

Long-term survival characteristics of 832 resin-retained bridges and splints provided in a post-graduate teaching hospital between 1978 and 1993

S. DJEMAL, D. SETCHELL, P. KING & J. WICKENS *Department of Conservative Dentistry, Eastman Dental Institute for Oral Healthcare Sciences, University of London, U.K.*

flSUMMARY The clinical performance of 832 resin-retained bridges and splints provided in the adult fixed prosthodontic clinic of a post-graduate teaching hospital was reviewed. Recall data was available for 58.4% of cases and the median survival was 7 years and 10 months. Analysis of clinical variables influencing survival revealed that the design and retainer coverage were significant factors. The experience of the operator carrying out treatment also

had a pronounced effect which was not readily explained in terms of the distribution of other significant factors. Resin-retained restorations made with minimal tooth preparation are shown to be capable of extended clinical service and their failure rarely resulted in adverse consequences for the patient. Patient satisfaction with their treatment was reportedly high.

Introduction

Reports of the clinical performance of resin-retained bridges and splints, including a number of meta-analyses, are common in the dental literature and the reasons for wishing to present data as quickly as possible are easy to appreciate. However, many published reports relate to small numbers of restorations followed up for periods that may be questionable as to their ability to enable failures to be seen in perspective. The recommendations regarding factors having an impact on longevity therefore appear somewhat contradictory.

This report was conceived as an attempt to document the results of a substantial sample provided in a single clinical setting over a period long enough to enable the effects of technical and clinical variables to be analysed with subgroups large enough for meaningful statistical analysis. It was not intended to be a prospective trial with controlled allocation of patients to specific design or material classes. Rather, it represents a large-scale audit of cases treated by what clinicians believed at the time to be methods that would lead to the best prospect of survival for each patient.

The limitations of such an approach are obvious and are discussed, but the relevance to realistic clinical practice is equally clear.

Method

Sample

The patients studied were drawn from all recorded individuals receiving a resin-retained cast bridge or splint restoration in the adult restorative departments of the Eastman Dental Hospital between June 1978 and December 1993. Records were retrievable for 1015 patients identified as recipients of resin-retained castings. Only those patients for whom outcome information could be updated between April 1994 and July 1994 were included in the analysis. A total of 832 restorations were followed up in 593 patients. The resulting overall recall rate (by patient) of 58.4% compares favourably with other studies of this type.

A total of 193 men and 400 women participated in the study and their ages ranged from 15 to 86 years. All had been referred for treatment by their general

dental practitioner. In most cases the resin-retained restoration was a fixed bridge, but the sample included many individuals who had received orthodontic treatment for anterior tooth migration in adult life and required subsequent 'fixed' retention. Also included were patients referred from a multidisciplinary clinic for management of young adults with hypodontia. Some patients received more than one restoration, but it was decided that analysis should be performed by restoration rather than by patient on the grounds that multiple restorations in one individual were by definition at different sites and usually inserted at differing times. Thus, the scope for variations in technique, materials, operator and biomechanical environment was considered as great as if the bridges had been in different patients.

All patients remained under the care of a general dental practitioner and in many cases routine recalls were made to the general practice rather than the hospital. However, by agreement patients returned or were referred back to the hospital whenever maintenance was required to restorations originally provided there.

Every effort was made to see all patients between April and July 1994 for completion of the survey records; patients who had not returned for routine recall were given appointments specifically for the survey. Where this failed, contact was attempted by telephone or mail to patients or their general dental practitioners to ensure that restorations were either in service at the survey date of 31st July 1994 or were known to have failed at a documented time. Inevitably, given the characteristics of a city-centre clinic, many patients could not be contacted. However, the follow-up rate analysed by restoration remained high even for older restorations. In 1985 174 restorations were available for recall from the total placed between 1981 and 1985 and at the end of the study 145 (83.3%) were still included in the sample.

Constructional details

The period of study covers virtually the entire development of resin-retained cast restorations at the Eastman Dental Hospital. In the first 4 years most of the restorations were made using non-beryllium-nickel-chromium alloys Wiron[®] 77* or Unibond[®]† and had

* Krupp, Essen, Germany.

† Unitek, Monrovia, CA, U.S.A.

perforated retainers attached with two-paste restorative composite resin (Concise[®]‡) frequently diluted with the same manufacturer's unfilled resins to reduce viscosity. During 1982 there was growing interest in electrochemical etching as the means of metal preparation and a move to purpose-made luting resins such as Comspan[®]§, Conclude[®]¶ and Kerr C&B[®] adhesive**. Beryllium-containing alloys were not used as a result of local health and safety restrictions and during 1983 Howmedica[®] NP2†† was introduced as a non-beryllium alloy that etched satisfactorily. There followed a period in which many variations of technique were used, including combinations of perforation, electrochemical etching and macromechanical retention using the Virginia salt and crystal bond methods. A small number of cases were attached using light-cured composite resin (Silux[®])‡ until the difficulties of complete illumination and curing were appreciated.

This period of experimentation ended in early 1985 when electrochemical etching was abandoned and a change occurred to unperforated retainers abrasive-blasted with 50 µm alumina and luted with the chemically-adhesive resin Panavia[®] Ex††. The alloy currently used with this technique is Panabond[®] NP§§. This technique was by far the most popular and remained in use until the end of the current period of study, at which time a reformulated version of Panavia[®] was introduced by the manufacturer (Panavia[®] 21).

Collection of data

Recall examination clinics were conducted by three of the authors. The patients were examined by one clinician only unless there was doubt about coding of the restorations. Collection of the data involved the

‡ 3M Dental Products, Loughborough, U.K.

§ L.D. Caulk Co., Milford, DE, U.S.A.

¶ 3M Dental Products, Loughborough, U.K.

** Kerr Sybron Corporation, Romulus, MI, U.S.A.

†† Howmedica, Enfield, Middlesex, U.K.

‡‡ Kuraray, Japan.

§§ Panadent, London, U.K.

use of a pro forma chart matching a dBASE IV^{¶¶} database designed for the study and running on an IBM-compatible PC.

A chart incorporated in the record form enabled the abutments and pontics to be identified together with retainer and connector type, all of which were entered as alphabetic characters. The sequence of characters could then be concatenated to produce a concise description of each restoration, e.g. APA would represent a three unit bridge with one pontic and two abutments. In the analysis, the character strings and associated fields revealed not only the arch, site and number of units for each restoration but could be manipulated by the statistical software to give a more detailed breakdown of the designs employed. Provision was made for a descriptive character string to be entered directly by the examining clinician where atypical numbers of pontics (e.g. three pontics in a space where two teeth were missing) or the inclusion of supernumerary abutment teeth could not be accommodated by the chart.

In addition to the design information the examiners recorded a variety of clinical information considered to have possible relevance to the survival of the restorations. The clinical record and radiographs were used in addition to clinical examination. The objective criteria for each score or category were agreed at the outset and incorporated into an aide-memoire for use at the chairside. The data items used are described in the results section together with an account of the record form used and the relevant descriptive statistics. The observations did not in general call for judgement on the part of the observer and interoperator standardization was not performed. However, if there was doubt as to a particular result, more than one examiner would confer to decide the score.

Where older restorations had failed early in their service life it was sometimes impossible to verify data for certain of the clinical observations, e.g. the extent of pre-existing restorations in abutment teeth, unless these had been adequately recorded at the time the restoration was first fitted. This meant in practice that up to 52 restorations were excluded from the analysis of certain factors.

Table 1. Simple design distribution of restorations included in study

Design category	<i>n</i>
Fixed-fixed	424
Cantilever	171
Hybrids/movable connectors	38
Splints	199

Finally, each patient was asked to indicate whether or not they were satisfied with the appearance and function of their restoration and any specific areas of dissatisfaction were noted.

