifteen years. In short, the curves and tables are statistically reliable.

Finally, Figures 7 and 8 show how survival varies according to the year of acceptance. Of course, each curve is constrained by the number of years of observation available: only 1990 and 1991 have a full fifteen years, and 2006 has only three months.

It will be noted that in both charts for year of acceptance the lines overlap heavily, indicating stability over the entire observation period.

Discussion

While the method of payment to NHS dentists changed in April 2006 and data are no longer collected centrally at the individual tooth level, there are no reasons to believe that dentists have not continued to carry out their work to the same high ethical and technical standards as were applied to the data in the data set. Furthermore, dentists in the UK operate within the systems pertaining at the time, and may be considered to provide an ethical and professional service to their patients, irrespective of the payment system. In addition, there has been little fundamental change to the dental procedures or the materials used since 2006. Figures 7 and 8 may be considered to reinforce this statement, given that the overall performance of all types of restoration has not altered during the observation period. This may not be considered surprising, given that changes in materials and techniques in dental practice occur gradually rather than dramatically, and few, if any, completely new materials have been introduced during the duration of the data collection or, indeed, since that time. In other words, the data may be considered valid at the current time, despite the change in system, and also until new technological advances are made and widely implemented. On the other hand, dentists in England and Wales have been remunerated under a different system of payment (units of dental activity) since 2006; this was intended to promote a trend to less interventive dentistry and an increase in the use of repairs, rather than replacement, along with a gradual improvement in the dental health of the community at large.[12] Even if this is the case, which cannot be proven because data are not collected as they were for the present study, with the analyses extending to 15 years, the data is of direct relevance to restorations placed prior to 2006, a substantial proportion of which will remain in clinical service through to 2020 and beyond.

It is anticipated that the data will be of interest, not only to the patients who have received restorations, but also third party funders, and government (and, in England and Wales, its National Audit Office), the clinician and his/her managers, especially with the fulfilment of clinical governance in mind. In addition, by being available as a comparison to the survival of treatments carried out by an individual general dental practitioner, the data may also be used for medico-legal reasons, for example, when predicting the potential for longevity of restorations which were made necessary by the trauma of an accident, or the perceived premature failure of a treatment.

One major change in materials relates to the change away from amalgam to resin composite for restoration of loadbearing cavities in posterior teeth[13] which is occurring as a result of patient demand for aesthetic restorations in posterior teeth and the acceptance of the Minamata Agreement[14] to reduce mercury use in dental restorations in 2013. However, no information regarding this can be gleaned from the present work, given the non-availability of tooth coloured restorations for the

