# The ultimate guide to restoration longevity in England and Wales. Part 10: key findings from a ten million restoration dataset

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## Key points

Overall, almost 14 million tooth restorations were included in the analysis, with survival to re-intervention at 15 years ranging by tooth type between 32% and 42%: with regard to time to extraction of the restored tooth, the range is from 77.8% to 84.2%.

Larger restorations of all types and in all types of teeth generally performed less well than smaller restorations. Crowns perform better in time to re-intervention than direct restorations, but worse, particularly for younger patients, in time to extraction.

Patient treatment history is a major factor in the survival of restored teeth, both to reintervention and to extraction. The greater the previous spend on treatment, the worse the survival. Dentists' age has been shown to play a part in the present investigation, with restorations placed by younger dentists performing better for all types of restoration except crowns.

**Introduction** This paper defines key points from a ten million restoration dataset in order to compare and contrast the data from the previous nine papers, identifying common themes and/or differences in the factors affecting the survival of restored teeth to next intervention or extraction. **Aim** It is the aim of this paper to present data on the survival of restorations in teeth by analysis of the time to re-intervention on the restorations and time to extraction of the restored tooth, and to discuss key findings regarding this. **Methods** A data set was established, consisting of General Dental Services (GDS) patients, this being obtained from all records for adults (aged 18 or over at date of acceptance) in the GDS of England and Wales between 1990 and 2006. The data consist of items obtained from the payment claims submitted by GDS dentists to the Dental Practice Board (DPB) in Eastbourne, Sussex, UK. This study examined the key findings with regard to recorded intervals between placing a restoration in any tooth and re-intervention on the tooth, with the size of the dataset also permitting examination of the time to extraction of the restored tooth. **Results** Data for more than three million different patients and more than 25 million courses of treatment were included in the analysis. Included were all records for adults (aged 18 or over at date of acceptance). Overall, 13,896,048 tooth restorations were included in the analysis. With regard to time to re-intervention, overall, between 32% and 42% of restorations, depending on tooth type, had survived at 15 years, and with regard to time to extraction of the restored tooth, the range was from 77.8% to 84.2%. **Conclusions** The analysis confirms that larger restorations of all types and in all types of teeth generally performed less well than smaller restorations. Crowns perform better in time to re-intervention than direct restorations, but worse, particularly for younger patients, in time to extraction. Patient treatment history, measured as the average annual spend on treatment, is a major factor in the survival of restored teeth, both to re-intervention and to extraction. The greater the spend, the worse the survival. Regarding dentists, there is little difference in the survival of restorations placed by dentists of different gender, but dentists' age has been shown to play a part in the present investigation, with restorations placed by younger dentists performing better for all types of restoration except crowns. For direct restorations, the older the patient the poorer the survival of the restoration, whether to re-intervention or to extraction. The prognosis of a tooth which receives a root filling in the same course of treatment as the other restoration is much poorer than for teeth without such a root filling.

## Introduction

The first nine papers of this series detailed the overall survival of restorations, plus sub-analyses by type of restoration and tooth type, with cross-analysis by patient age and other factors such as dentist age, patient history, and the presence of root fillings. This paper draws on those analyses to extract common themes, and identifies where there are important exceptions.

It is therefore the purpose of this paper to investigate the key findings related to the survival of restorations in teeth, by assessing:

- Time to re-intervention, and the factors associated with this
- Time to extraction and the factors associated with this.

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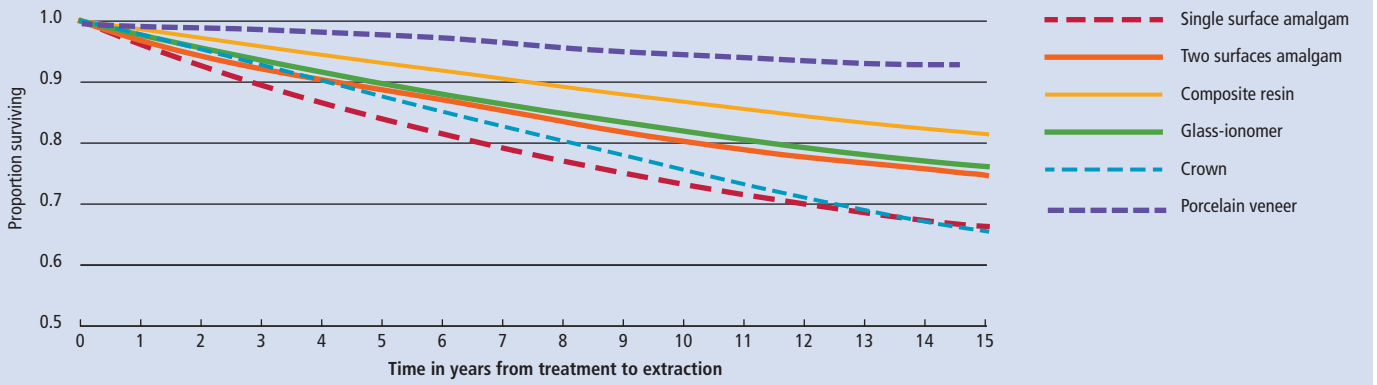
## Methodology

Using the methodology described in Paper 1 in this series,[1] and using a large dataset[2] derived from data at the former Dental Practice Board (DPB), now part of the Business Services Authority (BSA) of the National Health Service (NHS), it has been possible to produce precise

**Fig. 1 Time to extraction of restored canine teeth, with regard to the most commonly placed restorations**




information regarding the survival of restorations in all types of teeth and all types of restoration as were permitted under the General Dental Services (GDS) at the time of the data collection, and the factors which may influence this.