The information was then transferred to the micro-computer database by a single operator. The completed database was then subjected to extensive error checks before transfer to a SAS^{***} dataset for statistical analysis.

Results

Design

There were 832 restorations in the sample. There were 2146 adhesive retainers, 56 conventional retainers and 980 pontics. Of the connectors, 1933 were rigid and 56 were movable.

Six-hundred and four restorations were classified as anterior, 125 as posterior and 103 involved both anterior and posterior abutments; 638 were in the maxilla

Table 2. Elaborate design distribution of restorations included in study

Design—detailed category	<i>n</i>
Cantilevers—one abutment, one pontic	120
Cantilevers—two abutments, one pontic	25
Cantilevers—more than three units	26
Fixed-fixed—three units	265
Fixed-fixed—four units	110
Fixed-fixed—five units	21
Fixed-fixed—six units	28
Hybrid—one conventional and one resin bonded retainer and one pontic with movable connector	21
Splint—six units or more	116
Splint—less than six units	26
Splint—modified to include pontics or conventional units	57
Other	17

¶¶ Ashton Tate(UK), Maidenhead, Berks, U.K.

*** Release 6.08, SAS Institute, Cary, NC, U.S.A.

Table 3. Number of resin-retained restorations included in study for four intervals since 1978

Date range	<i>n</i>
1978–80	10
1981–85	145
1986–90	357
1991–94	329

and 194 in the mandible. The design distribution is shown in Table 1.

These design categories were subdivided according to number of retainers, number of pontics and connector type as shown in Table 2.

The dates when the restorations were fitted and inspected for the purposes of this study were recorded. Table 3 shows the number of resin-retained cast restorations included in the study for each of four intervals since 1978.

Aetiology

In the majority of cases the aetiology of the situation requiring a resin-retained restoration was known. However, in 52 (6.2%) cases this was uncertain. Management of hypodontia necessitated 276 (33.2%) of the restorations, 152 (18.3%) were adjunctive to adult orthodontic treatment and the remainder were part of the management of traumatic injury 101 (12.1%), dental caries and sequelae 53 (6.4%) and periodontal disease 198 (23.8%).

Operator

There were three operator types: senior staff, which included hospital consultants and senior university lecturers; post-graduate students providing treatment under supervision and junior staff (clinical staff in training grade appointments). Senior staff provided 436 (52.4%) of the restorations while junior staff and post-graduate students provided 238 (28.6%) and 158 (19%) of the restorations.

Constructional details

Tooth preparation

This was scored as a simple 'yes/no' response with the

intention that yes should be assigned whatever the extent of tooth reduction. The general approach at the Eastman Dental Hospital has consistently been that tooth preparation should be kept to an absolute minimum. Anterior teeth were frequently not prepared at all (303, 50.2%), whereas the majority of posterior abutments were modified for axial guide plane 'wrap-around' and occlusal rest seats or more extensive occlusal coverage (102, 81.6%). The number of restorations involving tooth preparation (375, 45.1%) was approximately the same as the number for whom no preparation was recorded (348, 41.8%) and there were 109 (13.1%) cases in which it was not possible to ascertain to what extent preparation had been used.

Coverage

There has been a tendency to increase tooth surface coverage as a result of early experience with minimal retainers. For anterior teeth the retainer coverage was scored:

- 1: Minimal palatal coverage.
- 2: Generous palatal coverage but no extension onto the incisal edge.
- 3: As 2 but all or part of the incisal edge was covered.

Incisal coverage was present in 235 (33.2%) of cases and 447 (63.2%) were scored 2 out of a total of 707 involving anterior retainers.

Of the 228 cases involving posterior abutments, 10 (4.4%) had minimal axial coverage only, 82 (36%) had axial coverage combined with occlusal rests whereas 89 (39%) had more extensive occlusal coverage. Reliable coverage information was not available for 47 (20.6%) of cases.

Restoration of abutments

Four-hundred and forty (76.4%) of cases had no previous restorations involving the area of retainer coverage whereas 136 (23.6%) had retainers that were partially attached to restorative materials, amalgam and/or composite resin in posterior teeth and composite resin in anterior teeth. (data was not available for 256 cases). Restorations were replaced before accepting them as substrates for retainers. No attempt was made to estimate the proportion of retainer area involved. Clinicians attempted wherever possible to

extend retainers onto tooth surfaces beyond restoration margins.

Framework alloy

The majority of the restorations (812, 97.6%) were made from nickel–chromium alloys already described, whereas 11 (1.3%) were made from noble alloys and nine (1.1%) had no alloy type recorded.

Retainer type

One-hundred and five (12.6%) of the restorations used perforated retainers whereas 727 (87.4%) were unperforated.

Metal preparation

Abrasive blasting of retainers was used in 688 (82.7%) of cases and electrochemical etching in 50 (6%) of cases. The remainder (94, 11.3%) were prepared with either salt wash out, tin plating or unspecified.

Luting resins

The wide range of luting resins used is shown in Table 4. All three colours of Panavia® Ex were recorded. Regular Panavia® Ex was used for the majority (308, 51.0%) of anterior situations followed by opaque (115, 19.0%) whereas tooth-coloured was selected in 22 (3.6%) cases. Regular Panavia® Ex cement was used in 157 (72%) of the posterior cases.

Relevant clinical data

Anterior occlusal relationship

The incisor relationship was noted (Table 5) according to orthodontic criteria.

Table 4. Distribution of cements used

Resin cement	<i>n</i>
Panavia® Ex	638
Concise®	48
Comspan®	38
Silux®	10
Other	34
Unknown	64

Table 5. Incisor relationship and restoration distribution

Incisor relationship	<i>n</i>
Class I	390
Class II div 1	160
Class II div 2	47
Class III	64

Opposing dentition

The nature of the occlusal surfaces opposing the restorations was noted. In a large majority of cases it was the natural dentition (715, 85.9%) and in 96 (11.5%) it was other bridgework. An opposing partial denture was present in 17 cases (2%) and the remaining four (0.5%) were opposing an edentulous span.

Occlusal contacts in the intercuspal position (ICP) were noted for all designs of prostheses. All of the posterior restorations had at least one intercuspal contact. Intercuspal contact (i.e. a complete overbite) was present in 511 (72.3%) of bridges involving the anterior segments while 143 (20.2%) exhibited an incomplete overbite and were not contacted in the ICP. In 53 (7.5%) of anterior cases, the presence or otherwise of ICP contact was uncertain.

Restorations were examined, with shim stock or marking media where indicated, to establish whether they were involved in tooth contacts during protrusive or lateral excursions of the mandible. In 50 cases this information was unavailable. An overall classification was scored negative where there was no such contact (125, 15.9%) and positive where it was present (659, 84.1%). The largest proportion of restorations with eccentric contacts (83, 88.3%) occurred, not surprisingly, in the 'both anterior and posterior' group which usually included the canine. Anterior cases had 477 (83.8%) with eccentric contacts whereas the proportion of posterior cases which were free of contact in excursive movements was surprisingly small. Ninety-nine (81.8%) of posteriors had at least one position in which contact was recorded away from ICP.

Whether excursive contact occurred on retainers or on pontics was recorded as shown in Table 6.

Previous orthodontic treatment

Where orthodontic tooth movement had been undertaken as part of an overall treatment plan prior to

Table 6. Eccentric contacts on retainers and pontics noted

Occlusal contact in excursive movements		
	Retainer	Pontic
Present	582	397
Absent	200	385

construction of the resin-retained restoration this was recorded. The proportion of restorations in this group (465, 55.9%) is uncommonly high and reflects the number of cases that were either adjunctive to an orthodontic treatment plan, involved hypodontia, or were to stabilize repositioned teeth in patients being treated for chronic marginal periodontitis. Multi-disciplinary treatments form a large part of the workload of a post-graduate teaching hospital.

