

An epidemiological study of certain factors influencing the  
life of dental restorations.

Volume 1.

Bruce Hunter

Doctor of Dental Surgery

University of Edinburgh

1981.



CONTENTS

ABSTRACT		1
ACKNOWLEDGEMENTS		3
PREFACE		4
SECTION A		
CHAPTER ONE	Introduction, literature review and aims of the study	6
CHAPTER TWO	Method	15
2.1.	Introduction	15
2.2.	Sources of Data	15
2.2.1.	Dental Estimates Board Records	16
2.2.2.	General Dental Practitioner Records	16
2.3.	Collection of Data	18
2.4.	Analysis of Data	19
2.4.1.	Criteria of Life and Fate	19
2.4.1.a.	Life	19
2.4.1.b.	Fate	19
2.4.2.	The life and fate of restorations described ambiguously	20
2.4.3.	The life and fate of all other restorations	21
2.4.4.	Calculation of the life of restorations	21
2.5.	Discussion	22
2.5.1.	Source of data	22
2.5.2.	Collection of data	22
2.5.3.	Analysis of the data	23
2.5.4.	Calculation of life of restorations	25
SECTION B	Results. Introduction	27
CHAPTER THREE	The dental treatment received during the study	28
3.1.	Introduction	28
3.2.	The study population	28
3.3.	The types of treatment	29
3.4.	The distribution of types of treatment	30
3.5.	The distribution according to tooth type	30
3.5.1.	Occlusal restorations	33
3.5.2.	Proximal restorations	33
3.5.3.	Buccal and Lingual restorations	33
3.5.4.	MO + DO, and MOD restorations	33
3.5.5.	Other surface combination restorations, Crowns, Root Treatments and Extractions	34
3.6.	The distribution according to the age of the patient at the time of treatment	34
3.6.1.	Occlusal restorations	35
3.6.2.	Proximal restorations	35
3.6.3.	Buccal and Lingual restorations	35
3.6.4.	MO + DO, and MOD restorations	35
3.6.5.	Other surface combination restorations, Crowns, Root Treatments and Extractions	37
3.7.	The distribution according to material	38
3.7.1.	Occlusal and Proximal restorations	38

3.7.2.	Buccal and Lingual restorations	38
3.7.3.	MO + DO, and MOD restorations	39
3.7.4.	Other surface combination restorations and Crowns	39
3.8.	The crude frequency of treatment	39
3.9.	Discussion	42
3.10.	Summary	46
CHAPTER FOUR	The fate of dental restorations	47
4.1.	Introduction	47
4.2.	The distribution of fates of restorations	47
4.3.	The fate according to the tooth surfaces restored	48
4.4.	The fate according to the sex of the patient	48
4.5.	The fate according to the type of tooth restored	49
4.5.1.	Introduction	49
4.5.2.	Incisors and canines	49
4.5.3.	Premolars	51
4.5.4.	Molars	51
4.6.	The fate according to the age of the patient at the time of treatment	51
4.6.1.	Introduction	51
4.6.2.	Occlusal restorations	53
4.6.3.	Proximal restorations	53
4.6.4.	Buccal and Lingual restorations	53
4.6.5.	MO + DO, and MOD restorations	54
4.7.	The fate according to material	54
4.8.	Discussion	54
4.9.	Summary	60
SECTION C	Results. The life of dental restorations	
	Introduction	61
CHAPTER FIVE	The actual survival of restorations	
5.1.	Introduction	62
5.2.	The survival according to the tooth surfaces restored	65
5.2.1.	Introduction	65
5.2.2.	The survival according to the tooth surfaces restored	65
5.2.3.	Discussion	69
5.3.	The survival of restorations according to the sex of the patient	71
5.4.	The survival according to material	72
5.4.1.	Introduction	72
5.4.2.	The survival according to material	73
5.4.3.	Amalgam restorations	77
5.4.4.	Silicate restorations	77
5.4.5.	Sevriton restorations	80
5.4.6.	The survival of differing materials used for the same restorations	81
5.4.6.1.	Introduction	81
5.4.6.2.	Proximal and Buccal restorations	81
5.4.6.3.	MO + DO, and MOD restorations	81