## Results

### Characteristics of the sample population

More than three million different patient IDs and more than 25 million courses of treatment were included in the analysis, each of which includes data down to individual tooth level. After restricting the data to that for adults, permanent teeth, and courses of treatment which started before 31 March 2006, a total of 13,896,048 tooth restorations comprised the data on which the charts have been based.

### Influence of type of restoration and type of tooth

There is an element of confounding between type of tooth and type of restoration, for example, amalgam restorations are placed mostly in posterior teeth and resin composite mainly in anterior teeth, and veneers are restricted to upper anterior teeth. The analysis was confined to more commonly-used restoration types: amalgam restorations,[3] resin composite[4] and glass ionomer (GI)[5] restorations, crowns[6] and veneers.[7,8] It is not surprising to report that different restoration types performed differently. With regard to overall survival of restorations to re-intervention, there are differences at 15 years between different tooth types, ranging from 32% for upper canines to 42% for upper molars, and for survival to extraction the range is from 77.8% for upper canines to 84.2% for lower molars.[1]

### Directly-placed restorations

Large amalgam restorations performed less well than smaller restorations[3] and GI restorations[5] (which will have principally been placed in class V cavities) performed less well than other types of restoration both in terms of time to re-intervention and time to extraction of the restored tooth. The data are similar for molar[9] and for premolar[10] teeth.

With regard to resin composite restorations[4] (which will have been placed in Class III and IV restorations in incisor and canine teeth and class V cavities in all teeth), Class III restorations perform better than Class IV in terms of time to re-intervention, with the difference being approximately ten percentage points at 15 years.

GI restorations perform worse than other restorations throughout the data.

### Indirect restorations

In incisor[7] and canine[8] teeth, with regard to re-intervention, it is apparent that veneers and crowns behaved similarly, outperforming other commonly provided restoration types (by *circa* ten percentage points at 15 years).

When the data are analysed with regard to time to extraction of a restored incisor tooth, the charts indicated a different story, with veneers continuing to perform optimally but crowns no longer representing the optimally performing restoration, since, at 15 years, resin composite restorations (overall) are performing approximately ten percentage points more favourably than crowns in time to extraction of the restored tooth and veneers performing optimally, with only 7% of teeth restored with a veneer being extracted at 15 years, compared with 25% of teeth which have received a crown and 16% of teeth which received a resin composite restoration. The picture for restored canine teeth is even starker (Fig. 1).

The performance of crowns, and indeed other restorations, is different in premolar and molar teeth. However, the differences are complicated by an interaction with patient age, as described below.

### Patient factors

#### *The influence of patient age*

For premolar teeth,[10] when the data are analysed with regard to patient age (<40 and >40 years) and restoration type, it is apparent that single surface amalgams and crowns out-perform other restoration types in terms of survival to re-intervention in the under-40 years age group, with MOD amalgams and GI restorations performing least favourably. However, when the over-40 years age group is examined in terms of time to re-intervention, a crown represents an enhanced treatment option, of around 20 percentage points better survival at 15 years than the next best performing restorative option, a two surface amalgam restoration.

When time to extraction of the restored premolar tooth is examined, a crown no longer represents the optimum treatment option. Indeed, it represents the worst overall performing option, with the cumulative survival at fifteen years of crowned premolar teeth being *circa* eight percentage points less than the best performing restoration, a two surface amalgam. This effect is even greater when the analysis is confined to the under-40 age group. For this younger age group there is an approximately 13 percentage point difference in fifteen-year cumulative survival between crowns and single surface amalgam restorations.

For molar teeth,[9] analysis of different age groups indicates that in the under 30 year age



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**Fig. 2 Time to re-intervention of restorations in molar teeth, in patients aged under 40 years of age**