Patient satisfaction

An enquiry into how the patients felt about their restorations revealed that the 730 (88%) rated the appearance good, 88 (10.6%) satisfactory and the remaining 12 (1.5%) were not happy. Corresponding replies in relation function showed 788 (94.9%) felt that function was good, 39 (4.7%) satisfactory and three (0.4%) felt that their restorations were unsatisfactory. In two cases responses were not available.

Failures (Table 7)

Criteria

Failure was defined as any significant adverse event related to the restoration requiring remedial treatment or a remake. Thus, the intentional removal by the dentist of a restoration used as an interim replacement, or caries arising in some part of an abutment tooth not

Table 7. Numbers and types of failures seen

Failure mode	<i>n</i>	%
Debond	209	91.7
Fractured metal	8	3.5
Other modes	7	3.1
Caries	3	1.3
Fractured porcelain	1	0.4

related to a retainer margin, were not regarded as failures.

Simple failure statistics

The authors feel that 'percentages of failures' or 'annual failure rates' have limited value in describing the behaviour of a group in which the restorations have ages ranging from 1–16 years. However, such figures are commonly quoted and for the present sample 27.88% of the restorations experienced a failure. Further discussion of failures may be found in the section on 'Survival analysis' below.

The modes of failure observed were:

Debond: One or more adhesive retainer became detached from its abutment. No attempt was made to distinguish between failure at the metal–resin or resin–tooth interfaces, nor to identify cohesive failure within the luting agent. All of these phenomena have equivalent implications for immediate management, if not for corrective measures to be taken in the construction of future retainers. Moreover, as resin adhesives have improved, all three failure modes are commonly seen affecting a single unit.

Since modification or removal-and-rebonding of debonded units is often possible, this definition of failure does not imply that the useful life of the restoration has ended. It does, however, conform to what is usually perceived by patients and clinicians (particularly those critical of resin-retained restorations) as a failure.

Caries: Caries requiring treatment and affecting the area under or immediately adjacent to a retainer was classified as a failure regardless of whether or not a debond had also occurred.

Fracture of porcelain: Any cohesive or ceramic–metal bond failure of a unit counted as a failure if it necessitated a repair or remaking of the prosthesis. Small chips or defects observed by the clinician that did not compromise the survival or function of the prosthesis and could be managed by simple smoothing or no treatment at all were identified but not classified as failure events.

Fractured metal framework: Any structural failure of the metal framework with implications for the survival of the restoration was included. Abrasion of occluding areas with minor loss of thinned metallic margins was

not included unless it was associated with a bond failure, in which case it was classified as a debond.

Other: Any case in which alteration or replacement of a restoration became necessary for reasons not classifiable as one of the above. This might include removal at a patient's request because the appearance was no longer acceptable, development of a pontic/residual ridge discrepancy with time, or periodontal loss of an abutment.

Failures classified as 'Other' included two restorations lost through generalized periodontal bone loss including the abutments, two rejected after a period of service for unacceptable appearance, one lost after root fracture of the conventional abutment of a hybrid design, one due to accidental trauma and one remade because the margins were considered unacceptably poor after 25 months of service.

Patients' awareness of failure

Patients were questioned to see whether they were aware of any problems with their resin-retained restorations at recall. In 180 cases where clinical examination revealed a failure the patient had correctly reported that the restoration did not feel quite right before being told of the failure. However, failure of 48 restorations occurred without any awareness by the patient that there was a problem. In view of the emphasis which is frequently placed on the need for patients to return if they think a restoration is debonded, this number is a concern. Unfortunately no inferences can be drawn about the number of patients who believed that there was a problem when in fact there was none.

Of the 180 who correctly reported a problem, only 11 were able to associate a specific activity with the failure. The reported activities were eating, clenching or grinding, and an accidental heavy contact.

Time of failure

The failure date was recorded as accurately as possible, taking into account recall intervals and the unawareness by some patients that a failure had occurred.

Action

The remedial action taken as a result of failure was

Table 8. Action taken for failed restorations

Remedial action	<i>n</i>
Recemented	139
Sectioned	44
Remade	33
Repaired	4
Remade as conventional	3
Unknown	5

recorded as were any subsequent failures and their outcome. In the present study only the first failure is reported (Table 8). Analysis of the survival of modified or rebonded restorations will form the basis of a later report.

Survival analysis

The objective of survival analysis was to characterize the service life that might be expected from restorations of the present type and to determine which of the clinical factors already described might exert a statistically significant effect on their survival. The difficulties of survival analysis have been discussed. For the present study, the SAS[®] dataset was checked thoroughly for internal errors (such as 'failure date before date inserted') and the survival time was calculated as the interval between fit date and failure for restorations that had failed, or the interval between fit date and last examination for those which had not yet failed and were therefore right-censored.

The life table approach is a rational method to analyse survival in a study of the present kind. Table 9 shows the life table derived from the data and column A represents the year intervals from the first, which is by definition entered by all 832 restorations. Column B shows the number of restorations at risk at the start of each year. Column C shows the number of failures in each year and column D the number of cases censored, i.e. either withdrawn from the study or not yet failed at the closing date. The number of restorations entering each year of service naturally falls until from year 12 only a handful remain. The reader should appreciate that this is not because the numbers have dwindled through failure, it is because relatively few restorations may have been in place long enough to enter that year of service in the first place. Column E shows the percentage of the number at risk at the start of each

year of service which failed during that year. It is remarkably uniform during the first decade of service.

Univariate (Kaplan–Meier) analysis

The Kaplan–Meier method resembles the life table except that the fixed intervals are replaced with intervals determined by failure events themselves. The usual expression of these calculations is in the form of a stepwise graph which has time on the horizontal axis and the survival function (SDF) on the y axis. The SDF expresses the probability that any individual restoration in the sample will have a life span exceeding the corresponding time on the plot.

Figure 1 shows the Kaplan–Meier survival plot for all of the data. It may be seen that considering the whole sample group there was a 50% probability of a resin-retained restoration made at the Eastman lasting more than 94 months (7 years and 10 months). It does not imply that after 180 months only 0.18 of the original number of restorations survives, although such a misinterpretation is commonly made.

Effects of survey variables on survival

A univariate analysis was performed using Proc Lifetest to produce log rank statistics and comparative survival

Table 9. Life table showing for each year of service the number at risk at the start of year, the number of failures and the number of censored restorations

Year	At risk	Failures	Censored	% Failures/At risk
A	B	C	D	E
1	832	61	86	7.33
2	685	43	129	6.28
3	513	34	116	6.63
4	363	32	77	8.82
5	254	16	64	6.3
6	174	15	40	8.62
7	119	11	21	9.24
8	87	8	13	9.2
9	66	5	19	7.58
10	42	2	17	4.76
11	23	3	11	13.04
12	9	0	5	0

The percentage of restorations failing in each period expressed as a proportion of those at risk (right hand column) is relatively uniform. The number at risk for the longer service intervals is dramatically smaller than at the outset, demonstrating the fallacy of relating cumulative failures to the initial sample size.

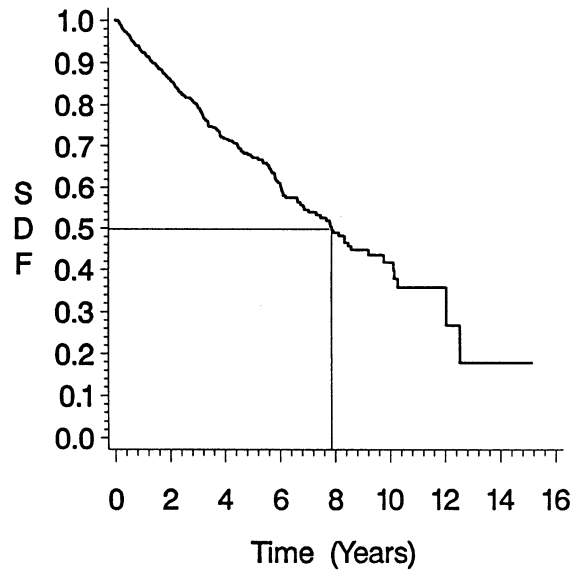


Fig. 1. Kaplan–Meier survival plot for all 832 restorations. The survival distribution function is 0.5 for a survival time of 7 years and 10 months, indicating that the probability of any individual restoration in the sample lasting for a longer period is one half. This value is commonly referred to as the median survival.

curves for each category of each main variable. Where the log rank score produced $P < 0.05$ the variable was assumed to significantly influence survival (see Table 10), the plots indicating what the effect would be. The variables investigated (with log rank P) are shown in Table 10.

