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THE ULTIMATE GUIDE TO RESTORATION LONGEVITY IN ENGLAND AND WALES:3: GLASS IONOMER RESTORATIONS: TIME TO NEXT INTERVENTION AND TO EXTRACTION OF THE RESTORED TOOTH

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THE ULTIMATE GUIDE TO DIRECT RESTORATION LONGEVITY IN ENGLAND AND WALES:3: GLASS IONOMER RESTORATIONS

Abstract

Aim: It is the aim of this paper to present data on the survival of glass ionomer 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: This study examined the recorded intervals between placing a glass ionomer restoration and re-intervention on the tooth, this being obtained from a data set consisting of General Dental Services' patients treated 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.

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, 1,598,698 glass ionomer restorations were included, of which 689,532 had a re-intervention over the duration of the dataset. The Kaplan-Meier analysis indicated that 28% had survived without reintervention at 15 years. When glass ionomer restorations are compared with the survival curves for other types of restoration, it is apparent that these restorations perform less well in terms of time to re-intervention than other treatment groups overall. They also perform less favourably in the charts dealing with time to extraction, with 23% of teeth restored with GI being extracted at 15 years.

Conclusions: The survival of glass ionomer restorations to re-intervention and in time to extraction of the restored tooth was found to be less good than other restoration types. This was particularly influenced by the age of the patient and the position of the restored tooth in the mouth.

Introduction

Satisfactory survival of restorations is of importance to patients, dental professionals, epidemiologists, third-party funders, governments, and other interested parties. It is also important that the data is derived from general dental practice (as opposed to secondary care), given that it is in this arena that the majority of dental treatment, worldwide, is provided and it is where the majority of dentists operate and where the majority of restorations are placed. Using the methodology described in Paper 1 in this series[1], it has been possible to produce precise information regarding the survival of glass ionomer restorations and all the known factors which may influence this.

Glass ionomer (GI) cements were developed in the early 1970s[2]. These materials comprised a Fluoro-Alumino-Silicate (FAS) glass, initially being derived from the FAS glass used in silicate materials, but with the phosphoric acid used in silicate being substituted by a polyacrylic acid[3]. Their popularity increased through the 1980s, and in 2000, these materials were used in the placement of *circa* 1.7 million restorations in the NHS in England and Wales, mainly in Class V non-load-bearing cavities[4]. Principal advantages of GI materials include their good compressive strength, their reliable adhesion to tooth substance (which, in turn, reduces the need for the clinician to cut sound tooth substance to create retention for the restoration), and release of fluoride, which was once considered to inhibit the progress of caries around the restoration, although the literature on this is, by no means, unequivocal[5]. Disadvantages of conventional GI materials included poor tensile/ flexural strengths and suboptimal wear resistance (which precluded the use of these materials in loadbearing cavities), moisture sensitivity, and poor aesthetics, because of their

opacity[3]. The most recently developed generation of GI materials have been termed fast-setting, high-strength, or reinforced glass ionomers, examples being Fuji IX (GC, Tokyo, Japan) or Ketac-Molar Universal (3M , MN, USA). Manufacturers claim improved early physical properties and resistance to dissolution over conventional GIs[6], this improvement being due to a reduction in the size of the glass particles in the matrix, allowing a faster speed of reaction between the glass and the polyacrylic acid. These materials are stiffer when mixed and have been termed “packable” as a result. Manufacturers have considered that a reinforced GI material may be suitable as long-term temporary restoration of Class I and II cavities in permanent teeth (Chemflex), or permanent small Class I restorations[7], notwithstanding its suggested use in Class III and V cavities, class I and II cavities in primary teeth, fissure fillings, core build-ups and Atraumatic Restorative Treatment (ART) technique. However, under the Regulations relating to the General Dental Services in force at the time of this study, GI materials were precluded from use in loadbearing cavities.
It is therefore the purpose of this paper to investigate the following:

- Survival of glass ionomer restorations, by assessing time to re-intervention, and the patient and dentist factors associated with this
- Time to extraction of teeth restored with glass ionomer restorations and the factors which influence this.

Results

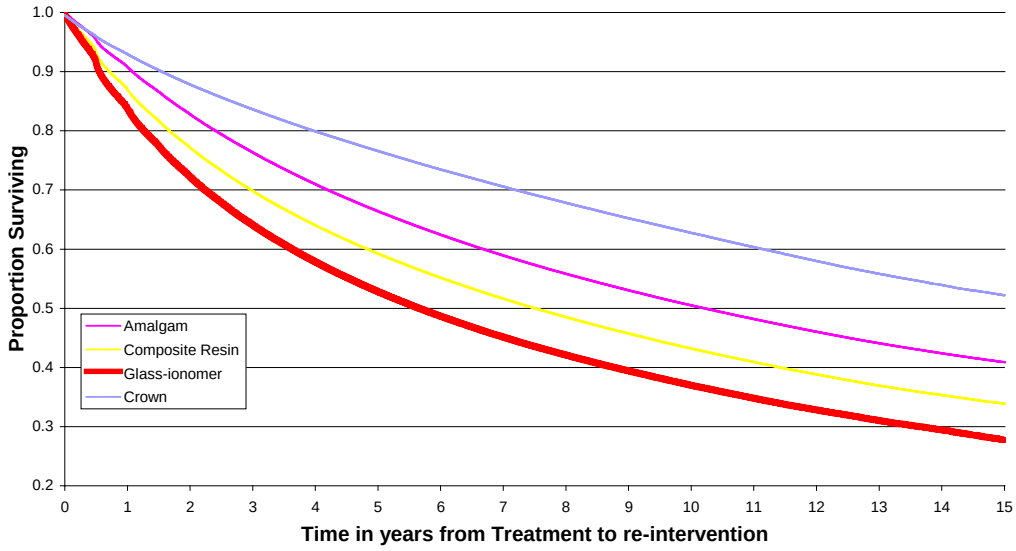
More than three million different patient IDs and more than 25 million courses of treatment were included in the analysis, each of which includes data down to individual tooth level[8]. Included were all records for adults (aged 18 or over at date of acceptance). Regarding GI restorations, 1,592,566 were included, of which 711,581

had a re-intervention. The Kaplan-Meier analysis (Figure 1 and Table 1) indicates that 28% had survived without reintervention at 15 years.