5.4.7.	Discussion	82
5.5.	The variation in survival with the type of tooth restored	84
5.5.1.	Introduction	84
5.5.2.	The variation in survival with the type of tooth restored	84
5.5.3.	The variation in survival of each restoration type with the type of tooth restored	86
5.5.4.	Discussion	89
5.6.	The variation in survival with the age of the patient at the time of treatment	92
5.6.1.	Introduction	92
5.6.2.	The variation in survival in each age group	92
5.6.3.	The variation in survival with increasing patient age	93
5.6.4.	Discussion	94
5.7.	Summary	98
CHAPTER SIX	The latent durability of restorations	100
6.1.	Introduction	100
6.2.1.	The durability according to the tooth surfaces restored	101
6.2.2.	Discussion	101
6.3.	The durability according to the sex of the patient	106
6.4.	The durability according to material	107
6.4.1.	Introduction	107
6.4.2.	The durability according to material	107
6.4.3.	Amalgam restorations	111
6.4.4.	Silicate restorations	111
6.4.5.	Sevriton restorations	114
6.4.6.	The durability of differing materials used for the same restoration	115
6.4.6.1.	Proximal and Buccal restorations	115
6.4.6.2.	MO + DO, and MOD restorations	
6.4.7.	Discussion	116
6.5.	The variation in durability with the type of tooth restored	118
6.5.1.	Introduction	118
6.5.2.	The variation in durability with the type of tooth restored	118
6.5.3.	The variation in durability of each restoration type with the type of tooth restored	119
6.5.4.	Discussion	123
6.6.	The variation in durability with the age of the patient at the time of treatment	126
6.6.1.	Introduction	126
6.6.2.	The variation of durability in each age group	126
6.6.3.	The variation of durability with increasing patient age at the time of treatment	128
6.6.4.	Discussion	128

6.7.	Summary	131
CHAPTER SEVEN	The difference between the actual survival and the latent durability of restorations	132
7.1.	Introduction	132
7.2.	The difference according to tooth surface	133
7.3.1.	The difference according to material	134
7.3.2.	Amalgam restorations	134
7.3.3.	Silicate restorations	135
7.3.4.	Sevriton restorations	136
7.4.	The difference according to tooth type	136
7.5.	The difference according to the age of the patient at the time of treatment	140
7.5.1.	Occlusal restorations	140
7.5.2.	Proximal restorations	140
7.5.3.	Buccal restorations	141
7.5.4.	Lingual restorations	142
7.5.5.	MO + DO restorations	143
7.5.6.	MOD restorations	143
7.6.	Discussion	144
7.7.	Summary	146
SECTION D		
CHAPTER EIGHT	Discussion	148
8.1.	The study in perspective	148
8.2.	Comparison with other studies	149
8.2.1.	General Practice studies	149
8.2.2.	The R.A.F. study	149
8.3.	The effect of attending a dentist regularly	151
8.4.	Implications for dental materials	154
8.5.	Occlusal restorations and fissure sealants	158
8.6.	The quality of dental care and the performance of dentists	166
8.7.	The success of restorative dentistry	167
CHAPTER NINE	Summary of principal findings, Conclusions and suggestions for further research	169
9.1.	Principal findings	169
9.2.	Conclusions	171
9.3.	Suggestions for further research	173
SECTION E	Appendices	
APPENDIX ONE	Analysis of survival	176
1.1.	Introduction	176
1.2.	The Lifetable	177
1.3.	Compilation of a lifetable	178
1.4.	Calculation of the proportions surviving	179
1.5.	Calculation of standard error	180
1.6.	Comparison of lifetables	180
1.6.1.	Loss Rates	180
1.6.2.	Calculation of relative loss rate	180
1.6.3.	The logrank test	181
1.6.4.	Computation	183
PREFACE TO APPENDICES 2 and 3		184

APPENDIX TWO	The life of crowns and root treatments	185
2.1.	Crowns	185
2.2.	Root treatments	186
APPENDIX THREE	The life of partial dentures	187
APPENDIX FOUR	Abbreviations	188
4.1.	Restorations	188
4.2.	Teeth	188
4.3.	Statistics	189
APPENDIX FIVE	References	190

## TABLES

1:3.5.1.	The distribution of treatment by tooth type and sex	31
1:3.5.2.	The distribution of treatment by dental arch and sex	31
1:3.5.3.	The distribution of treatment by tooth type	32
1:3.6.1.	The distribution of treatment by age and sex	36
1:3.8.	The frequency of treatment	41
1:3.9.1.	The numbers of teeth treated under the N.H.S. in Scotland	44
1:4.5.	The fate of restorations according to tooth type	50
1:4.6.	The fate of restorations according to the age of the patient at the time of treatment	52
1:5.2.2.	The survival of six types of dental restorations	68
1:5.3.	The survival of restorations according to the sex of the patient	72
1:5.4.2.a & b	The survival of restorations according to material	76
1:5.4.3.	The survival of amalgam restorations	79
1:5.4.4.	The survival of silicate restorations	80
1:5.4.5.	The survival of sevricon restorations	80
1:5.4.6.	The survival of differing materials used for the same restorations	82
1:5.5.2.	The variation in survival of restorations according to tooth type	85
1:5.5.3a.	The survival of restorations in premolars and molars, and incisors and canines	86
1:5.5.3b.	The survival of restorations in maxillary and mandibular incisors and canines	87
1:5.5.3c.	The survival of restorations in premolars and molars	88
1:5.6.2.	The survival of restorations in each age group	93
1:5.6.3.	The survival of restorations with increasing age	94
1:6.2.2.	The durability of six types of dental restorations	104
1:6.3.	The durability of restorations according to the sex of the patient	106
1:6.4.2.a & b	The durability of restorations according to material	110