These results for the full duration of the study raised questions because the variables that were significant differed from those at earlier interim analyses and also

Table 10. Log rank P results of variables tested

Clinical covariate	P
Aetiology	0.02*
Alloy	0.3
Arch	0.8
Cement	0.3
Coverage (anterior)	0.001*
Coverage (posterior)	0.07
Design	0.01*
Extent (more or less than 4 units)	0.0048*
Site	0.107
Opposing dentition	0.4
Operator (senior staff, junior staff, post-graduate)	0.003*
Tooth preparation	0.4
Previous orthodontics	0.5
Perforated v. Unperforated retainer	0.02*
Site	0.1
Surface preparation	0.2

* Statistically significant.

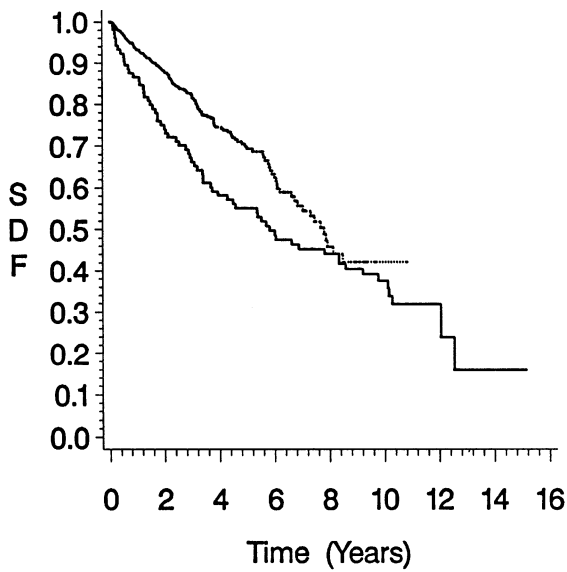


Fig. 2. Kaplan–Meier survival plots comparing restorations with perforated (lower curve) and unperforated (upper curve) retainer types over the full duration of the study. At survival times greater than 6 years the numbers at risk mean that single events show as major impacts. The *P* value derived from the log rank test after 6 years of service was 0.003, indicating that the unperforated retainers had a significantly greater probability of survival.

because in several cases the survival plots became ‘confused’ at longer survival times when relatively few restorations remained in service. At such times a small number of failure events can dramatically affect the relationship of the survival curves. Figure 2 shows the curves for the perforated and unperforated classes of retainer. It may be seen that the perforated retainers have the smaller SDF for intervals up to 96 months when the plots meet. Subsequently they appear to diverge again but reference to the life table (Table 9) reveals that the number of cases ‘at risk’ at that part of the curve is 87, or approximately 10% of the sample number, and falls further with increasing time. Other variables behaved similarly. A decision was therefore taken to make all further Kaplan–Meier analyses using a 6-year period when 20% or more of the sample number was in service. The following criteria are illustrated: anterior coverage (Fig. 3), posterior coverage (Fig. 4), design (Fig. 5) and operator type (Fig. 6).

It is not acceptable statistical practice to plot survival curves and then select a time interval at which to compare them, but the question naturally arose as to what the effects of the variables might have been had they been analysed at the end of each year interval.

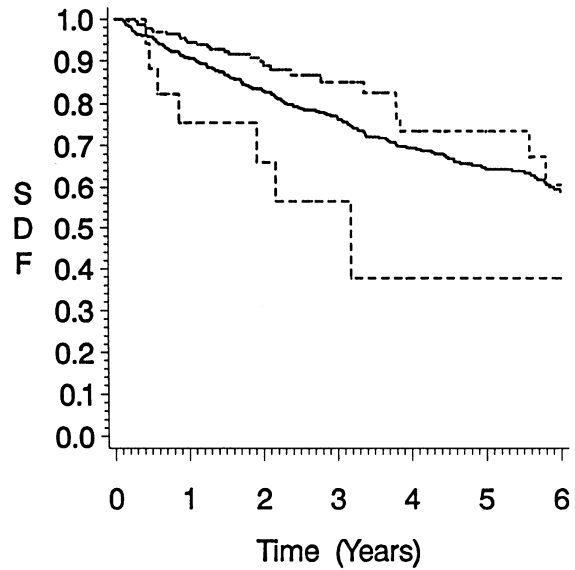


Fig. 3. Kaplan–Meier survival plots comparing anterior restorations with coverage of the incisal edge (upper curve) to those having generous palatal/lingual coverage but no incisal coverage (middle curve) and those with inadequate coverage (lowest curve). Log rank *P* = 0.007; *n* = 640.

Table 11 shows the significance or otherwise of log rank *P* values calculated for 1–6 years of service and for the whole period. The blank cells contain non-sig-

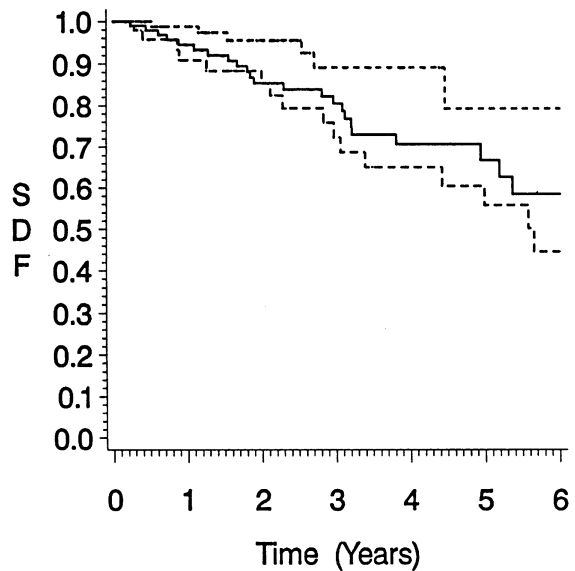


Fig. 4. Kaplan–Meier survival plots comparing posterior restorations with generous occlusal and axial coverage (upper curve) to those with axial and occlusal rest coverage (middle curve) and those with negligible occlusal support (lower curve). Data are shown for the first 6 years of service only (see text). Log rank *P* = 0.028; *n* = 192.