Table 1 Overall Survival to Reintervention by Treatment Type

	Survival (%) at				
Type of Treatment	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

Figure 1 Overall Survival to Reintervention by Treatment Type

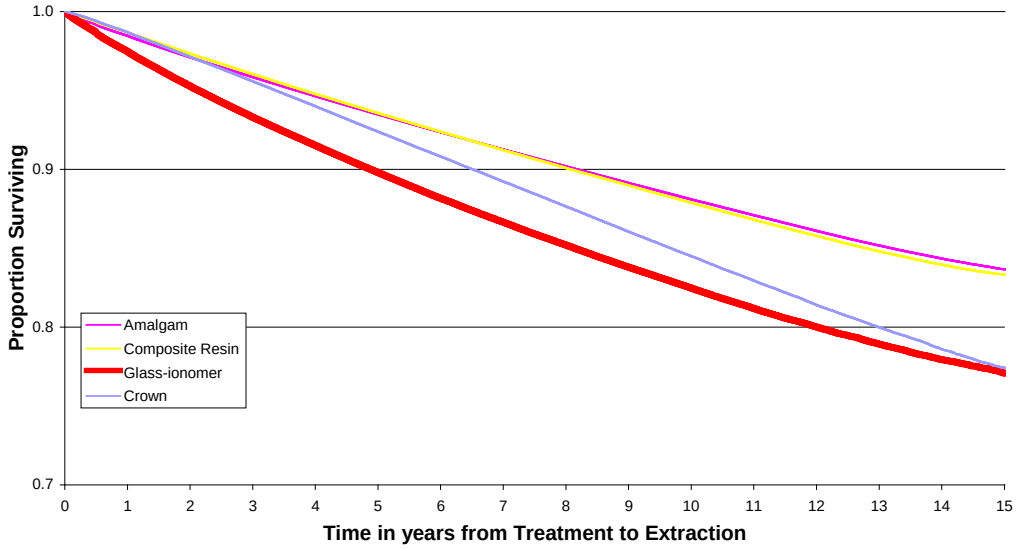


However, when GI restorations are compared with the survival curves for other types of restoration, it is apparent that these restorations perform less well in terms of time to re-intervention than other treatment groups overall (Figure 1). They also perform less favourably in the charts dealing with time to extraction (Figure 2), with 23% of teeth restored with GI being extracted by the 15-year mark, compared with 16% of teeth restored with an amalgam restoration (Table 2).

Table 2 Overall Survival to Extraction by Treatment Type

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

Figure 2 Overall Survival to Extraction by Treatment Type



Influence of tooth position

GI restorations have been found to perform more favourably in the lower arch than in the upper (Figure 3 and Table 3). With regard to tooth position, it is apparent that GI restorations survive optimally in premolar and lower incisor teeth and least well in upper incisor teeth (Figure 4 and Table 4).

Table 3 Survival to Reintervention by Mouth Quadrant

	Survival (%) at				
Quadrant	1 year	5 years	10 years	15 years	n
Lower Left	84	54	39	30	393,699
Lower Right	84	54	39	30	378,493
Upper Left	84	52	36	26	409,819
Upper Right	84	52	36	26	410,555
All Restorations	84	53	37	28	1,592,566

Figure 3 Survival to Reintervention by Mouth Quadrant

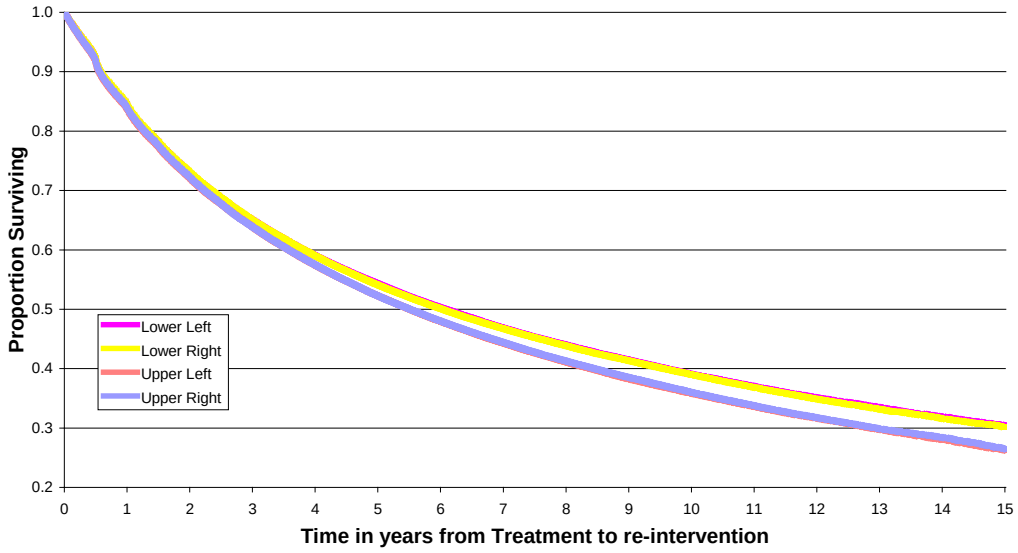
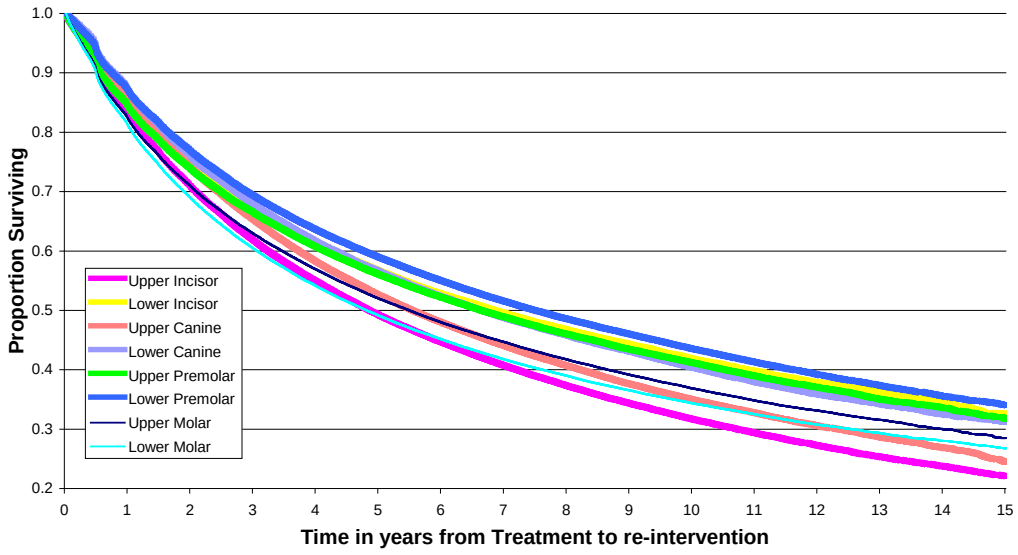