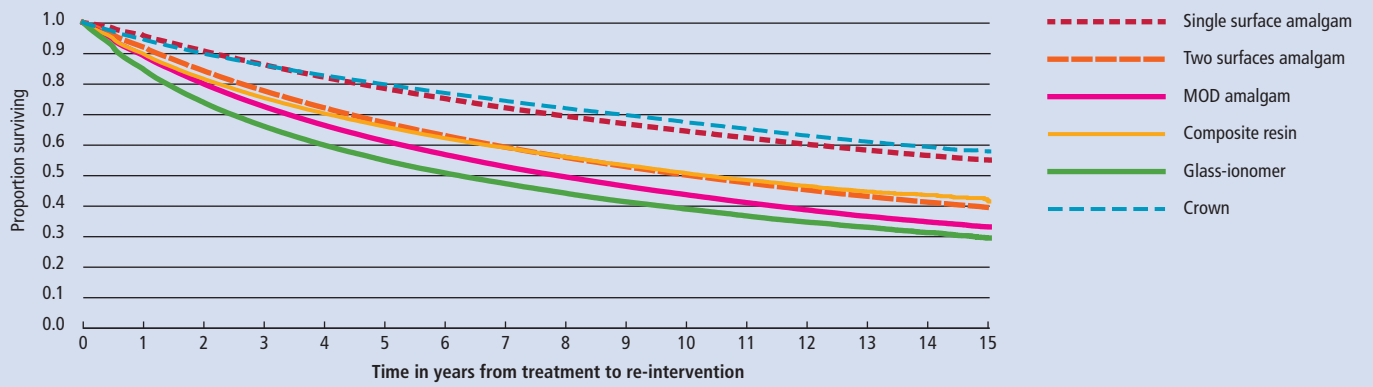
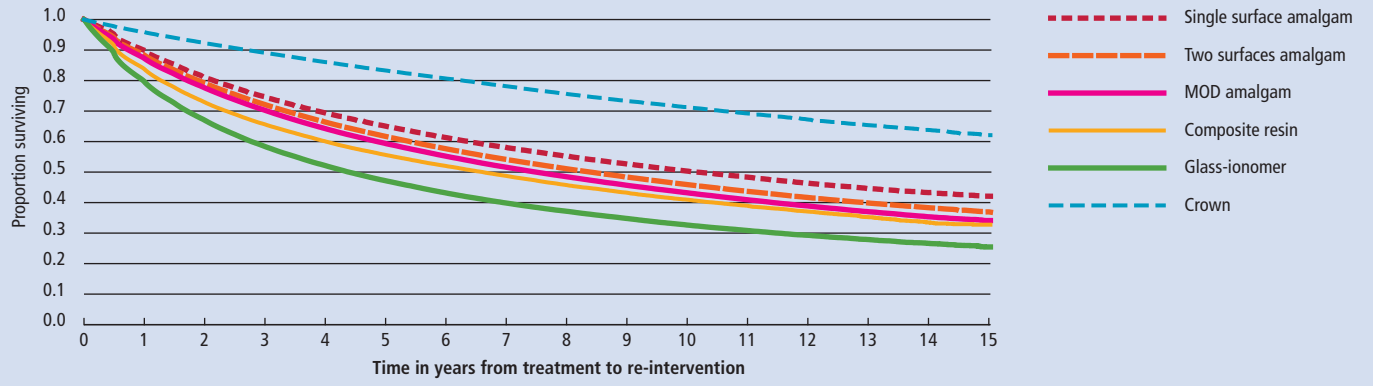



**Fig. 3 Time to re-intervention of restorations in molar teeth, in patients aged over 40 years of age**




groups, crowns, closely followed by MOD amalgams, represent the worst outcome of any treatment modality in terms of time to extraction of the restored tooth. However, at the opposite end of the age spectrum, crowns in the over 50 year age groups represent a better option in terms of years to extraction of the restored tooth, with crowns outperforming all other restorations. Indeed, there is a steady improvement in the relative performance of crowns with increasing patient age in molar teeth.

Other than the data presented above, it is apparent that there is a relentless decrease in restoration survival as patient age increases. For example, in canine teeth,[8] when the data are analysed with regard to patient age and restoration survival to re-intervention, it is apparent that restorations perform less well in older than in younger patients, with a difference of *circa* ten percentage points between the under-40 and 40 or over year age groups for canine teeth.[8] The data on time to extraction of the restored tooth present a similar result.

In terms of tooth loss, the oldest age groups can expect to lose over 30% of their restored canine teeth, compared with under 10% tooth loss for the younger age groups at 15 years.

Regarding crowns, overall, when patient age is examined, it is apparent that, with respect to time to re-intervention, crowns perform best in patients in the 30- to 60-year-old age groups, with crowns placed in patients aged under 30 or over 60 years performing less well.

When time to extraction of the crowned tooth is examined, the chart tells a slightly different story, with time to extraction being best in the age groups of 18 to 39 years, and with crowns in the age groupings above this performing less well.

However, although the performance of crowns eventually deteriorates with age, it does so at a more gradual rate than other types of restoration. Crown performance is therefore less age-dependent than with other restorations, this being borne out by the examining of Figure 8 of part 5 in this series.[5]

The resultant relative improvement in crown performance is exemplified by the charts for molar teeth. When the data are analysed with regard to patient age and restoration survival to re-intervention in molar teeth, it is apparent that restorations in molars generally perform less well in older than in younger patients. When the data are re-analysed with regard to patient age (<40 and >40 years) and restoration type in molars, crowns out-perform other restoration types in terms of survival to re-intervention in the under 40 years age group (Fig. 2). Again, in this age group, MOD amalgams and GI restorations perform least favourably in time to re-intervention. When the over-40 years age group is examined in terms of time to re-intervention (Fig. 3), a crown represents, for a molar tooth, a much enhanced treatment option of over 20% longer survival than the next best performing restorative option, a one surface amalgam restoration. Indeed, the absolute performance of crowns on molar teeth in terms of time to re-intervention is also greater for the patients aged over 40 than for younger patients.