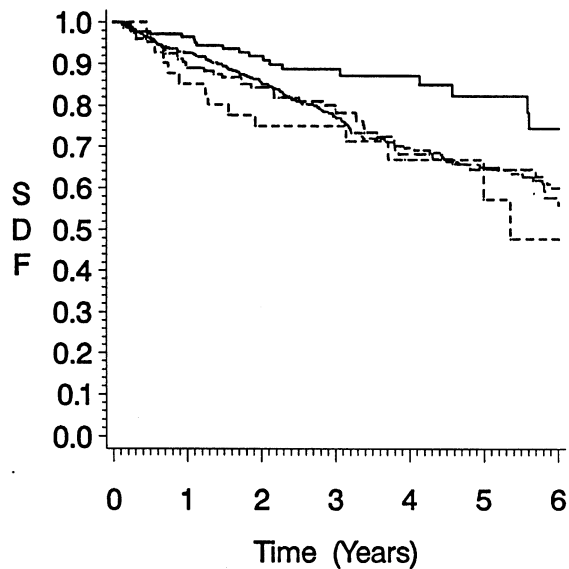


Fig. 5. Kaplan-Meier survival plot comparing design categories: cantilever (solid line), fixed-fixed and splints (overlapping middle lines) and hybrid (lowest broken line). The contrast between cantilever and other designs is apparent. For discussion of other comparisons please see text. Log rank $P=0.01$; $n=832$.

nificant values. In view of the reliance which has been placed on this type of analysis in the literature it is interesting to note that in the early years there are considerable differences in the variables that would

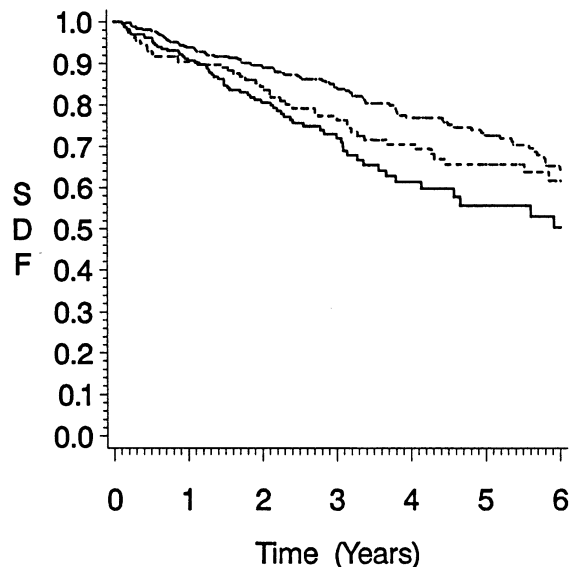


Fig. 6. Kaplan-Meier survival plot comparing the operator classifications: senior staff (upper line), post-graduate student (middle line) and junior staff (solid line). Log rank $P=0.001$; $n=832$.

have been reported as significant. Aetiology, coverage (anterior), and retainer type were the only variables to appear significant throughout. The cement comparison was for Panavia® Ex versus all other cements to accommodate the small numbers in the minority cement groups and was significant at years 1–5. Surface preparation (abrasive blasting, salt, etch, tin plating) was significant at 2 and 3 years but not elsewhere, as was previous orthodontic treatment. Interestingly, operator type was strongly significant apart from the first year. Design and coverage (posterior) became significant in the fourth year.

A comparison of the survival curves for extensive (greater than four units) versus 'small' designs (four or fewer) showed a significant difference after 6 years of service ($P=0.0048$) (Fig. 7).

All variables not included in the table such as alloy, arch, opposing dentition, the functional occlusal variables, tooth preparation and site (anterior, posterior or both) were not significant and are not shown in this study to have any influence on survival. This is not to say that they have no effect, merely that the sample size and methods used did not permit any effect to be detected.

This initial analysis indicated that aetiology, design, operator type and perforated versus unperforated retainer were class variables that would need to be included in a multivariate model.

The variable coverage appeared significant but in both the anterior and posterior coverage survival plots the proportional hazards assumption was rejected. In the anterior coverage analysis there seemed to be disproportionately few early failures in the small 'Unclassified' group, which went on to have a large failure rate. Similarly in the posterior coverage case, the small group with least coverage (axial only) appeared to perform better for the first 35 months than subsequently, when it showed more failures than the other groups. The coverage subgroups were therefore merged to combine groups 1 and 2 so that three groups remained—axial coverage only, occlusal plus axial coverage and unclassified. The results showed that occlusal (or incisal) coverage significantly reduced the risk of failure ($P=0.0013$ for anterior, $P=0.03$ for posteriors).

The $-\log(\text{survival})$ and $-\log(\log \text{ survival})$ curves were also plotted to check the assumptions of each model and provide an indication of the likely failure model. The $-\log(\text{survival})$ curve was used to verify

Table 11. Summary of univariate log rank test results for principal clinical covariates over different study periods

Covariate	Years of service after which data censored for log rank test						
	1	2	3	4	5	6	All
Aetiology	*	*	*	*	*	*	*
Alloy							
Resin	*	*	*	*	*		
Coverage (anterior)	*	*	*	*	*	*	*
Coverage (posterior)				*	*	*	*
Design type	*	*		*	*	*	*
Opposing dentition type							
Operator group		*	*	*	*	*	*
Tooth preparation Y/N							
Previous orthodontics		*	*				
Perforated/Unperforated	*	*	*	*	*	*	*
Anterior/Posterior/Both							
Metal surface preparation		*	*				

An asterisk indicates $P < 0.05$ and a blank cell denotes $P \geq 0.05$. The 'All' column indicates that the full duration of the study was included.

* Statistically significant.

the proportional hazards assumption over the period of interest (6 years) and the $-\log(\log \text{ survival})$ provided an indication that the failure distribution was of an exponential rather than Weibull characteristic. No further formal statistical methods were applied to model the failure distribution as has been reported by Smales, Berekally & Webster (1993).

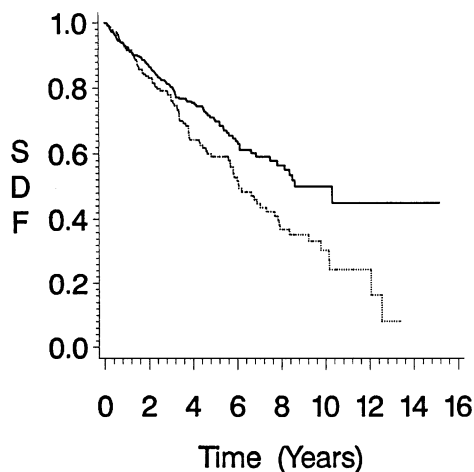


Fig. 7. Kaplan-Meier survival plot comparing restorations with four or fewer units (solid line) to those with more than four units (broken line). The clinical impression that more limited restorations have greater longevity is supported. Log rank $P = 0.01$; $n = 832$.

Multivariate analysis

Multivariate analysis was then performed using Proc Phreg of the SAS® system to generate a proportional hazards regression model including the variables that had appeared to be important in the univariate analyses, namely aetiology, retainer type, coverage, cement, design and operator type.

In order to include these in the analyses it was necessary to code variables that were not continuous to indicator variables (having the value 0 or 1). Where justifiable from the previous analysis, categories were merged. Variables were omitted in turn and the resulting values for $-2 \log L$ were compared to that for the full model in order to include or reject that variable from the final model.

Since a number of the class variables were specific to anterior or posterior cases it was necessary to test models for the anterior and posterior groups separately. However, there was insufficient data to support this type of analysis for the posterior group (125 restorations) or the 'both' group (103 restorations). The remainder of the analysis therefore concentrated on the anterior group ($n = 604$).

The covariate cement was reclassified as any of the Panavia® materials versus any other resin cement. Although there was an indication in the risk ratio calculated that Panavia® conferred a survival advantage over other resins this cannot be supported statistically for the anterior subgroup ($P = 0.1538$). We suggest that this was a consequence of the small number of cases in which Panavia® was not used.

Similarly, the coverage scores were recoded into a simple 'poor anterior coverage' yes/no indicator and although a positive score appeared to give a more adverse risk ratio this was not supported statistically ($P = 0.1526$).

The aetiological categories caries, periodontal, hypodontia, trauma and other did not appear to have any significant effect and were therefore omitted.

The final model retained the factors design, retainer type and operator. The interaction effects of all included factors were examined and could be omitted. Design groups included were cantilever, fixed fixed, splints and (complex + hybrid).

When relative risk ratios were calculated for this factor assigning a value of 1.0 to the fixed-fixed group as a baseline the following ratios were calculated:

Cantilever	0.515
Fixed-fixed	1.000
Splints	1.335
Complex + hybrid	1.749

Unperforated retainers had a risk ratio of 0.724 compared to perforated. Operator type showed that when senior staff was taken as baseline, the post-graduate group had a risk ratio of 1.645 and the junior staff 2.135.