Fig. 5 Survival to re-intervention by patient age

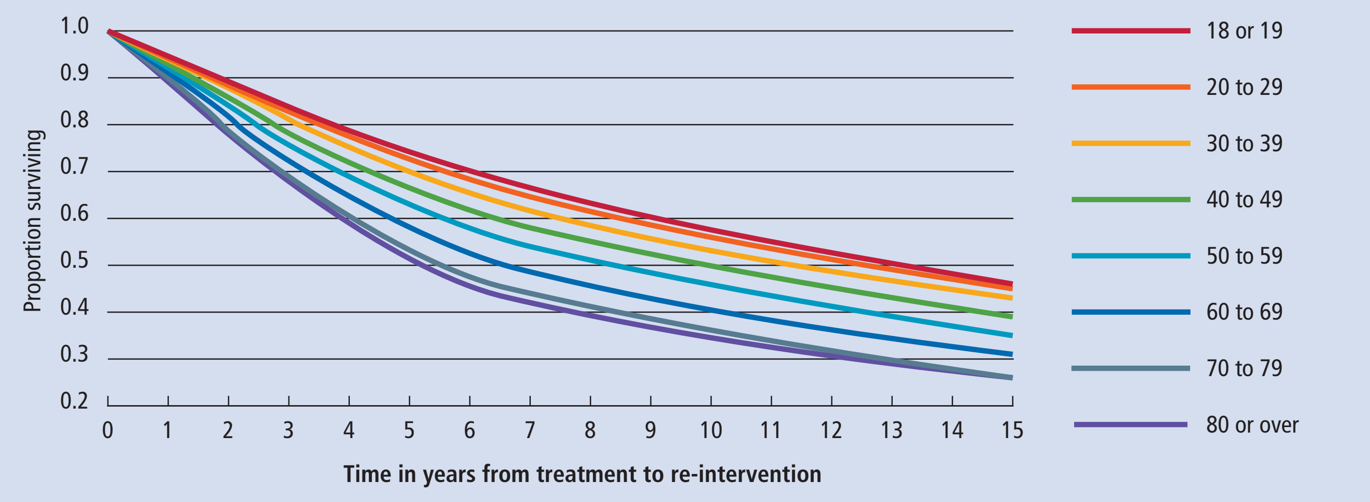
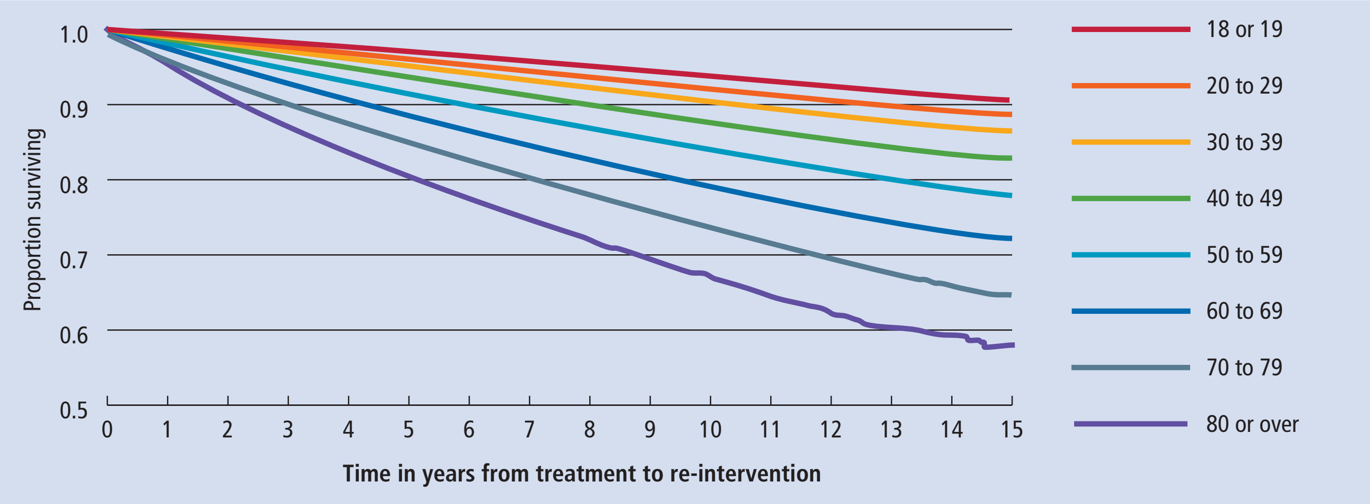


Fig. 6 Survival to extraction by patient age



restoration of load bearing surfaces within the GDS arrangements.

A majority of publications on restoration survival have evaluated the time to replacement of the restoration. This may be considered to be a readily understood methodology, particularly when compared to cross-sectional studies and especially when the information is expressed as annual failure rate (AFR). The present work represents a study on re-intervention, given that it records the time to re-intervention on a particular restored tooth. However, Robinson[15] demonstrated that a potential measure of the performance of a dental restoration is time interval from placement to re-intervention on the same tooth, and, since all restorations are treated similarly, the work will allow comparisons between different restoration types to be made, and the factors that influence this.

It has also been considered that restoration survival information does not present all the facts and that Kaplan Meier methodology presents a more meaningful picture.[16] The age of the restored tooth to extraction is a much less frequently considered parameter, possibly for operational reasons, given that such calculations require a large database in which teeth are extracted as well as restored over a long period of time, but also because dentists may be considered to be reluctant to consider that a given restoration may predispose a tooth to premature loss. Our analysis of this new dataset facilitates the assessment of age of tooth to extraction.