1:6.4.3.	The durability of amalgam restorations	113
1:6.4.4.	The durability of silicate restorations	114
1:6.4.5.	The durability of sevruton restorations	114
1:6.4.6.	The durability of differing materials used for the same restorations	115
1:6.4.7.	Some physical properties of enamel, dentine, silicate cement, and acrylic resin	117
1:6.5.2.	The durability of restorations by tooth type	119
1:6.5.3a.	The durability of restorations in incisors and canines, and premolars and molars	120
1:6.5.3b.	The durability of restorations in maxillary and mandibular incisors and canines	121
1:6.5.3c.	The durability of restorations in premolars and molars	122
1:6.6.2.	The durability of restorations by age group	127
1:6.6.3.	The durability of restorations with increasing age	128
1:6.6.4.	Reasons given for failure of restorations	130
1:7.2.	The difference between actual survival and latent durability for six types of restorations	133
1:7.3.1.	The difference between actual survival and latent durability according to material	134
1:7.3.2.	The difference between actual survival and latent durability of amalgam restorations	135
1:7.3.3.	The difference between actual survival and latent durability of silicate restorations	135
1:7.3.4.	The difference between actual survival and latent durability of sevruton restorations	136
1:7.4.1.	The difference between actual survival and latent durability of incisor and canine restorations	137
1:7.4.2.	The difference between actual survival and latent durability of premolar restorations	138
1:7.4.3.	The difference between actual survival and latent durability of molar restorations	139
1:7.5.1.	The difference between actual survival and latent durability of occlusal restorations according to age	140
1:7.5.2.	The difference between actual survival and latent durability of proximal restorations according to age	141
1:7.5.3.	The difference between actual survival and latent durability of buccal restorations according to age	142
1:7.5.4.	The difference between actual survival and latent durability of lingual restorations according to age	142
1:7.5.5.	The difference between actual survival and latent durability of MO + DO restorations according to age	143

1:7.5.6.	The difference between actual survival and latent durability of MOD restorations according to age	144
----------	---	-----

## FIGURES

1:5.2.2A.)	The survival of six types of dental restorations	66
1:5.2.2.)		67
1:5.4.2A.)	The survival of restorations according to material	74
1:5.4.2.)		75
1:5.4.3.	The survival of six types of amalgam restorations	78
1:6.2.1A.)	The durability of six types of dental restorations	102
1:6.2.1.)		103
1:6.4.2A.)	The durability of restorations according to material	108
1:6.4.2.)		109
1:6.4.3.	The durability of six types of amalgam restorations	112

ABSTRACT

In a retrospective study of the records of regularly attending patients at a general dental practice, the influence of certain factors on the life of restorations was determined from the sequence of treatment of permanent teeth using lifetable analysis. A restoration may be lost in one of three ways: it may be replaced by one of identical tooth surface description, converted to one involving a larger number of tooth surfaces, or extracted. Replacement implies restoration failure, whereas both conversion and extraction imply premature restoration loss before failure has occurred. Intra-coronal restorations, crowns, root treatments and extractions accounted for 6,434 items of treatment received by 41 males and 72 females between 1949 and 1976. The ages of the patients at the time of treatment ranged from 5.4 to 84.4 years. Proximal and MO + DO restorations were the commonest treatments, and together with occlusal, buccal, lingual, and MOD restorations accounted for 80% of all treatment. Of 3,754 lost restorations, 54% were replaced, and 46% were converted or extracted. The relative importance of replacement, conversion and extraction was influenced mainly by: the type of tooth restored, the tooth surfaces restored, and the age of the patient at the time of treatment. The life of restorations was calculated in two ways: firstly, the actual survival was determined by including all losses in the analysis, and secondly, the latent durability was determined by including only replacements in the analysis. The 10 year actual survival rates and latent durability rates for

MOD, lingual, MO + DO, occlusal, buccal and proximal restorations were: 58%, 49%, 48%, 44%, 34%; and 68%, 69%, 74%, 80%, 58%, 46% respectively. The median actual survival times and median latent durability times for these restorations were: 12, 9, 9, 8, 8, 7 years; and 18, over 28, over 28, over 28, 14, 9 years, respectively. The 10 year actual survival and latent durability rates for amalgam, gold, silicate and sevriron restorations were: 48%, 38%, 32%, 42%; and 74%, 51%, 42%, 59% respectively. The median actual survival times and median latent durability times for these restorations were: 9, 7, 7, 8 years; and over 28, 13, 8, 13 years, respectively. Actual survival varied with: the age of the patient at the time of treatment, the type of tooth restored, the tooth surfaces restored, and material. Latent durability varied with: the type of tooth restored, the tooth surfaces restored and material. The existence of a difference between actual survival and latent durability indicates that part of the life of restorations was unused. This excess life was greatest for occlusal restorations in young people, and MO + DO restorations, and least for proximal restorations in patients aged between 21 and 50 years. The restorative techniques investigated in this study appear to be able to maintain the permanent dentition of a regularly attending patient throughout life, based on median actual survival times. This ability would be dramatically improved if supplemented by preventive measures, particularly water fluoridation.