When time to extraction of the restored molar tooth is examined (Figs 4 and 5) there is



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**Fig. 4 Time to extraction of restorations in molar teeth, in patients aged under 40 years of age**

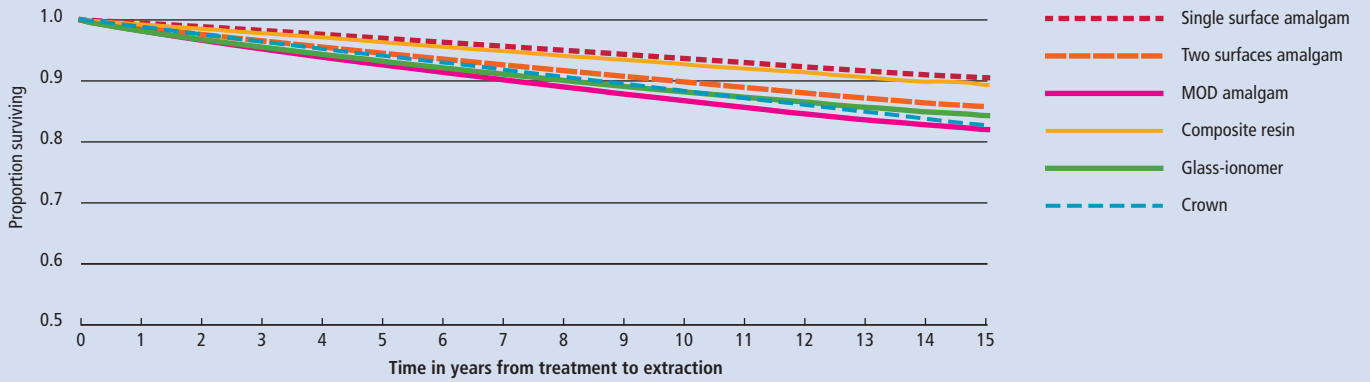
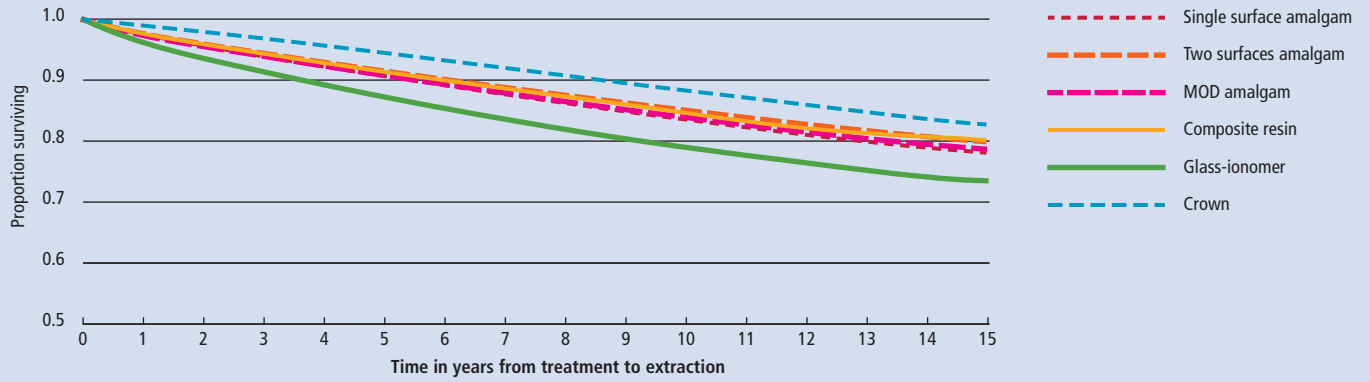



**Fig. 5 Time to extraction of restorations in molar teeth, in patients aged over 40 years of age**




a similarly strong inverse correlation between the age of the patient and the survival of the tooth to extraction. The contrast in performance between different types of restoration already noted between survival to re-intervention and survival to extraction can be seen by comparing the charts for the under-40 age group (Figs 2 and 4), where crowns perform relatively much worse to extraction. For the over-40 age group crowns perform better to extraction than other restorations (Fig. 5). Again, it may be noted that the improvement in relative performance of crowns is mostly attributable to the reduction in the performance of other restorations.

Further analysis indicates that in the under-20 age group, crowns represent the worst outcome of any treatment modality in terms of years to extraction of the restored tooth.

At the opposite end of the age spectrum, crowns again represent a good option in terms of years to extraction of the restored tooth in the 60 to 69 year age group. This effect is similar in the over-70 age group.

### *Patient gender*

Patient gender generally plays only a minor role in the survival of restorations, whether to re-intervention or to extraction.