Table 4 Survival to Reintervention by Tooth Type

	Survival (%) at				
Tooth Type	1 year	5 years	10 years	15 years	n
Upper Incisor	84	49	32	22	196,773
Lower Incisor	86	57	42	32	90,022
Upper Canine	86	52	35	24	162,726
Lower Canine	87	56	40	31	95,509
Upper Premolar	84	56	41	31	211,427
Lower Premolar	87	59	43	34	277,276
Upper Molar	82	52	36	28	249,448
Lower Molar	81	49	34	26	309,385
All Restorations	84	53	37	28	1,592,566

Figure 4 Survival to Reintervention by Tooth Type



With regard to time to extraction of the restored tooth, it is apparent that teeth restored with GI in the lower arch survive *circa* five percentage points better at 15 years than those in the upper arch (Figure 5 and Table 5). This may be further explored in Figures 6 and 7 which present the influence of individual tooth position,

indicating that performance of GIs is best in first premolar teeth and least good in incisor teeth (Figure 6 and Table 6). The variation between upper and lower jaw within tooth type (Table 7 and Figure 7) demonstrates that performance of glass-ionomer is highly tooth-dependent.

Table 5 Survival to Extraction by Mouth Quadrant

	Survival (%) at				
Quadrant	1 year	5 years	10 years	15 years	n
Lower Left	98	91	84	79	393,699
Lower Right	98	90	84	79	378,493
Upper Left	97	89	81	75	409,819
Upper Right	97	89	81	76	410,555
All Restorations	97	90	82	77	1,592,566

Figure 5 Survival to Extraction by Mouth Quadrant

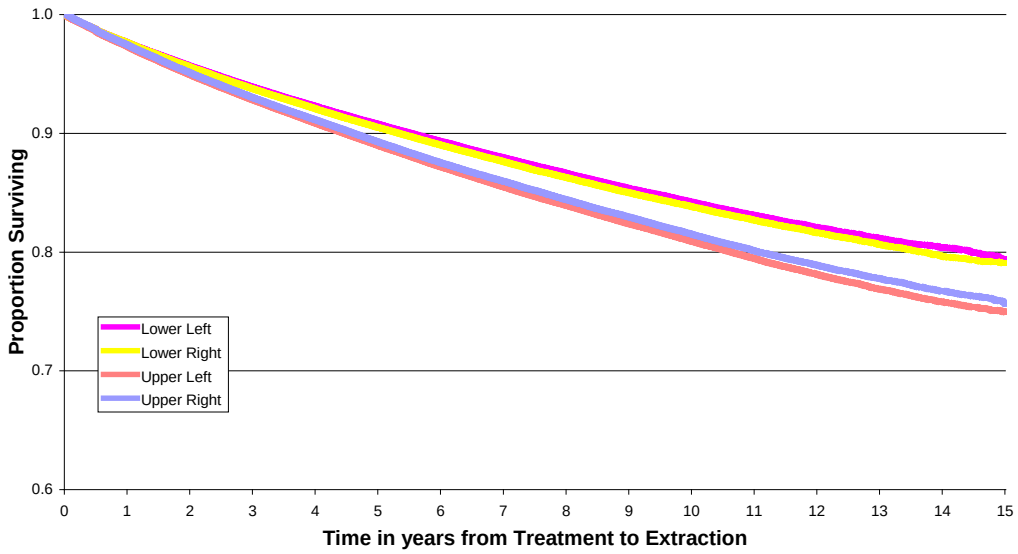


Table 6 Survival to Extraction by Tooth position

Tooth Position	Survival (%) at 1 year	5 years	10 years	15 years	n
tooth 1	97	89	80	74	140,258
tooth 2	97	87	78	72	146,537
tooth 3	98	90	82	76	258,235
tooth 4	98	92	86	81	267,530
tooth 5	98	90	83	78	221,173
tooth 6	98	91	84	80	275,335
tooth 7	97	89	81	76	214,575
tooth 8	96	86	78	73	68,923
All Restorations	97	90	82	77	1,592,566