ACKNOWLEDGEMENTS

I am grateful for the assistance I received from a number of people during the preparation of this thesis and the following deserve particular acknowledgement.

Mrs. S. R. MacMillan spent many hours helping me to transcribe the data from the patient records. Miss M. D. Brown gave valuable guidance on the preparation of the data for analysis, and ran the computer programmes for me. I am especially grateful to Miss K. E. Andrew, who not only helped to prepare the transcribed data for analysis, but also typed the manuscript.

The original idea of investigating the life of dental restorations came from a conversation with Professor Philip Sutcliffe. I am particularly grateful for his helpful advice and permission to use the facilities of the Department of Preventive Dentistry, University of Edinburgh.

Finally, without the diligent recording of patient treatment made by Dr. R. S. Sanderson over many years, this thesis would not have been possible. I am indebted to him for the use of his practice records.

PREFACE

This thesis is in two volumes. Volume 1 contains the text and Volume 2 contains the detailed tabulated results of the study.

A system of numbering the tables and figures has been adopted which allows reference from the text to the appropriate tables and figures in either Volume 1 or Volume 2. In each table or figure reference, the number preceding the colon refers to the volume. The chapter number immediately follows the colon, and any subsequent numbers refer to the appropriate part of that chapter.

In the list of contents some of the titles have been shortened.

SECTION A

INTRODUCTION, LITERATURE REVIEW,

AIMS OF THE STUDY AND METHOD

CHAPTER 1INTRODUCTION, LITERATURE REVIEW AND AIMS OF THE STUDY.

The period of Pierre Fauchard (1678 - 1761) can be considered to be the beginning of dentistry as a healing art. Dental amalgam has been in use as a restorative material from the beginning of the nineteenth century and the early amalgam fillings were made of filings from silver coins mixed with mercury. Early amalgams were unpredictable and their use was considered malpractice by the American Society of Dental Surgeons during part of the nineteenth century. Amalgam is usually confined to premolar and molar teeth because of its poor aesthetic appearance.

Silicate cements have much better aesthetics than amalgam and since 1903, when they were introduced, they have been used as anterior restorative materials. Their disadvantageous properties led to the search for alternative materials and acrylic resins gained in popularity in the late 1940's and 1950's. Further improvement in the properties of aesthetic restorative materials has been achieved in the composite resins which are now widely used for restorations of incisors and canines.

In 1976 the total cost of National Health Service dental care provided by general practitioners in Scotland was £20,280,000 and of this £6,458,000 was spent on plastic restorations including amalgam, silicate, acrylic and composite materials. Not only did these restorations account for 32% of the cost of all types of

dental care but also accounted for 79% of the cost of all conservative dental procedures (SDEB Summary Report 1976).

Despite the major importance of conservative dentistry to the patient and the N.H.S., little is known of the success of restorative procedures (Holloway 1975). In times of economic stringency and when health care priorities are under scrutiny, it is important for the dental profession to be able to demonstrate the value of the care it provides. In addition, at a time when new restorative materials appear with increasing frequency, it is important to have a standard against which these new materials may be compared. One valuable index of the success of conservative dentistry is the life of restorations. Since dental amalgam has been in use from the early nineteenth century as a restorative material, and is today the commonest filling material, its survival may be used as a standard against which other materials can be compared. The literature describing the life of dental restorations is sparse and the subject has yet to be examined in great detail.

One of the earliest studies related to 887 filled teeth of patients who attended a dental hospital for conservative dental care (Allan 1962, 1969). The fillings were examined clinically and radiographically, and diagnosed as 'failed' or 'not failed'. The group of failed restorations was further subdivided into 'true failures' and 'false failures'. True failures were due mainly to poor restorative technique, and false failures were not due primarily to poor restorative technique. False failures included