### *Did the patient have to pay for treatment?*

Similarly, the charge-paying status of the patient had little influence on the survival of the patient's restored teeth.

### *Patient's state of oral health*

Two different proxies for the patient's state of oral health have been considered in the papers: the annual average cost of GDS dental treatment for the patient, with the median attendance interval between courses of treatment for the patient also being considered in papers 2[3] and 3.[5] There is a strong correlation between the two measures, and in this paper only the average annual fees measure will be considered.

## Average annual fees

All the analyses indicate clearly that the patient's history of dental treatment may be a major factor in determining the likely survival of amalgam restorations, both to time to re-intervention and time to extraction, with the results being classified into patients perceived to have low treatment need (up to £20 per annum during the 15 years of the data collection), medium treatment need (£20 to £60 per annum) and high treatment need (over £60 per annum).

For time to re-intervention, the difference, at fifteen years, is between nearly 70% for those with low annual expenditure on dental treatment, and under 30% for those with high annual dental treatment fees (Fig. 6). For time to extraction the corresponding figures are 93% and 76% (Fig. 7). Looked at in terms of tooth loss, patients with high annual dental expenditure face the prospect of losing teeth earlier, for example, *circa* 24% of their amalgam-restored teeth are lost within 15 years, compared with 7% for patients with low annual dental fees.

## Influence of dentist factors (gender and age)

Regarding amalgam, composite and GI restorations, there is a consistent, though modest,



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**Fig. 6 Survival to re-intervention by patient mean annual fees of teeth restored with amalgam restorations**

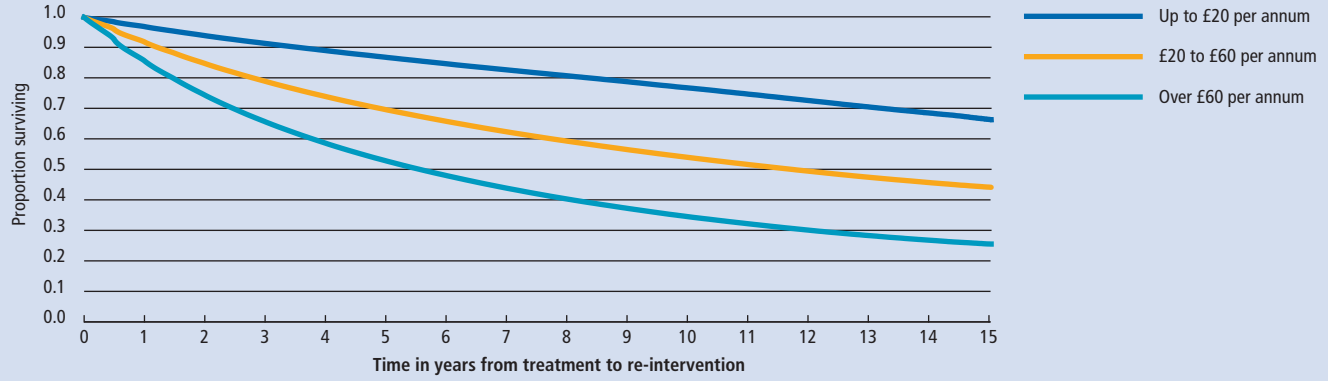
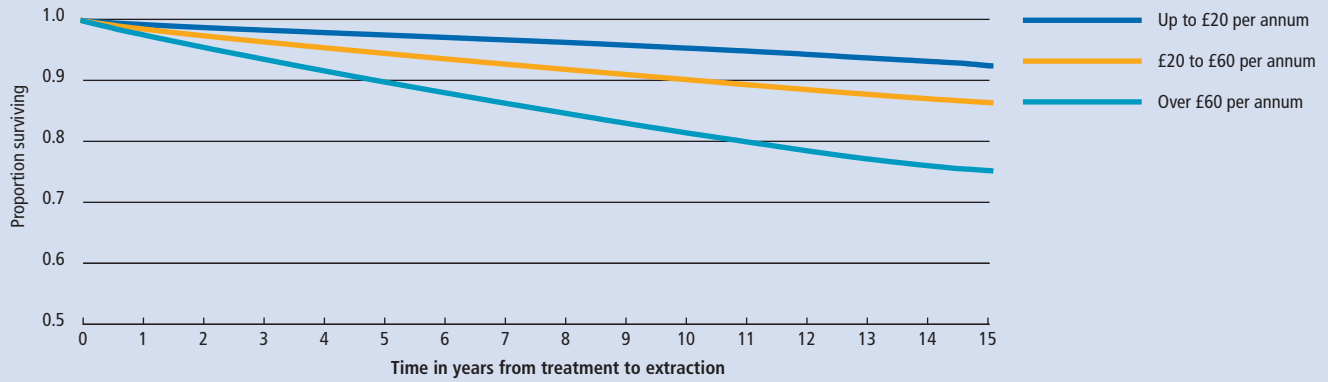



**Fig. 7 Survival to extraction by patient mean annual fees of teeth restored with amalgam restorations**




inverse correlation between the age of the dentist and the proportion of restorations surviving, with restorations placed by younger dentists surviving better. This applies to both survival to re-intervention and survival to extraction. For example, composite restorations placed by younger dentists also outperform those placed by older dentists by *circa* 5 percentage points at 15 years, and also survival to extraction, in which the effect is accentuated.