Figure 6 Survival to Extraction by Tooth position

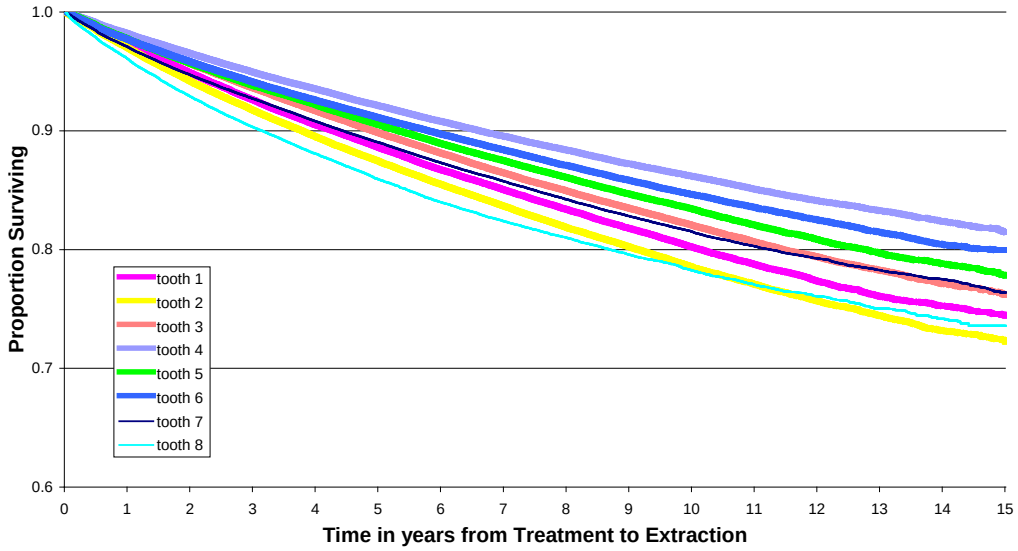
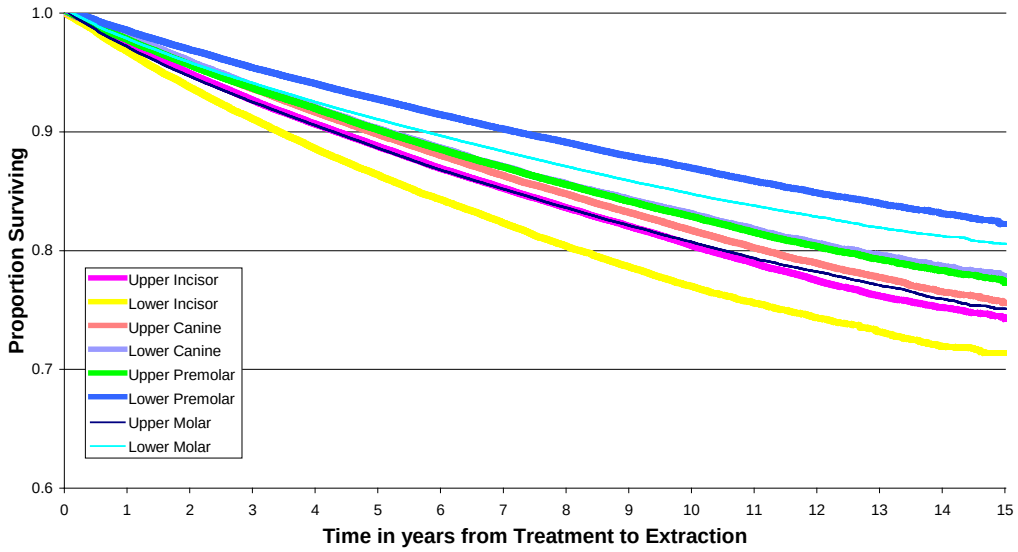


Table 7 Survival to Extraction by Tooth Type

	Survival (%) at				
Tooth Type	1 year	5 years	10 years	15 years	n
Upper Incisor	97	89	80	74	196,773
Lower Incisor	97	86	77	71	90,022
Upper Canine	98	90	81	75	162,726
Lower Canine	98	90	83	78	95,509
Upper Premolar	97	90	83	77	211,427
Lower Premolar	98	92	87	82	277,276
Upper Molar	97	88	80	75	249,448
Lower Molar	97	90	84	80	309,385
All Restorations	97	90	82	77	1,592,566

Figure 7 Survival to Extraction by Tooth Type



Influence of dentist factors

Gender of dentist was not found to have any influence with regard to overall survival of GI restorations, with age of dentist having only minimal influence, with younger

dentists' restorations surviving slightly longer than dentists in older age groups. When time to extraction is investigated, it is apparent that there was minimal influence of dentist age or gender.

Influence of patient factors

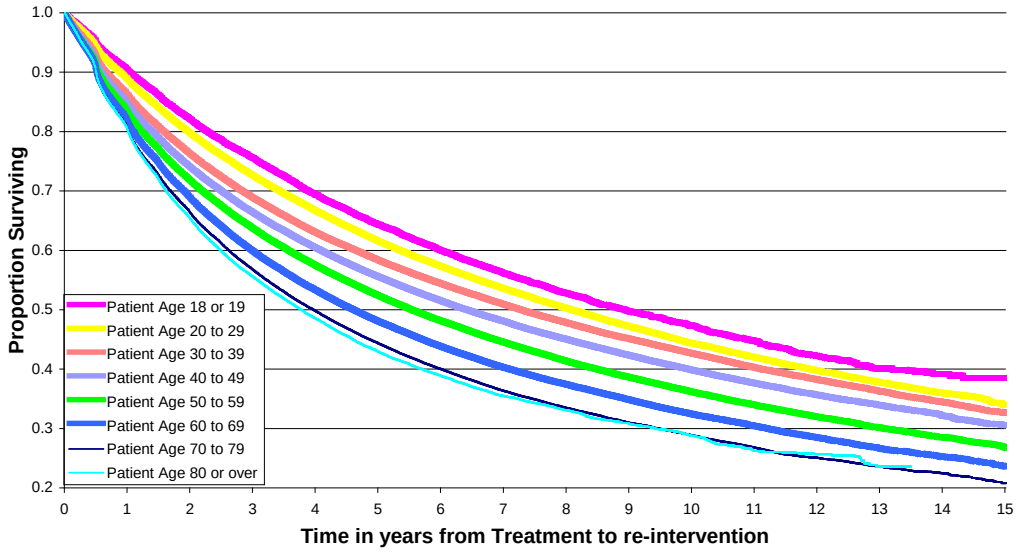
There was no difference in survival of GI restorations among male or female patients up to 10 years, after which restorations placed in females performed better.

	Survival (%) at				
Patient Age	1 year	5 years	10 years	15 years	n
18 or 19	91	64	47	39	19,202
20 to 29	89	62	44	34	151,104
30 to 39	86	58	43	33	266,822
40 to 49	85	56	40	31	314,967
50 to 59	83	52	36	27	317,039
60 to 69	82	48	32	24	274,780
70 to 79	81	44	29	21	182,325
80 or over	80	43	29	-	66,327
All Restorations	84	53	37	28	1,592,566

However, as observed with many other restoration types, GI restorations performed optimally in younger age groups of patients (Figure 8 and Table 8).