caries elsewhere in the tooth, lack of contact point, pulpal or other pathology, cement irritations, and prosthetic, orthodontic or surgical loss. The patients were asked to recall from memory when a filling had been placed, and the life of the filling was the time which had elapsed between placement of the restoration and the date of examination. Dental records were used when these were available. The maximum life of the following restorations was reported, gold foil - 45 years, amalgam - 25 years, bridges - 15 years, silicates - 13 years, gold inlays - 13 years, crowns - 12 years, and acrylic resin - 3 years. In addition, of those that had been placed 10 years earlier 54% Class I amalgams were diagnosed 'not failed' compared to none of Class I gold inlays, 39% Class II amalgams, 15% Class II gold inlays, 18% Class III silicates and 50% Class III gold inlays. Of the restorations studied  $\frac{1}{3}$  were diagnosed as failed, and of these  $\frac{2}{3}$  were true failures and  $\frac{1}{3}$  were false failures. When the numbers failed in 2, 3, 5 and 10 years were compared, no significant difference was found between Class I amalgams, gold inlays and gold foils, Class II amalgams and gold inlays, and Class III gold inlays and silicates. The author commented that repetition of a similar study in a practice might show some differences in results and concluded that the way a material was employed was more related to its duration than the actual material used.

In this early study the method of retrospective follow-up of restorations was demonstrated. Unfortunately, because of the limited availability of patient records, recourse was made to patient recall of the date when a filling was placed, which is

unreliable. Despite using a subjective assessment of whether a filling had failed, the author made a valuable distinction between restorations which failed because of poor technique, and those which failed for reasons not related to the restorations. The life of restorations was not, however, related to these two fundamentally different restoration fates.

Following this study, a retrospective study over 20 years of the records of a dental practice was reported (Robinson 1971). Forty-three patients, aged between 13 years and 57 years at the start of the study, were identified, who had attended regularly throughout the period of the study, and who had not received care at any other practice. Two groups, one of 145 amalgam restorations and the other of 23 silicate restorations, placed in the first year of the study, were followed through the patients' records until loss occurred either by extraction, or replacement by a similar restoration, or more extensive filling or crown. Allowance was made for ambiguities which occurred in the records, but the reasons why a restoration required replacing were not defined. One quarter, one half, and three quarters of the amalgam restorations had failed after 5, 10 and 20 years. One half of the silicate restorations had failed after 10 years, and almost all had failed after 20 years. The average number of fillings replaced per patient per year was two.

This study was the first to use retrospective examination of dental practice records of regularly attending patients and the results, expressed graphically, showed the gradual depletion of the original groups of restorations. It was recognised that the

proportions of restorations failing in a given time was a more accurate description of the survival of restorations than the average life. In addition, the author recognised that the description of restorations by tooth surface may be ambiguous and proposed a method of resolving that ambiguity (2.4.2.). Although small, this study elegantly demonstrated the value of practitioner records in the study of the life of fillings.

Two further studies also used this retrospective approach. The durability of 536 amalgam restorations placed by 3 dental practitioners was studied using practice records (Lavelle 1976). The average number of restorations placed per patient per year was seven. The progressive loss of restorations was not reported in detail but the proportion of amalgam restorations having a life of less than 5 years was 20%, and 50% survived less than 10 years. The method of reporting the study makes further interpretation and comparison difficult.

The other report of the life of restorations using practitioner records relates to two groups of amalgam restorations followed up for 15 and 20 years, and two groups of silicates followed up for the same periods (Allan 1977). All the restorations were placed in one practice. Only replaced fillings were regarded as having failed, and no allowance was reported for the ambiguities occurring in the records. Detailed criteria of replacement were not given. Again, only regularly attending patients were included. In the 20 year group there were 148 amalgam and 42 silicate restorations, and in the 15 year group

there were 90 amalgam and 11 silicate restorations. Half of the amalgam restorations in the 20 year cohort were lost in 8 years and 90% were lost in 20 years, while half of the silicate restorations was lost in 8 years and all had failed in 14 years. In the 15 year cohort, half of the amalgam restorations was lost in 5 years and 90% in 15 years, while all of the silicates were lost in 4 years. Despite the large difference between the life of restorations in the two cohorts, all of the patients had been selected because they remained in the constant care of one practitioner over the period of the study.

While the last two retrospective follow-up studies of practice records broadened the knowledge of the life of amalgam and silicate restorations, no new methodology was used, each being a virtual replication of the original study carried out by Robinson. While the life of amalgam restorations varied between 50% lost between 5 and 10 years after placement, this variation is to be expected considering the different locations of the practices, and the varying diagnostic and operative standards of the practitioners. Nevertheless, with the exception of the 15 year cohort reported by Allan (1977), the life of amalgam restorations appears to be around 50% surviving 10 years, based on the results of the studies described earlier.

In these studies factors which might have been expected to influence the life of restorations were not reported, e.g. patient age and sex, the type of tooth restored and the shape of the cavity, and only data relating to amalgam restorations can be regarded as

reliable because of the very small samples of other materials studied. In addition, the effect of the way in which loss occurred on the life of restorations was not considered.