Crowns, however, are different! When the present data are analysed, it is apparent that the charts indicate that dentists under the age of 30 years provide crowns of significantly reduced longevity, both in terms of time to re-intervention and time to extraction of the crowned tooth.

When dentists' age is further examined, the chart indicates that crowns placed by dentists in the under-30-year-old age group and in the over-60 year age group perform less well in terms of time to re-intervention than those placed by dentists in other age groups by approximately four and two percentage points respectively at 15 years.

With regard to dentists' gender, there are no differences in survival of restorations to re-intervention for direct restorations, but for crowns the performance of female dentists is slightly poorer, by *circa* two percentage points, than that for their male colleagues. However, when time to extraction of the restored tooth is examined, there is a smaller difference, of less than one percentage point, again with crowns placed by male dentists performing better. However, canine teeth restored by female dentists show a higher cumulative survival to extraction by approximately two percentage points at fifteen years.

## Other factors

When the effect of placement of a root canal filling in the same course of treatment as the amalgam restoration is examined, the differences are dramatic with regard to time to re-intervention and time to extraction of the restored tooth. At 15 years the proportion surviving to re-intervention is reduced by *circa* 15 percentage points and the proportion surviving to extraction of the root filled restored tooth is reduced, again by *circa* 15 percentage points.

Canine teeth may be considered typical of these data. Figure 8 presents the chart relating to whether a root filling was placed in the same course of treatment as the restoration placed in the canine tooth, and indicates compromised fifteen-year survival of the restoration to the extent of approximately 12 percentage points. When time to extraction is examined (Fig. 7), it is apparent that the placement of a root filling in the same course of treatment leads to a reduced life expectancy of the tooth, by approximately 19 percentage points in cumulative survival at fifteen years.

The effect is also noted for crowns: the chart indicates a *circa* 14 percentage point difference in overall survival of crowns, with crowns on teeth which have received root fillings performing less well. When time to extraction of the restored tooth is examined, the chart indicates a *circa* 12 percentage point difference at fifteen years, this equating to six years extra life for teeth without a root filling.



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**Fig. 8 Time to re-intervention of restorations in canine teeth, with regard to whether the restored tooth also received a root canal filling on the same course of treatment**

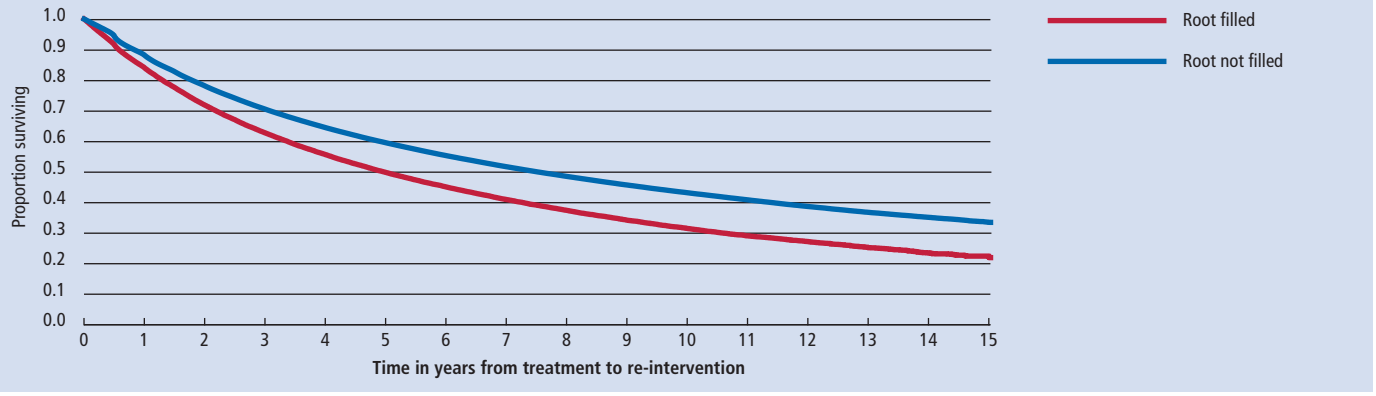
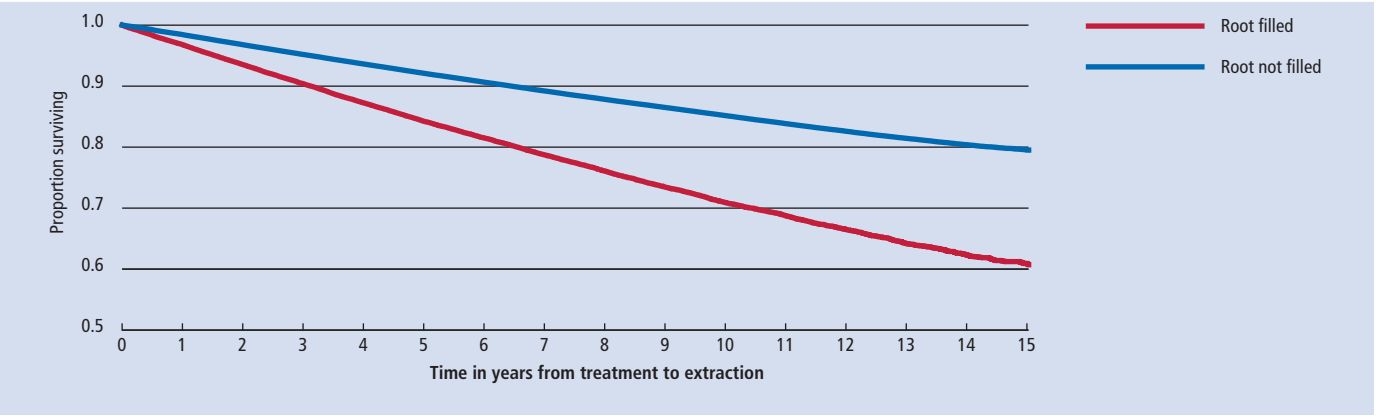