Table 8 Survival to Reintervention by Patient Age

Figure 8 Survival to Reintervention by Patient Age

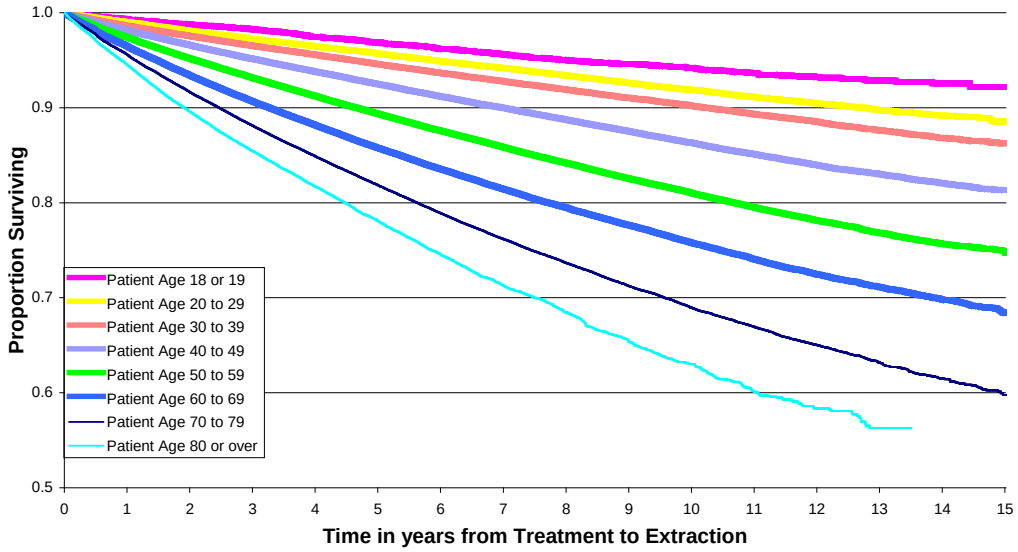


With regard to time to extraction of the restored tooth, this is two percentage points less in female patients than in male patients and a substantial difference of *circa* 30% was observed between the youngest and oldest patient groups (Fig 9).

Table 9 Survival to Extraction by Patient Age

Patient Age	Survival (%) at 1 year	5 years	10 years	15 years	n
18 or 19	99	97	94	92	19,198
20 to 29	99	96	92	89	151,104
30 to 39	99	95	90	86	266,822
40 to 49	98	92	86	81	314,967
50 to 59	97	89	81	75	317,039
60 to 69	96	86	76	68	274,780
70 to 79	96	82	69	60	182,325
80 or over	95	78	63	-	66,327
All Restorations	97	90	82	77	1,592,566

Figure 9 Survival to Extraction by Patient Age



Did the patient have to pay for treatment?

Patients who were exempt from charge or whose charge was remitted had restorations which survived two percentage points better at 15 years than those who paid the appropriate patient charge. However, with regard to time to extraction of the restored tooth, there was minimal difference between those who were charge payers and those who were not, although initially and up to 12 years, patients who were non-payers received restorations which performed better in terms of years to extraction, with the graphs reversing at *circa* 12 years.

Patient's state of oral health

Two different proxies for the patient's state of oral health have been considered: the annual average cost of GDS dental treatment for the patient, and the median interval between courses of treatment for the patient, given that it may be considered that patients with high treatment need will attend more often, and will have additional emergency attendances.

Average Annual Fees

Figures 10 and 11 show clearly that the patient's history of dental treatment is a major factor in determining the likely survival of GI restorations, both to time to reintervention (Figure 10) and time to extraction (Figure 11). For time to re-intervention, the difference, at fifteen years, is between 58% for those with low annual expenditure on dental treatment, and 17% for those with high annual dental treatment fees (Table 10). Looked at in terms of tooth loss, patients with high annual dental expenditure face a 31% prospect of losing any GI-restored tooth within 15 years, compared with 9% for patients with low annual dental fees (Table 11).

Table 10 Survival to Reintervention by Patient Mean Annual Fees

	Survival (%) at				
Mean Annual Fees	1 year	5 years	10 years	15 years	n
Up to £20 per annum	94	81	70	58	96,402
£20 to £60 per annum	86	60	44	34	753,318
Over £60 per annum	79	41	25	17	692,715
All Restorations	84	53	37	28	1,592,566