Following groups of restorations all placed in one year, or cohorts, is an elementary approach to analysing survival and wastes much valuable information about restorations placed in subsequent years before the end of the study. A more efficient use of the data available from practice records may be achieved by following multiple cohorts of restorations and analysing survival using lifetable analysis, which allows partial survival data, from restorations surviving to the end of the study, to be used. This approach was used in a study of the dental records of R.A.F. personnel, designed to show the durability of amalgam restorations (Gray 1976).

Unlike previous studies, the work of many operators was included in this study of 6731 amalgam restorations followed for up to 25 years. The criteria of failure were: 1. Where a tooth was crowned or extracted, all fillings were regarded as having failed, 2. Where caries in one part of a tooth necessitated a restoration incorporating a restoration already existing in another part of the tooth, the original was deemed to have failed, 3. Placing an occlusal restoration indicated a failure of an existing occlusal, mesio-occlusal, or disto-occlusal restoration, 4. Any addition to, or extension of a filling was recorded as a replacement covering all the surfaces restored.

Overall, the lifetable estimate of the proportion of amalgam

restorations surviving 10 years was 50%. Occlusal amalgams survived longer than proximo-occlusal amalgams, which survived longer than mesio-occlusal-distal restorations. Buccal restorations survived as well as occlusal restorations. The life of an amalgam restoration decreased with an increase in the number of tooth surfaces restored and with each subsequent replacement. The durability of amalgam restorations was not found to be lower in personnel who were required to be maintained at a particularly high level of dental fitness, compared to other personnel.

This study of the records of R.A.F. personnel is sophisticated, and the durability of amalgam restorations was examined in greater detail than in any other study. Nevertheless, the effect of patient age and sex, and the type of tooth restored, and the fate of restorations was not reported. There remains a gap in our knowledge of the life of restorations related to these factors. In particular, little is known of the life of silicate restorations and virtually nothing of the lives of acrylic resin, composite resin and gold restorations.

AIMS OF THE STUDY

1. To investigate the life of dental restorations placed in a general dental practice.
2. To determine the influence on the life of dental restorations of:-
  - (a) Fate
  - (b) Age of the patient at the time of treatment
  - (c) Sex of the patient
  - (d) Type of tooth restored
  - (e) The shape of the cavity - the type of surfaces restored
  - (f) The restoration material

CHAPTER 2METHOD2.1. Introduction

The life of dental restorations may be investigated in two ways, either by prospective or by retrospective studies. The prospective approach has the advantage that the study may be carefully designed with a consequent reduction in sources of bias, and both regular and irregular attenders may be included. Its major disadvantage is that a considerable time must elapse before useful results become available. On the results of studies described in the previous chapter, which showed that 50% of amalgam restorations may survive more than 10 years, a prolonged prospective study of 20 years may be needed to give meaningful results. The retrospective approach has the advantage of producing results relatively quickly, but has all the disadvantages of having to make use of recorded data designed for some other purpose. All of the published studies to date have used the retrospective approach, and in view of the relative impracticality of conducting a 20 year prospective study, the retrospective approach was adopted in the present study.

2.2. Sources of Data

There are two potential sources of retrospective data relating to dental care in Scotland, the records of the Scottish

Dental Estimates Board and the records maintained by General Practitioners.

#### 2.2.1. Dental Estimates Board Records

The Scottish Dental Estimates Board authorises payment to practitioners working within the National Health Service. Their records show the care to be given during a course of treatment, without reference to care given during previous courses of treatment, and are filed phonetically by patient surname. These records have been used to trace the sources of care sought by Scottish school leavers (Sutcliffe and Hunter 1976) and to follow up a sample of adults who participated in the survey of adult dental health carried out in Scotland (Todd and Whitworth 1974). In both of these studies the follow-up period was severely limited as the Board keeps records for up to a maximum of only 27 months. Other limitations of the records of the Dental Estimates Board are that they exclude all private work and they do not distinguish between people who attend frequently and those who attend occasionally. In the summary reports all data is given in terms of courses of treatment, this being the basis of costing, and the data is not analysed in terms of individuals (Moser, Gales and Morpurgo 1962). The quality of the information and the short period for which records were kept, makes the records of the Scottish Dental Estimates Board unsuitable for a retrospective study of dental restorations, extending beyond 2 years.

#### 2.2.2. General Dental Practitioner Records

General practitioners maintain records as an aide-memoir

during a course of treatment, as a record of treatment given previously, for accounting purposes, for forensic purposes, and as part of the terms and conditions of providing care within the General Dental Service of the National Health Service. There is no control over the quantity and quality of information recorded, and wide variation between practices may be expected. Unlike the Dental Estimates Board, records may be maintained by practitioners for many years. Before the records of a practice can be used in a retrospective study, several conditions must be satisfied.