Finally, examination of the data and charts presented here indicates, first, a marked difference in the Kaplan Meier survival curves for survival of the restoration to re-intervention and survival of the restored tooth, and it could be argued that the latter is, by far, the most important criterion. As this series of papers progresses, it will be seen that this difference is more acute in certain tooth types when the difference in tooth survival between a tooth which is crowned and those which receive a direct-placement restoration is examined. Examination of the charts in Figures 3 and 4 also reveals that canine teeth perform least well in terms of time of survival of the restorations in these teeth and also time to extraction, perhaps a surprise, insofar as there is anecdotal evidence that prosthodontists and, indeed, general dentists look upon canine teeth (with their long roots) as being ideal bridge and denture abutments. It may also be a surprise that molar teeth outperform other teeth in terms of time of survival of the restorations in these teeth and also time to extraction, given that the first molar is generally the first tooth, in a given patient, to require a restoration. Perhaps the two- or three-rooted anatomy of these teeth predisposes to longer term survival. Examination of the tables and

Fig. 7 Survival to re-intervention by year of acceptance

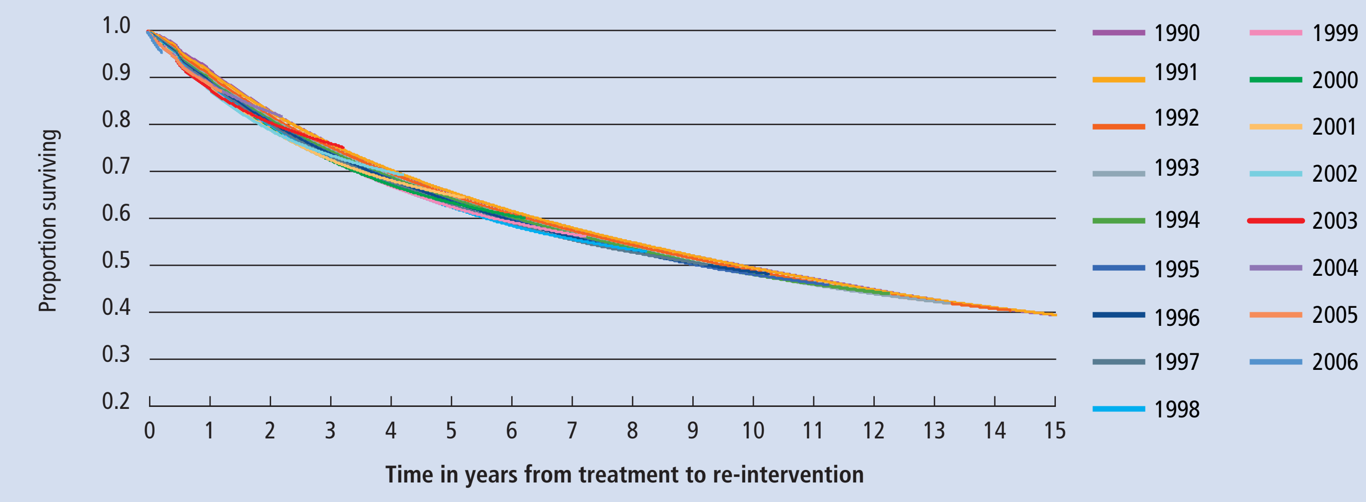
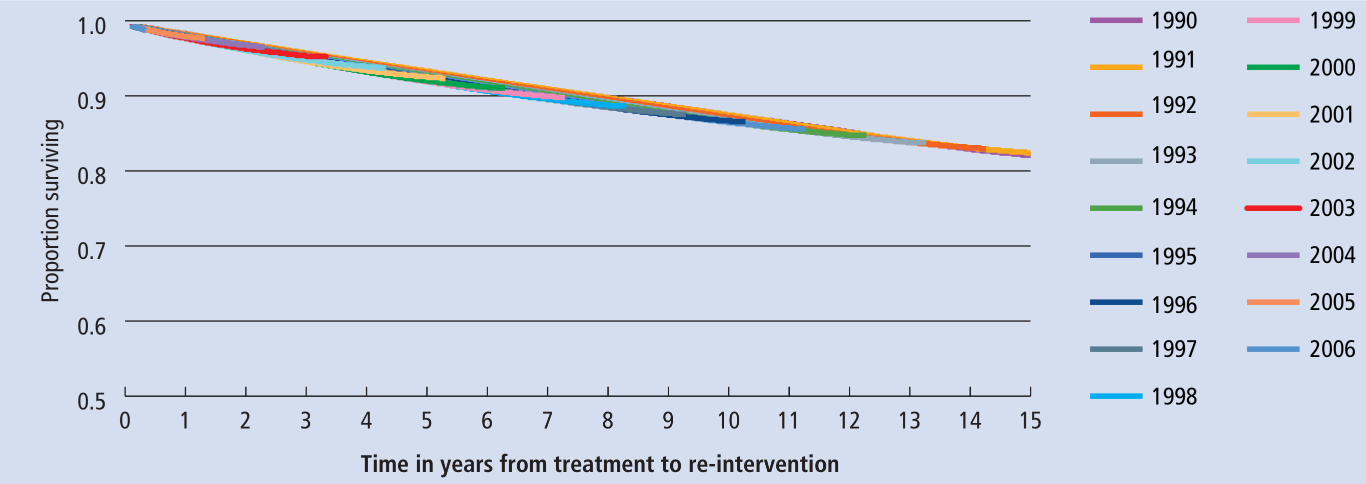