Figure 10 Survival to Reintervention by Patient Mean Annual Fees

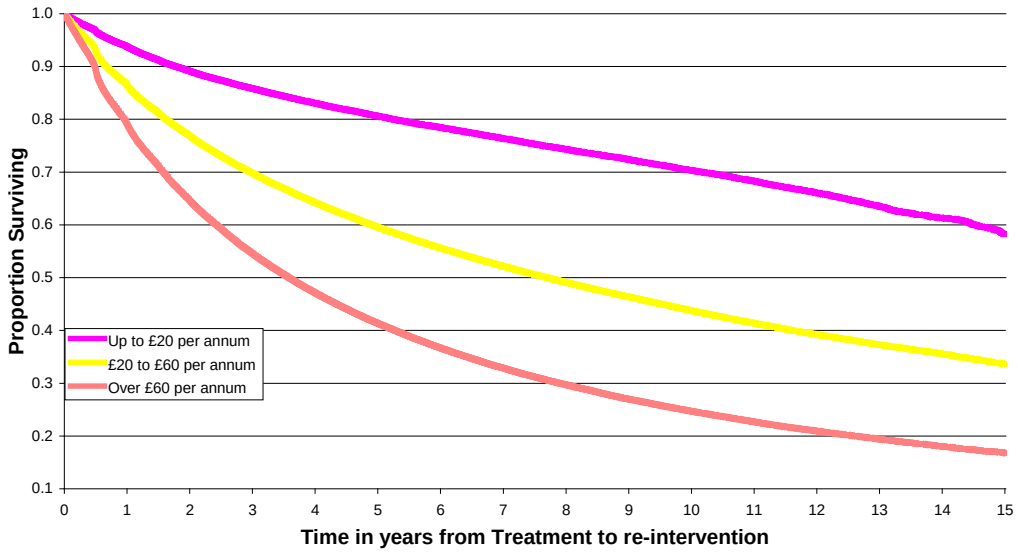
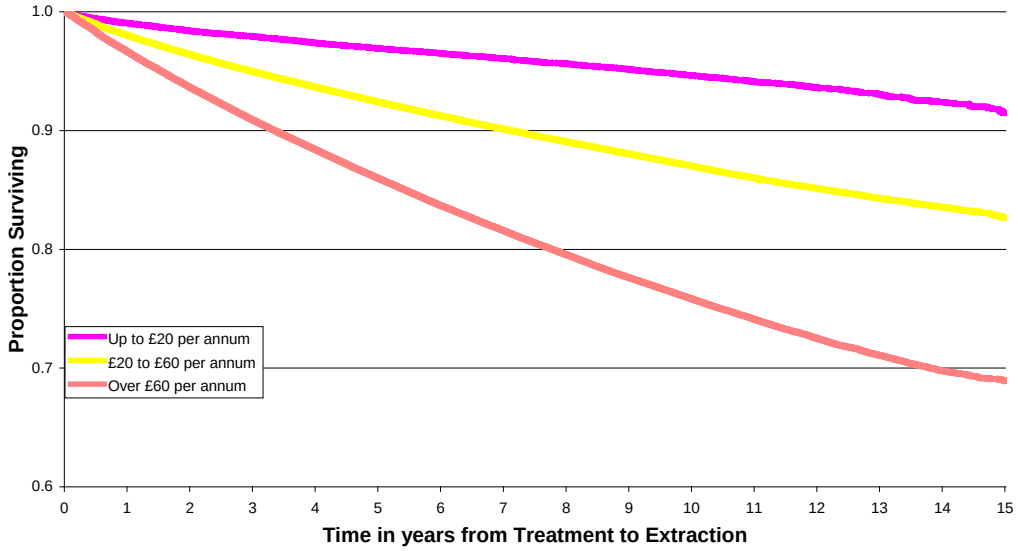


Table 11 Survival to Extraction by Patient Mean Annual Fees

	Survival (%) at				
Mean Annual Fees	1 year	5 years	10 years	15 years	n
Up to £20 per annum	99	97	95	91	96,402
£20 to £60 per annum	98	92	87	83	753,318
Over £60 per annum	96	86	76	69	692,715
All Restorations	97	90	82	77	1,592,566

Figure 11 Survival to Extraction by Patient Mean Annual Fees for teeth restored with GI



Median interval between courses of treatment

Figures 12 and 13 show that patients who attend more frequently than once every six months have worse outcomes by ten percentage points or more, in terms of survival of GI restorations over periods of up to 15 years, than those who attend at longer intervals.

Table 12 Survival to Reintervention by Patient Median Attendance Interval

	Survival (%) at				
Median Attendance Interval	1 year	5 years	10 years	15 years	n
up to 190 days	78	44	29	22	693,394
190 to 380 days	87	57	41	32	682,615
over 380 days	96	73	54	37	166,426
All Restorations	84	53	37	28	1,592,566

Figure 12 Survival to Reintervention by Patient Median Attendance Interval

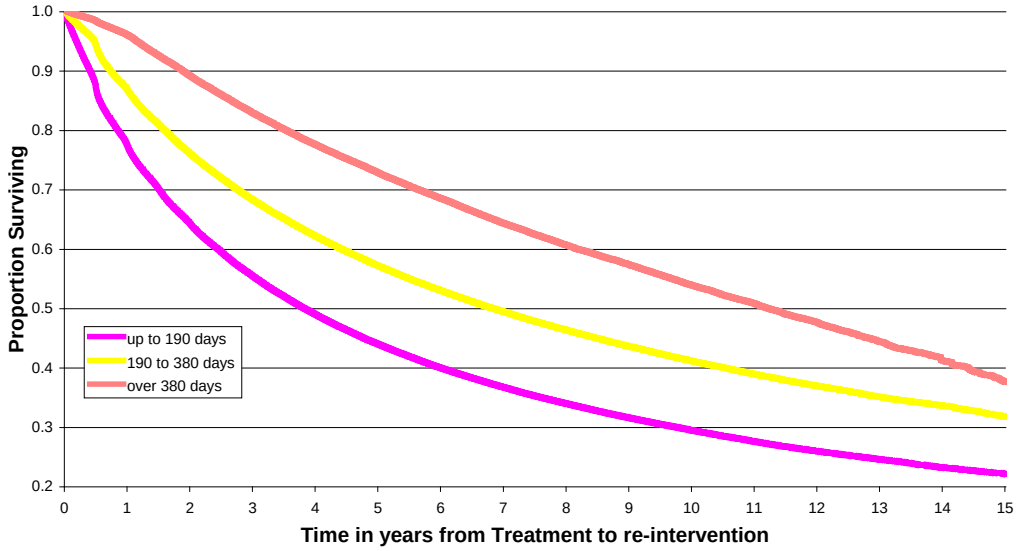
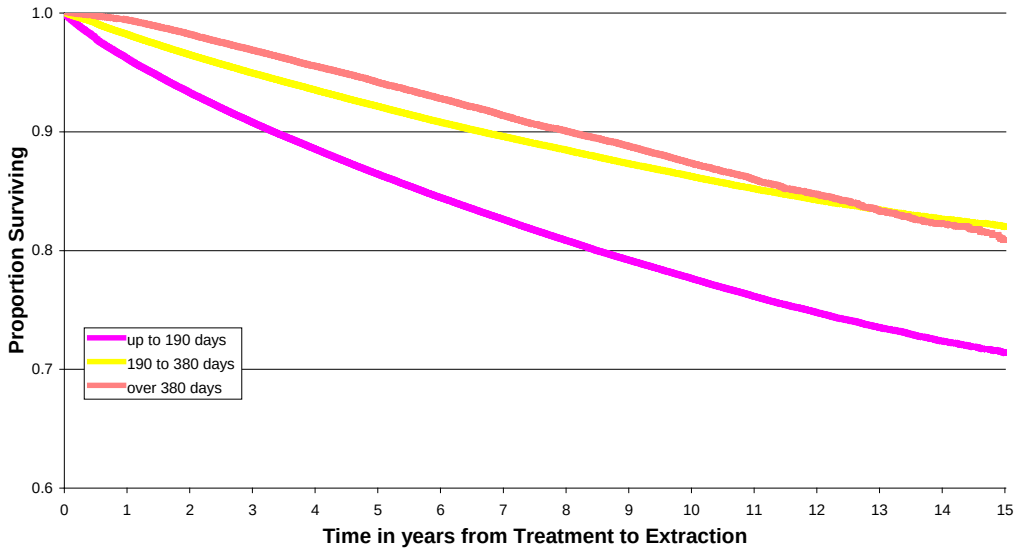