In general, the failure of the proportional hazards model to confirm the significance of factors that emerged from univariate analysis as having an influence on survival is disappointing but not surprising in view of the smaller numbers used and some doubt as to the validity of the proportional hazards assumption over the entire period for some of the factors. We regard the confirmation of the importance of previously unreported factors as useful. However, from a clinical point of view it is suggested that the survival curves, supported by log rank *P* values are sufficient to cause those factors shown to be significant to receive serious consideration when planning treatments involving resin-retained restorations.

Discussion

The intention of this study was to monitor the performance of a large number of resin-retained restorations over a period long enough to allow a realistic impression of their survival and of the factors contributing to success or failure. In general, this objective has been met in so far as the sample size and duration of the study exceed those of virtually all previous reports not dependent on meta-analysis. The survival of the restorations compares favourably with published data from other centres but interestingly the importance of many of the individual clinical factors that were recorded remains uncertain.

Creugers & Kayser (1992) considered the cost-effectiveness of adhesive and conventional bridges and concluded that in the Netherlands adhesive bridges became cost-effective when the 50% survival was approximately 6.5 years. According to that criterion the Eastman data indicate satisfactory performance from a health economics viewpoint. Resin-retained restorations have clearly established themselves as a responsible method of treatment and the authors feel that better survival performance is achievable by attention to a relatively small number of factors discussed below.

Follow-up

All clinical studies contain restorations of varying age because it is impractical to insert large numbers close to the starting date. Unfortunately, many reports make it difficult to establish the proportions of newer and older cases and undue emphasis may be placed on the survival period of the older restorations in describing the results. It is common to find unhelpful statistical information such as the mean age of restorations in the sample or the percentage of failed restorations in a sample with variable periods in service. Unless survival analysis is used as in Berekally & Smales (1993) and Creugers & Van't Hof (1991), it may be impossible to compare results. Smales *et al.* (1993) reported results after 6 years for perforated restorations and 5 years for the Maryland technique. Other reports relating to comparable periods of service include Dunne & Millar (1993), Nevins (1993), Thayer *et al.* (1993) and Priest (1995) although in all except the last study the numbers included were relatively small.

The oldest reported restoration in the present study had survived for more than 16 years and yet the proportion of the original sample number still at risk and available for recall with survival times more than 8 years was less than 10% (Table 9). The higher the failure rate in the early years of a study the more pronounced this effect will be. We question the acceptability of describing studies as 'results after 1-*X* years' whatever the value of *X*.

The literature is filled with references in which observation periods of only a few years are used. Whilst the incentives to early publication are understandable, these reports seem useful only where a warning is indicated that a specific new material or technique carries a particular risk of premature failure (Hansson, 1994; Kellett *et al.* 1994).

Whilst following up a large number of cases over an extended period would seem to be the best way to assess results, it poses certain problems. The first is that treatment concepts may change during the study and this is true of the present sample. Where possible the results of different methods are compared statistically though there are likely to be intrinsic problems with the relative ages and numbers. The second problem is that the results, when analysed, may relate to designs that are obsolete and materials that have been withdrawn.

Ideally, survival studies should be prospective and the proportion of cases lost to recall should be small. Few of the published studies of resin-retained restorations appear to be truly prospective (including this), whilst those that are, include Creugers, Kayser & Van't Hof (1992), Kellett *et al.* (1994), Verzijden, Creugers & Mulder (1994a) and Hussey & Linden (1996). There is a tendency for these to include smaller numbers where the acceptance criteria are strict and for data to be reported after short intervals.

Numbers

Small sample sizes are of limited value because the numbers of failures will also be small and therefore the numbers of any particular subtype which fail are unlikely to permit statistical analysis. With 832 restorations the present study is large for a single centre study but not large enough to avoid the problem completely. Marinello *et al.* (1990), Haastert *et al.* (1992) and Kerschbaum, Haastert & Marinello (1996) also report on large numbers, whereas a more economical way to obtain more degrees of freedom is meta-analysis (Creugers & van't Hof, 1991) in which the results of separate but comparable groups are combined. Sixty publications were reviewed with a number of inclusion criteria. Sixteen different samples were used for the meta-analysis constituting 1598 restorations in total. Overall survival after 4 years in the meta-analysis was 74% compared to 79.6% in the Eastman data.

Survival analysis

Formal survival techniques similar to those used here have been used in a number of other studies (Creugers & Kayser, 1992; Berekally & Smales, 1993; Boyer *et al.*, 1993; Smales *et al.*, 1993; Kerschbaum *et al.*, 1996). Of those that quote median survivals, the values are much smaller than for the Eastman data. Berekally & Smales (1993) report 2.14 years for Rochette bridges and 2.60 years for Maryland bridges constructed in Adelaide Dental Hospital which contrasts with 5.75 years for perforated restorations and an overall 7.82 years in the present study. Creugers & Kayser (1992) calculated the equivalent figure for rebonded restorations as 2.1 years and Kerschbaum *et al.* (1996) in a large study reported 66.1% of restorations still in place after 5 years.

Attempts to fit statistical distribution models such as the Weibull or cubic polynomial distributions to resin-bonded bridge data have indicated that a simple model is not appropriate. Predicted life spans based on these models, such as the characteristic life of 318 months (26.5 years) presented by Boyer *et al.* (1993) are difficult to interpret and must await clinical verification. Smales *et al.* (1993) demonstrated the superiority of a modified Weibull distribution that more successfully fitted actual data from their clinical study, though the median survivals of that group were low. The benefits of such model fitting are not clear and it was not attempted for the Eastman data.

The Kaplan–Meier method has achieved popularity as a univariate test of the effects of clinical variables on the survival time of restorations. We suggest that when this is performed using small samples and after short periods of observation, factors may be considered significant that actually have minimal impact on survival. This may account for the poor agreement between studies that emerges in the ensuing discussion. Table 11 clearly demonstrates how different clinical recommendations could have been made based on annual analyses of the same sample.

Age and sex

Although some reports have indicated that the sex of the patient (Olin, Hill & Donahue, 1991) or the age group (Dunne & Millar, 1993) had an effect on survival, in the majority of reports they receive no consideration whereas in others (Hosseini, 1994) no effect could be demonstrated. These factors were not included in the present analysis as they are beyond patient or operator control and it is unlikely that they would influence the decision to provide a restoration or not.

Aetiology

There was a tendency for *trauma* and *other* groups to look worse in the univariate analysis than *caries*, *hypodontia* and *tooth loss due to periodontal reasons*. This was not supported in the multivariate analysis. A relatively large number of early failures were found in the trauma group. There was no evidence that either recurrent trauma or delayed loss of abutment teeth contributed to the failures. We suggest that it may be

related to exposure of dentine on the bonding surfaces of traumatized abutments and/or shorter clinical crown heights which may be further aggravated by the need to restore lost incisal edges as part of the retainer casting. Creugers (1993) presented a valuable discussion of the use of resin-bonded restorations in the management of trauma and our findings are consistent.

Design

In general our results support the frequently repeated observations that more extensive bridges and splints carry a higher risk of failure and that cantilevers had a greater median survival than all other designs. The cantilever bridges were a substantial design group (171) and the majority had only one retainer. The predictability of such bridges is clear and is probably attributable to the freedom from the high stresses involved when rigid designs attempt to unite abutments with differing individual mobility characteristics. Such stresses place great demands on the rigidity of the metal framework, the importance of which has been emphasized by Sato *et al.* (1995).