**Fig. 9 Time to extraction of restored canine teeth, with regard to whether the restored tooth also received a root canal filling on the same course of treatment**




## Discussion

'Ultimate guide' is an ambitious title for any piece of work, yet it is arguably appropriate to describe such a large and comprehensive data source and the relevance that it still has to today's dental practice. Regrettably, the central collection of such activity data ceased with the abolition of the Dental Practice Board, and so the data on which this set of papers is based is likely to remain the only such source for many years to come.

Although the economics of dentistry and the consequences for human resource planning within the dental profession are outside the scope of these papers, the findings are clearly of relevance both at a national level and within individual dental practices. In many other fields, a product for which over 30% need repair or replacement within five years would be a major concern, to both the provider and the client. Sadly, there is no sign of any improvement over the sixteen year timescale of this set of data.

There are plausible explanations for the different performance to extraction of crowns and veneers, namely the theoretically minimally invasive nature of the veneer preparation, but it is also reassuring to see the optimum performance in terms of time to extraction of a restoration which is generally placed for elective (aesthetic) reasons. The retention of the (stiffer) enamel substrate therefore appears key to the success of the veneers placed in the present study. However, as indicated in part 9 of this series, the question must still be asked – does under 50% at 15 years survival to re-intervention represent a good return for what is generally an elective restoration provided solely for aesthetic reasons, even if the cumulative survival time of the tooth to extraction is still 95%[7] (Fig. 1)?

The explanation for these findings may be considered to be related to the more extensive tooth preparation required for a crown, whereas the preparation for a veneer should, technically, be intra-enamel,[11] with the (stiff) enamel covering of the tooth remaining to a large degree intact.

Concerning the findings of the relatively poor performance of crowns to extraction, the message is loud and clear, crowns should be avoided if possible, particularly if there is sufficient sound tooth substance to retain directly-placed restorations.

These results have important implications for the choice between crowns and direct restorations for patients of different ages. Although the absolute performance of crowns to extraction may be worse for older patients, the relative performance is better, since other restoration performance is much more age-sensitive.

The trend to optimal restoration survival in younger patients may not be considered surprising. Cavities in younger patients are not likely to involve so many surfaces as in the older patient – teeth get "tired" as patients get older and their teeth become more heavily filled and, as a result, more prone to fracture.

By contrast, a crown provides a complete new upper body to the tooth, so its life effectively starts when it is placed. This may explain why there is relatively little correlation between the performance of crowns and the age of the patient. Such variation as there is may be more a reflection of the changes in the underlying remaining tooth structure.



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The strong influence of patient treatment history is also unsurprising. This may be considered to be a 'chicken and egg' situation: patients who receive the highest volumes of treatment obviously are judged by their clinician to need such treatment and therefore receive more restorations which do not survive so well. Might this be as a result of poor oral hygiene and cariogenic diet, or both, or other factors, for example, these patients inherited teeth which were poorly calcified? These are factors into which further research is indicated.

The reasons for the differential performance by dentists of different ages can only be surmised: it may be considered that experience is needed for the preparation and placement of successful crowns, possibly involving the achievement of good resistance and retention form, whereas this may not be so critical for direct-placement restorations. Furthermore, given that the number of crowns placed is less than the number of direct-placement restorations, the building of experience in this area of restorative dentistry for the younger dentist comes more slowly than the achievement of experience in direct placement restorations. This may also be as a result of the fewer numbers of crowns placed at undergraduate level in comparison with direct-placement restorations and/or the deficiencies in crown preparations which were apparent when the preparations of recently qualified dentists were assessed.[14] These comments may also help to explain why male dentists appear to place crowns of better longevity to re-intervention and time to extraction than female dentists, the only restoration type to exhibit this difference, given that female dentists may predominantly be in younger age groups than male dentists, given the increasing proportion of women in the dental profession which is being seen in the UK.[15]

The reasons for the poorer performance of the younger dentists with respect to crowns has already been discussed, so why are teeth restored with crowns placed by dentists in the over-60 age groups performing less well in terms of time to extraction than those placed by dentists in the other age groups? Why the poor showing of the older (potentially more experienced) dentists? Could it be that as they approach retirement, the joy of creating an ideal preparation or an ideal impression and occlusal recording have become too commonplace? Experience counts, but not when it breeds complacency or boredom!