Table 13 Survival to Extraction by Patient Median Attendance Interval

	Survival (%) at				
Median Attendance Interval	1 year	5 years	10 years	15 years	n
up to 190 days	96	86	78	71	693,394
190 to 380 days	98	92	86	82	682,615
over 380 days	99	94	87	81	166,426
All Restorations	97	90	82	77	1,592,566

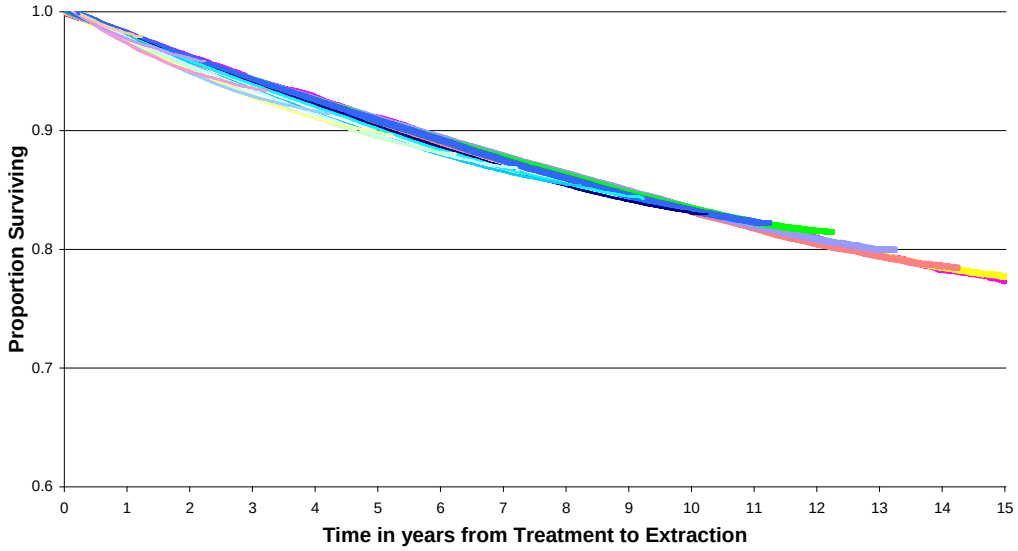
Figure 13 Survival to Extraction by Patient Median Attendance Interval of teeth restored with GI



Other factors

When the data are analysed with regard to year of placement of the glass-ionomer restoration, no major differences are apparent, either in terms of time to re-intervention or time to extraction of the restored tooth, between restorations placed in 1990 and those placed in 2006, and the years between these (Figure 14). In particular, there is no indication of any improvement over that time period.

Figure 14 Survival to Extraction by Year of Acceptance



However, when the effect of placement of a root canal filling in the same course of treatment as the GI restoration is examined, the charts indicate substantial effects with regard to time to re-intervention and time to extraction of the restored tooth. The probability of re-intervention within fifteen years is increased by five percentage points (Figure 15 and Table 15) and that of extraction of the root filled restored tooth is increased by eight percentage points (Figure 16 and Table 16).

Table 15 Survival to Reintervention by Whether a Root filling was placed

	Survival (%) at				
Root filling in same course	1 year	5 years	10 years	15 years	n
root filled	80	48	31	23	34,637
root not filled	84	53	38	28	1,557,929
All Restorations	84	53	37	28	1,592,566

Figure 15 Survival to Reintervention by Whether a Root filling was placed

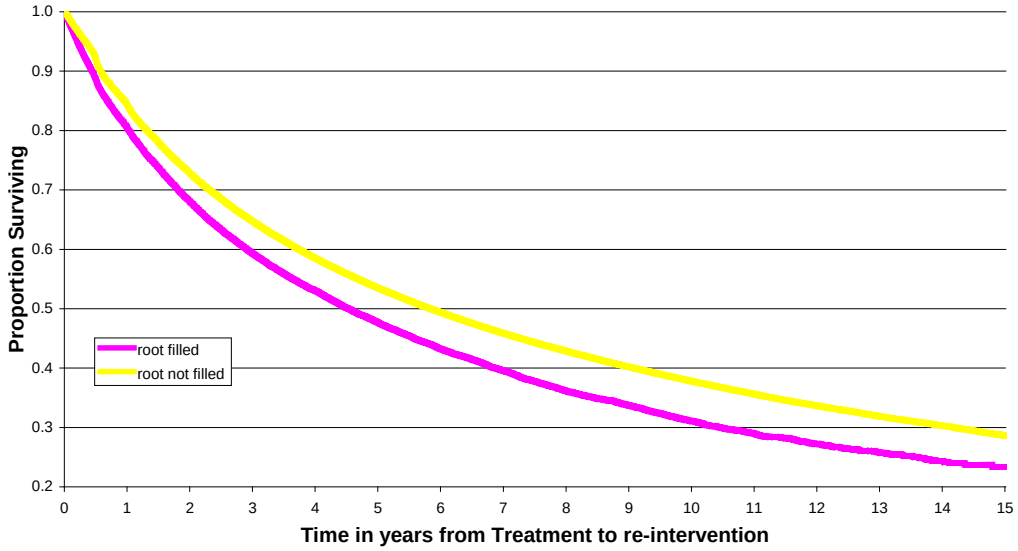
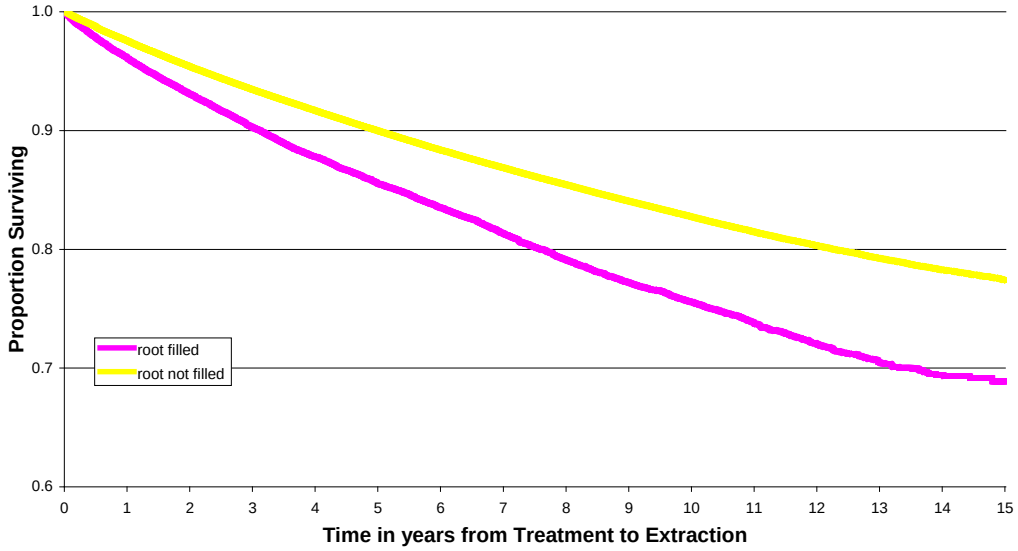