Fig. 8 Survival to extraction by year of acceptance



related charts (Figs 5 and 6) indicate that teeth in younger patients perform better, both in terms of time of survival of the restorations in these teeth and also time to extraction, than teeth in older patients. Is this because teeth in older patients are more likely to be more heavily restored when they enter the dataset and the teeth are more likely to be affected by periodontal disease than those in younger patients? The further analysis, in subsequent papers, may shed further light on this question.

Conclusion

It is concluded that the new data set will enable the analysis of the intervals between placing a restoration and re-intervention on the tooth, and, because of its size, will also make possible the analysis of time to extraction of the restored tooth.

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1. Elderton R J. Longitudinal Study of Dental Treatment in the General Dental Service in Scotland. *Br Dent J* 1983; **155:** 91–96.
2. Bogacki R E, Hunt RJ, delAguila M, Smith W R. Survival Analysis of Posterior Restorations Using an Insurance Claims Database. *Oper Dent* 2002; **27:** 488–492.
3. Pallesen U, van Dijken J W V, Halken J, Hallonsten A-L, Hoigard R. Longevity of posterior composite in permanent teeth in Public Dental Health Service: A prospective 8 years follow up. *J Dent* 2013; **41:** 297–306.
4. Raedel M, Bohm S, Priess H, Samietz S X, Wagner Y, Walter M H. Four-year outcomes of restored teeth – a massive data analysis. *J Dent Res* 2017; **97(Spec Issue A):** Abstract No.559.
5. Palotie U, Eronen A K, Vehkalahti K, Vehkalahti M M. Longevity of 2-and 3-surface restorations in posterior teeth of 25-to 30-year olds attending Public Dental Service – a 13-year observation. *J Dent* 2017; **62:** 13–17.
6. Laske M, Opdam N J M, Bronkhorst E M, Braspenning J C C, Huysmanns M-C D N J M. Longevity of direct dental restorations in Dutch dental practices. Descriptive study out of a practice-based research network. *J Dent* 2016; **46:** 12–17.
7. Lucarotti P S K, Holder R L, Burke F J T. Analysis of an administrative database of half a million restorations over 11 years. *J Dent* 2005; **33:** 791–803.
8. Information Centre for Health and Social Care, NHS Business Services Authority. Longitudinal Dental Treatment, 1990–2006. [data collection]. UK Data Service, 2012.
9. Lucarotti P S K, Holder R L, Burke F J T. 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* 2005; **33:** 805–815.
10. Burke F J T, Lucarotti P S K. Ten-year outcome of crowns placed within the General Dental Services in England and Wales. *J Dent* 2009; **37:** 12–24.
11. Burke F J T, Lucarotti P S K, Holder R L. Outcome of direct restorations placed within the General Dental Services in England and Wales (Part 2): Variation by patients' characteristics. *J Dent* 2005; **33:** 817–826.
12. Steele J G, O'Sullivan I. Adult Dental Health Survey 2009. London, Health and Social Care Information Centre, 2009.
13. Brunton P A, Burke F J T, Sharif M O *et al*. Contemporary dental practice in the UK in 2008: aspects of direct restorations, endodontics and bleaching. *Br Dent J* 2012; **212:** 63–67.
14. Lynch CD, Wilson NHF. Managing the phase-down of amalgam. Part 1: Education and training issues. Br Dent J 2013; 215: 109-113.
15. Robinson A D. The life of a filling. *Br Dent J* 1971; **130:** 206–208.
16. Opdam N J, Bronkhorst E M, Cenci M S, Huysmanns M-C, Wilson N H F. Age of failed restorations: a deceptive longevity parameter. *J Dent* 2011; **39:** 225–230.