The present authors feel that it is simplistic to assume that longevity is automatically associated with cantilever design. Cantilevers have traditionally been selected where occlusal demands are modest and the stability of abutment position is predictable, in other words in relatively 'safe' situations. Moreover, what is frequently taught about occlusal design for cantilever pontics may mean that the pontic is little more than an aesthetic appendage. Whereas there is every indication that the cantilever RRB may be the superior design in the situations where it has been tested, caution would appear to be justified when considering ambitious cantilevers simply to avoid a fixed-fixed alternative.

Fixed-fixed bridges and splints were more numerous in the Eastman data than the cantilevers and had a greater risk of failure. It is certain, however, that when a fixed-fixed design was chosen the cantilever alternative would have been considered and rejected for at least one clinical reason, often concern about the stability of post-orthodontic tooth positions. The median survival for fixed-fixed designs was 7.8 years and is certainly significantly shorter than the 9.8 years for the cantilever design. The risk of any fixed-fixed bridge failing was nearly twice that of a cantilever.

Splints have been reported to be more likely to fail than bridges (Dunne & Millar, 1993) and the high proportion of multi-unit splints and orthodontic retainers in the present sample (198) had given rise to a clinical impression that such extensive designs were troublesome. In fact, the risk associated was only one-third larger than for the fixed-fixed bridges, but again more than twice that for the cantilevers. It may be that the difficulties of maintenance when a six or eight unit splint has debonded contribute to the clinical reservations. Splints would obviously emerge unfavourably from a comparison with bridges if cantilevers were included in the bridge group. The authors are well aware of other types of splints used for post-orthodontic retention including the simple wire retainers advocated by Zachrisson (1977) with particular emphasis on ease of maintenance. However, in many of the cases reviewed here, the requirement for stabilization went beyond routine orthodontic retention as was apparent from the rapid relapse seen after some bond failures. A palatal casting in the anterior maxilla gives control of the anterior guidance, better control of tooth mobility and creates a more comfortable contour than a wire and composite retainer.

Hybrid and complex designs emerged from the analysis as relatively risky. It was standard practice in our clinic to incorporate a movable connector whenever mixed resin-retained and conventionally cemented units were combined. This was to enable optimal seating of the different types of casting and to facilitate maintenance in the event of failure. In the posterior region a conventional movable connector can be difficult to arrange so that the resin-retained unit can be removed without disturbing the remainder of the bridge. With experience, this has been overcome by making the resin-retained casting the major retainer whenever possible. However, the study sample contained a number of cases in which 'through-and-through' female connectors were used when occlusal support ought to have been provided. Subsequent displacement of the pontics towards the ridge tissue required the replacement of several bridges in an already small group. We suggest that the risk associated with a well-planned hybrid design may therefore not be as high as it appears but nevertheless recommend that careful thought is given before embarking on such designs. Dummer & Gidden (1990) have suggested that many failures of resin-retained bridgework are caused

by a lack of consideration of the dissimilar abutment support at each end of a span and they advocated two-part designs to overcome differing movement potential. In our data the 'both' classification for site was comprised of frameworks that needed to connect the radically different mobility patterns of anterior and posterior abutments. This group did not show a significantly higher tendency to failure. Moreover, many of the longest surviving bridges of rigid design did have abutments of contrasting support characteristics and there is therefore no direct support for increased use of movable connectors.

It had been one of the intentions of the present study to attempt to identify specific bridge designs that were associated with a high risk of failure but as shown in Table 2 the numbers of ambitious designs were too small to permit meaningful analysis. However, many previous reports have indicated that designs with many units are less successful than three or four unit ones (Chang *et al.*, 1991; Olin *et al.*, 1991; Dunne & Millar, 1993; Hosseini, 1994). In the present results designs with four or fewer units had significantly better success at 6 years than more extensive restorations, supporting the contention that resin-retained bridges are more suitable for shorter restorations of limited scale and that more extensive cases may usefully be divided into smaller sections.

Notwithstanding these remarks, the data for all of the restorations showed greater survival rates than Haastert *et al.* (1992) in which all of the restorations were three unit bridges.

Although not supported statistically, we suggest that it is increasing the number of bonding sites at risk by increasing the number of retainers which accounts for the 'size' effect rather than length of span or number of pontics. For example the sample included 27 bridges replacing all four incisors with single terminal abutments that survived quite well (median survival 53 months).

Location

It has frequently been suggested that the arch in which the restoration is located and/or its anterior or posterior position within the arch have a bearing on success. No such effects could be demonstrated in our data suggesting that these factors do not warrant clinical consideration.

Operator

The observation that different classes of operator significantly influenced survival is in agreement with Dunne & Millar (1993). However, in that study it was the cases treated by undergraduate students which fared better than those treated by staff, whereas in the present data the senior staff group did best. The post-graduate students who worked under close supervision of clinical teachers and carried out their own laboratory procedures experienced greater success than junior hospital staff. Other studies have reported no effect (Smales *et al.*, 1993; Verzijden, Creugers and Mulder, 1994a; Priest, 1995). Whilst it is tempting to infer that greater experience or intensive clinical supervision may have produced greater longevity, other factors may well have contributed. Junior hospital staff may have received unfavourable cases to treat in the first place and may have had less accomplished technical and chairside support. They may also have felt themselves to be under greater pressure of time. The junior staff and post-graduate groups were subject to frequent change and their work would therefore involve a relatively high proportion of individuals' early attempts. Interestingly, many of the junior staff group would have previously been post-graduate students. The distribution of various design types and coverage scores and resin cements used were relatively homogeneous between the operator groups and do not appear to account for the observed difference. It seems probable therefore that factors not available for analysis, such as whether rubber dam was used for isolation and the criteria applied for accepting the fit of a framework may have been involved.

Tooth preparation

There appears to be a current trend towards more extensive tooth preparation including, in some cases, intracoronal grooves or pin channels designed to increase retention and resistance form. The merits of such developments are the subject of vigorous debate and there would seem to be a balance to be struck between reducing the risk of a debond occurring and increasing the chance of dentinal caries should a bond failure go undetected for some time. Minimal preparation was used in all of the cases under review and every attempt was made to conserve as much enamel thickness as possible. The results show that very re-

spectable survival results are possible without substantial preparation and that debonds were largely inconsequential. It will be some time before comparable data are available to demonstrate the safety and effectiveness of tooth preparation. Rammelsberg *et al.* (1991), Haastert *et al.* (1992) and Berekally & Smales (1993) are amongst those suggesting that tooth preparation enhances survival whereas Verzijden, Creugers & Van't Hof, (1994b) in a meta-analysis found that it was significant only when combined with the variable location.

Coverage

It is clear that covering as much of the abutment surface as practically allowed by aesthetic and occlusal factors was a powerful factor tending to enhance survival. This may be argued to reflect the practice of not including intracoronal preparation features, but we suggest that in addition to increasing the area for bonding it is effective in increasing rigidity through the introduction of compound curvatures and additional bulk of metal. It also may reduce the risk of direct occlusal contact on an uncovered incisal edge or occlusal stop pushing an abutment out of the retainer in rigid designs. Clinically it appeared that extension of anterior retainers over the cingulum bulge was a helpful feature and in younger patients, particularly, some localized crown lengthening would appear justified to enable this.

The frequently-described phenomenon of 'greying' caused by metal shine-through in translucent teeth appears to have been overcome by the use of opaque resin cements and this is supported by the recorded level of satisfaction with appearance. Opaque resins do result in a loss of translucency and several patients remarked on a 'creamier', more opaque appearance.

An interesting incidental finding was the small number of bridges replaced because the colour match of a pontic which had originally been acceptable became unacceptable as the natural abutments changed colour, mainly accountable to a reduction in value, with age. With increasing use of long-lasting restorations of all types which do not require abutments or adjacent teeth to be restored, this may well become a more frequent indication for replacement.