Table 16 Survival to Extraction by Whether a Root filling was placed

	Survival (%) at				
Root filling in same course	1 year	5 years	10 years	15 years	n
root filled	96	86	76	69	34,637
root not filled	97	90	83	77	1,557,929
All Restorations	97	90	82	77	1,592,566

Figure 16 Survival to Extraction by Whether a Root filling was placed



Discussion

With 25 million courses of treatment being linked over 15 years, the dataset used in this work is the largest ever to become available for work on dental treatment. This is the first publication on glass ionomer restorations related to the interrogation of this dataset. Because of the size of the dataset, not only can complex interactions be explored, but the robustness of resultant models and algorithms can be tested by replication.

When interpreting the results, it should be borne in mind that the General Dental Services Regulations in force at the time of the present study precluded the use of Glass Ionomer (GI) materials in loadbearing situations, in other words, the cavity types under investigation were Class III and class V, thus rendering direct comparison with amalgam restorations (which may be placed in loadbearing situations) inappropriate, although it may be considered that restorations placed under the forces of occlusal loading may be more prone to failure than those which are not. Notwithstanding this, GI restorations were found to perform suboptimally when compared with other restoration types and it may be considered that this is

related to (a) the material's properties and (b) the clinical situations in which these materials are used. With regard to the properties of GI, its modulus of elasticity is low, at least in comparison to resin composite and amalgam, this precluding its use under conditions of heavy occlusal load, but making them appropriate for class V restorations, given that it has been considered that this area of the tooth may flex under occlusal load[9]. Notwithstanding that, however, GI restorations have performed suboptimally overall. One saving grace might be that such restorations may be placed in class V non-carious cervical cavities with no or minimal preparation: in other words, no preparation damage to the tooth has occurred and the restoration may be replaced at no or minimal cost, in terms of tooth substance, to the tooth. There also a consideration that dentists may use GI in clinical situations where they consider that the prognosis of the tooth is uncertain[10], or, anecdotally, as a last resort, thereby reducing the overall data on survival, this factor possibly being reflected in the results from the present work which indicated that *circa* 23% of teeth restored with GI were extracted at 15 years.

The results indicate better performance of GI restorations in the lower arch than in the upper and that GI restorations survive optimally in premolar and lower incisor teeth and least well in upper incisor teeth. This may relate to the placement of GI, a fluoride-releasing material, in upper incisor teeth rather than resin composite for patients with high perceived caries activity, despite the fact that the effect of GI materials upon cariostasis has been called into doubt[5]. Nevertheless, it is clear that, for GI restorations at least, tooth position and dental arch interact in their relationship with restoration survival.

There is little influence of patient gender and dentists' gender in survival of GI restorations either *per se* or in years to extraction, but large differences are apparent with regard to patient age in respect of years of the restored tooth to extraction, with circa 30% percentage points difference between younger and older patients. This again might be considered to indicate that clinicians place GIs in situations in older patients where clinicians consider that the prognosis of the tooth is guarded.

With regard to patients who are exempt from payment for treatment, the data with regard to GI bucks the normally seen trend of patients who are non-payers having restorations which perform less well. This might relate to patients in the lower socio-economic groups (who may be exempt from payment) also having poorer oral health[10]. In the present work on GI restorations, patients who were exempt from charge had restorations which survived better at up to 12 years than those who paid the appropriate patient charge, albeit with restorations in the non-payer group finishing worse at 15 years. This trend is repeated in the chart relating to time to extraction of the restored tooth, again with the graphs reversing at *circa* 12 years. This is an interesting finding, although it should also be noted that the difference between charge-payers and those with exemption or remission was small.

Regarding the type of GI material employed by clinicians in the present study, the collection of data commenced in 1991 and continued until 2006. This would tend to indicate that the GI materials utilized will more likely have been conventional GIs at the commencement of the study, rather than the more recently-introduced resin-modified (RMGI) and reinforced GIs later in the work. However, as is indicated in Figure 14, there is no improvement in the performance of GI restorations placed at

the start of the data collection compared with those placed later. This might be considered surprising, given the improvements in GI materials during that time (as described in the introduction), but might also indicate that the majority of dentists in the study had not implemented the use of newer materials into their clinical practice. In this regard, the result of recent research[12], in which 1,000 Class V restorations were followed for 5 years in dental practices in the West Midlands (England), restorations formed in RMGI outperformed conventional GIs in terms of restoration survival by over 20%.

Conclusions

The survival time of GI restorations to re-intervention and in time to extraction of the restored tooth was found to be less good than other restoration types. This was influenced by the age of the patient and the position of the restored tooth in the mouth, with restorations in lower premolar teeth performing best.

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