- a. The practitioner must be willing to allow confidential records to be scrutinised, either by tolerating a minor disturbance at the practice premises, or allowing the records to be removed temporarily.
- b. Records of patients who have attended regularly for periods in excess of 20 years must be available. Regular attendance in this context has been taken to mean that the patient had not received care from any other practice.
- c. Each entry on the records must be legible.
- d. The minimum information available for each patient should be the name, date of birth and sex.
- e. The minimum information for each item of treatment should be the date, the tooth treated, the nature of the treatment and material.

There are two possibilities in using practice records. A random sample of patients from many practices may be used, or a group of patients from one practice only may be used. In view of the conditions to be fulfilled before the records of a practice

could be used and the limited resources available the latter option was chosen.

### 2.3. Collection of Data

A practitioner, close to retiring, heard of the proposed study and offered the use of his records. The practice satisfied the selection criteria and was studied in depth. Patients were identified who had attended regularly for at least 20 years. To reduce the possibility that a patient might be included who had in addition received care at another practice, the practitioner was consulted whenever an interval between courses of treatment and examinations exceeded 12 months. The maximum interval which occurred was 3 years, with the majority attending at least once per year. If any doubt remained that the patient had only received care from the study practice, the record was not included in the study.

The complete treatment history for each patient up to 31st December, 1976, was transcribed on to cards. One card was used for each item of treatment. The patient was identified by a unique code, the date of birth and sex. For each item of treatment, the tooth treated, the type of treatment, material and the date of treatment were recorded. Treatment of deciduous teeth was not included. The transcription was carried out by the author and an assistant. Periodically a sample of the transcribed data was compared with the original to check the accuracy of the transcription.

Detailed dental chartings were not available and restorations were described in the conventional way, i.e. by tooth surface (Frykholm and Lysell 1962). Cards recording treatment of maxillary first and second molars, mandibular first premolars and first molars were identified additionally by a notch punched at the periphery. Certain restorations of these teeth may be described ambiguously, which made the later identification of the cards necessary.

#### 2.4. Analysis of the Data

##### 2.4.1. Criteria of Life and Fate

(a) Life           The life of a restoration was taken as the number of years between the placement of the restoration and when it was lost as the result of another treatment of the tooth or the end of the study, 31st December, 1976. Life was rounded to the next whole year.

(b) Fate            The way in which a restoration was lost from a patient's mouth, i.e. its fate, was determined by the nature of the treatment resulting in its loss. Restorations surviving at 31st December, 1976 had censored survival times (Appendix 1.2.) as they had not then suffered a fate. A restoration may be lost in one of three ways:-

Replacement       A restoration may be replaced by one of identical tooth surface description, the implication being that the original had failed. This category includes recemented inlays and crowns, and 'patch' repairs.

Conversion        A restoration may be converted to one involving a greater number of tooth surfaces, e.g. conversion of an occlusal to a mesio-occlusal restoration. In this case the implication is that treatment of carious attack on a surface remote from the restoration had required sacrifice of the original, before failure had occurred.

Extraction        A restoration may be lost when a tooth is extracted.

In cases of conversion and extraction it was not possible to tell from the records whether or not the original had been diagnosed as failed, at the time of loss.

#### 2.4.2. The life and fate of restorations described ambiguously

Restorations involving the occlusal surface of maxillary first and second molars, and mandibular first premolars, where there are two anatomically distinct pit and fissure systems, may be described ambiguously. For first molars, restorations involving the palatal surface in maxillary teeth and the buccal surface in mandibular teeth present similar problems.

The transcribed data was arranged by patient, and cards relating to treatment of maxillary first and second molars and mandibular first premolars and first molars, were identified by means of the notches punched at the periphery. The sequence of treatment, for each tooth in turn, was inspected and the fate and date of loss of restorations were entered on the appropriate card. The ambiguities were resolved according to a modification of the method described by Robinson (1971). The first recorded

restoration was assumed to occupy one anatomical site, and the second recorded restoration to occupy the other site. A third restoration replaced or converted the first, and a fourth restoration was assumed to include all sites.

#### 2.4.3. The life and fate of all other restorations

Where there was no ambiguity in the description of a restoration, the fate and date of loss were determined using a computer programme. Each restoration was compared in turn with subsequent treatments of the tooth. If the first subsequent treatment of the tooth did not result in the replacement, conversion or extraction of the restoration, it was compared with the next subsequent treatment until either the restoration was lost or the end of the study was reached.

#### 2.4.4. Calculation of the life of restorations

The survival of restorations with respect to a particular fate only, or with respect to all fates combined, was calculated using lifetable analysis. The method used in this study was developed by a group of British and American statisticians as a result of the Medical Research Council encouraging collaborative clinical trials of leukaemia and other cancer therapies (Peto et al 1977), and is summarised in Appendix 1.