The perceived wisdom might be that the older dentists are more experienced but it appears that such experience is more than balanced by the younger dentists, fresh and enthusiastic out of dental school (although a recent publication has challenged that view),[16] brimful of knowledge with the latest materials and techniques. On the other hand, their workload may not be so challenging as the established practitioner with his/her 'list' of longstanding (potentially demanding) patients.

The strong negative association with a root filling is worth underlining. Clinicians should therefore try to educate patients to attend a dentist before their teeth are irreparably damaged by caries or by periodontal disease and should themselves seek to carry out optimum preventive strategies and minimally invasive restorative treatment modalities. However, given the fact that 191,476 (compared with 1,010,529 which were crowned and not root filled) teeth have been crowned and root filled in the present dataset, it may be considered that patients may feel that this is a worthwhile price to pay.

During the time span of the present study, it could be considered that there were advances in a number of the materials employed by clinicians, in particular resin composite materials (particularly with regard to filler size and composition) and glass ionomer materials (for example, the development of resin modified GIs and reinforced GIs). In addition, it could be argued that dentine bonding agents have improved in terms of reliability in the years between 1991 (when these materials were relatively poorly developed) to 2006, when dentine bonding agents more resembled the materials which are available today.[17] It is therefore surprising that no improvement in the overall performance of composite restorations or GI restorations has been demonstrated, this in itself reinforcing the validity of the present work to general dental practice in England and Wales today.

The data also may be considered to demonstrate that, no matter what material is employed by the dentist, (s)he will provide ethical treatment to the top of his/her ability. On the other hand, the data may indicate that, despite the advances in the materials outlined above, clinicians are not using them, possibly because newly-developed materials tend to be more expensive than their older counterparts.

Finally, given the size of the dataset, it could be considered that the information gleaned from it is representative of dentists from England and Wales during the time of the data collection, and as discussed previously.[1] Furthermore, the materials used for restoration of teeth, particularly dental amalgam, have changed little over the years since the data for this work ceased to be collected and, in the analysis of restoration performance over the duration of the data collection (1990 to 2006), the charts show no difference in performance over those years, another potential indication that the results remain valid at the present time.

Might the data be representative of countries outwith the UK? The dental materials used in continental Europe and in countries such as Japan, Australia and North America, are similar to those used in the UK, and the majority of countries utilise a fee per item method of payment, such as was in use at the time of the data collection for this study. The principal difference is that, in the present work, under the GDS regulations, tooth-coloured dental materials were not available for use in loadbearing positions in posterior teeth as they are in the majority of the countries named above. It is therefore suggested that factors identified in the present work, such as the influence of cavity size, the effect of tooth position, the effect of root filling and the need to restore teeth with direct placement restorations rather than crowns, are all factors which could translate to dental services outwith the UK.

In this regard, the work of Raedel and coworkers[18] is worthy of comment. They collected data on permanent teeth from a major German national health insurance company, focusing on re-intervention on one surface, two-surface, three- and four-surface restorations (direct-placement and inlays) at periods of up to four years and a mean observation period of approximately two years. Crowns were not included: their dataset included 17 million restorations (in anterior and posterior teeth) in over 3.9 million patients. Their results indicated a cumulative re-intervention rate, by direct restoration, crown or extraction, at four years, of 66.1% for one-surface (that is, class I and Class V) restorations, 67.5% for two-surface, 63.0% for three-surface and 55.8% for four-surface restorations, but their data did not include any details of the materials used. The results are in broad agreement with those presented in the present study with regard to amalgam restorations,[3] perhaps indicating that dentists in England and Wales place restorations which perform similarly despite the difference in the funding systems in the two studies.



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## Conclusions

- The analysis confirms that larger restorations of all types and in all types of teeth generally performed less well than smaller restorations
- Crowns perform better in time to re-intervention than direct restorations, but worse, particularly for younger patients, in time to extraction
- For direct restorations, the older the patient the poorer the survival of the restoration, whether to re-intervention or to extraction.
- Patient treatment history, measured as the average annual spend on treatment, is a major factor in the survival of restored teeth, both to re-intervention and to extraction. The greater the spend, the worse the survival
- Regarding dentists, there is little difference in the survival of restorations placed by dentists of different gender, but dentists' age has been shown to play a part in the present investigation, with younger dentists performing better on all types of restoration except crowns
- The prognosis of a tooth which receives a root filling in the same course of treatment as the other restoration is much poorer than for teeth without such a root filling.

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