Restoration of abutments

Aboutsh & Jenkins (1991) have suggested that when

retainers are bonded to mixed substrates, the overall bond obtained is equivalent to that with the weakest adherand present. The difficulty of determining the area and nature of restorations underlying restorations once they are bonded is considerable without photographs or casts of every case. These were not universally available and we feel that no firm conclusion should be drawn from the fact that 'previous restoration' did not appear significant.

Framework alloy

Nickel–chromium alloys were used almost exclusively because their rigidity in thin section is unsurpassed and the bond with resin is reliable. Poor results reported in studies where high gold alloys were used (Hansson, 1994) tend to support this practice but it is impossible to comment on the relative merits of the small number of noble metal units included, nor on differences between the brands of nickel–chromium alloy used at different times.

Retainer type

Our results are in agreement with virtually all published reports (Bastos *et al.*, 1991; Creugers *et al.*, 1992; Boyer *et al.*, 1993; Dunne & Millar, 1993) in showing that unperforated retainers perform better than perforated. However, some of the longest serving restorations were of the perforated design. Interestingly, it was noted that in many cases no composite resin remained in the holes of the Rochette type frameworks and the conventional understanding of the mode of action of the resin 'rivets' must be questioned.

Metal preparation

The abrasive blasting method of metal preparation was far more expedient and predictable than electrolytic etching and the other minority techniques included. The preponderance of this method rendered it unsurprising that no significant differences were demonstrated.

Luting cements

Panavia® was by far the most commonly used resin cement and the number of cases in which individual other brands were used rendered individual contrasts impossible. It would have been desirable to have more comparable numbers of cases in which other chemi-

cally active adhesive resins were used but this is a drawback of this longitudinal study in which clinicians had a free choice in the material selected.

Occlusal factors

Since the post-graduate teaching of occlusion has been an area of emphasis at the Eastman, particular care was taken over documentation of the occlusal relationships and contacts present. Whilst it was not particularly surprising that the nature of the opposing dentition and the class of anterior jaw relation were not significant factors, it was disappointing to note that the functional occlusal relationships originally prescribed were no longer present after a period of service. In particular the presence of excursive contacts on half of the pontics and most retainers of posterior bridges would not have been planned. However, it provided interesting evidence to suggest that such contacts had no significant adverse effect on survival.

Orthodontic treatment

Whether or not orthodontic treatment was carried out prior to construction of resin-retained restorations did not appear to have any significant effect on survival. This is surprising since many clinicians consider that it is technically more demanding to achieve a well-fitting framework in post-orthodontic cases. Furthermore, any tendency to orthodontic relapse might be thought to place additional stresses on to the cement lute. Conversely, recently moved teeth may be able to adapt more easily to the demands of being splinted together. There was a suggestion from the univariate analyses that previous orthodontics might have been an advantage in the second and third years of service, but this is not significant overall. Certainly there is no support from the two well-matched groups in the present work for any clinical reservations about the longevity of resin-retained castings provided after orthodontic tooth movement except insofar as may be accounted for by other factors such as coverage and design. We support the contention of Schaffer & Richter (1991) that correct palatal contours and anterior guidance are critical in the anterior maxilla but this can not be demonstrated from the existing data.

Type of failure

Some papers include rebonded bridges as successes (Priest, 1995; Kerschbaum *et al.*, 1996) where all or part of the prosthesis remains in function. In our study, any intervention was recorded as a failure since it would be regarded as such by the patient and is indicative of a weakness in the design or construction of the original restoration. A further report will examine the outcome of remedial measures such as rebonding or removal of retainers. Pontic fractures have constituted a major cause of failure in other studies (Creugers *et al.*, 1990; Berekally & Smales, 1993), but where ceramo-metal bridges are used the present data suggest that they should be an infrequent problem. Unlike Thayer *et al.* (1993) in which 6% of retainer teeth became carious, surprisingly few carious lesions were detected in association with resin-bonded retainers in this adult population. Whilst this should not invite complacency, caries does not appear to be a major risk.

Periodontal condition

The lack of objective data concerning the long-term effect on the periodontium is a weakness of the present study. However, documentation in an acceptable form would have a considerable impact on the examinations involved and baseline data were not always available. Periodontal disease led to the demise of only two restorations despite the fact that previous periodontal therapy was an aetiological factor in 198 cases. Monitoring of oral hygiene and periodontal health is part of the routine clinical culture in which recalls were conducted and if the presence of restorations had produced localized adverse changes sufficient to warrant specific periodontal interventions this would have been apparent from the clinical records. Patients who were already undergoing periodontal therapy when they joined the study tended to remain on maintenance whereas there was no particular trend for other participants to be referred. This is in agreement with other reports (Freilich *et al.*, 1990; Marinello & Scharer, 1990; Romberg *et al.*, 1995) which suggest that the presence of resin-retained frameworks does not adversely affect periodontal health, at least not more than other types of restoration. The large number of cases in which tooth preparation was not performed would have led to

relatively bulky retainer margins and the lack of periodontal consequences must make it questionable whether tooth preparation to accommodate retainers within the original tooth contour is necessary with this type of supragingival restoration.

Patients awareness of failure

It is a common clinical practice to advise patients that they should return for advice if they suspect that a bond failure has occurred, for example if they hear or feel a breakage occur, encounter an unfamiliar sharp edge, mobility or squelching sensations or sense a foul taste. This advice is generally given with the risks of secondary caries, tooth migration, soft tissue irritation or unplanned occlusal changes in mind.

Whilst these observations are commonly reported by patients, it would be unwise to assume that they invariably give an indication that something untoward has happened. Alarming, in over a quarter of the present cases where failure had clearly occurred, the patient was unaware of anything wrong. This finding has not been reported previously and the authors suggest that this prevalence of 'silent failure' supports the need for vigilant long-term maintenance regimes, despite the fact that relatively few of the more unfortunate potential sequelae of untreated bond failures were recorded in our sample.

Patient satisfaction

The vast majority of patients were satisfied with the function of their restorations, but about one in ten had reservations about the appearance. The factors contributing to reduced satisfaction with appearance were the direct display of metal, 'greying' caused by metal shine-through in early cases, loss of translucency, staining of resin at the margins and the difficulty of matching pontics with young natural teeth. Whilst the responses are interesting, it is recognized that some patients who lost their restoration early or who sought treatment elsewhere did not attend for recall and it is highly probable that they would have been less satisfied than those who did attend.

Conclusions

1. Resin-retained bridges and splints observed over long

periods of service can offer survival times that are acceptable in view of the minimally invasive technique.

2. Bond failure was by far the most common mode of failure. The consequences of failure were rarely harmful to the abutments used. More than half of the failed cases were amenable to remedial action without remaking the restoration and the subsequent effectiveness of such action is under review.

3. When examined over a long period, the factors that affected survival were relatively few and principally included clinical variables that determined the area available for bonding, the inherent rigidity and resistance form of the framework and the demands placed by the design on the retention provided.

4. The results obtained by operators of varying experience differed substantially and this was not accounted for by differing distribution of the other factors shown to be significant. The explanations of this effect can only be speculative.

5. The relative success of cantilever designs reported in other studies is confirmed.

6. Analysis of survival data after short periods of service appears likely to suggest misleading effects of factors that are in fact relatively unimportant.

7. Tooth preparation appears to be unnecessary for acceptable survival performance although the data presented does not permit the estimation of benefit to survival of more radical preparation techniques that were not used.

8. Orthodontic movement of abutment teeth before construction of a resin-retained framework did not incur additional risk of failure.

9. Patients were not necessarily aware that bond failure had occurred and periodic recall of patients with this type of restoration would appear sensible.

10. The level of satisfaction with the appearance and function of the restorations amongst patients who continued to attend for recall was high.

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Correspondence: D. J. Setchell, Department of Conservative Dentistry, Eastman Dental Institute, 256 Gray's Inn Road, London WC1X 8LD, U.K. E-mail: d.setchell@eastman.ucl.ac.uk