The life of restorations was calculated in two ways. Firstly the actual survival of the restorations was calculated by including all lost restorations in the analysis, irrespective of fate. Secondly the latent durability was calculated by including

replacements alone as lost restorations in the analysis.

## 2.5. Discussion

### 2.5.1. Source of Data

The data was derived from the records of patients who had been treated over many years by the same practitioner. The patients were therefore not representative of Scottish adults, two thirds of whom do not attend a dentist regularly (Todd and Whitworth 1974). Of the one third who do attend regularly, little is known about their loyalty to one practice, or how they move between one practice and another. Little is known about how a patient chooses the practice from which care is sought. It may be that the group of patients in this study were unusual in remaining loyal to one practice over a period in excess of twenty years and retaining some natural teeth into old age. The consequence of this loyalty was that the practitioner diagnosed fillings which had been placed by himself, and he may have been more reluctant to replace his own fillings compared to fillings placed by another operator. The combination of a group of loyal patients and a practitioner diagnosing his own work may have prolonged the life of restorations in this study, beyond the time when they would have been condemned by an 'average' operator.

### 2.5.2. Collection of Data

In effect, the data was collected in two stages. Firstly a record was made at the time treatment was carried out, and secondly, at the time of the study this record was transcribed

into a form suitable for later analysis. The assistant who helped with the collection of data was trained and periodic checks of the transcribed data against that on the patient's practice record card were made. The number of errors detected was so small as to be insignificant, but they were detectable from the sequence of treatment of a particular tooth, e.g. a restoration placed in a tooth which had previously been recorded as extracted, or transposing the patient's date of birth and the date of treatment.

### 2.5.3. Analysis of the Data

An important feature of this study was the recognition that restorations may be lost in one of three ways, replacement, conversion and extraction. Converted and extracted restorations were defined as having been lost before failure had occurred. It is implicit that such prematurely lost restorations had not completed their full potential lives. Only those restorations that were replaced had achieved their full potential lives, as replacement implied failure.

In analysing the life of restorations, the actual survival was calculated by including replacements, conversions and extractions as restoration losses. The latent or potential durability of the restorations was calculated by only including replacements as losses, and treating conversions and extractions as having censored survival times. The difference between latent durability and actual survival represents the unused life of a filling.

In compiling lifetables it is usual to keep the numbers with censored survival times as small as possible as an assumption is made that they have similar survival to those for which complete data is available. In a study of this kind there are two possible groups of restorations with censored survival times. Firstly, those which survived beyond the end of the study, and secondly those in teeth of patients who were lost to follow-up, for example because they changed dental practice. In the first case no bias is introduced as there is no reason to suppose that restorations surviving beyond the end of the study are different from those observed for a longer period. Whether the survival of cases lost to follow-up is better than, equal to, or worse than those remaining under observation is unknown.

In the present study in the calculation of actual survival, when restorations lost through all fates were included in the analysis, there were no restorations lost to follow-up as all the patients were regular attenders at the one practice. In analysing latent durability, when losses occurred by replacement alone, losses to follow-up were artificially created, i.e. conversions and extractions. There is no reason to suppose that if these restorations had survived long enough to fail, their survival would have been different from those known to have been replaced, and any bias therefore is likely to be minimal.

In calculating the life of restorations it was assumed that the fates were independent and that a restoration suffered one fate only. For replacements, this assumption is valid. For

conversions however, it was not possible to tell from the record whether or not the lost restoration had also been diagnosed as in need of replacement. For extractions, it was not known whether or not the lost restoration had been diagnosed as in need of replacement, or conversion, or both. In calculating the actual survival of the restorations no bias was introduced by assuming independence of fates. However in calculating latent durability, any bias introduced would have been to lengthen the life of restorations, although such bias is unlikely to be large.

#### 2.5.4. Calculation of Life of Restorations

In the present study, the life of restorations was calculated using lifetable analysis. This technique has been used in previous dental studies to investigate: the natural history of dental caries (Carlos and Gittelsohn 1965), the success of treating primary molars with formocresol (Thylstrup and Rölling 1975), sealing occlusal fissures with ordinary sealant resin and diluted composite resin (Raadal 1978), and the life of amalgam fillings in RAF personnel (Gray 1976).

The method of lifetable analysis described in Appendix 1 measures time in discrete units, and the smaller the unit, the more accurate the lifetable. Time at risk, in the present study, was measured in whole years, as previous reports have shown that restorations may survive in excess of twenty years, in which case whole years gives sufficient accuracy.

Another approach to lifetable analysis treats time as a

continuous variable measured in intervals. The numbers at risk at the start of an interval are corrected to allow for those surviving part of an interval. The numbers at risk are not constant throughout an interval because of gradual depletion by withdrawals and losses to follow-up. Cases withdrawn and lost to follow-up would be at risk on average for half the interval assuming that: for cases withdrawn and lost to follow-up, survival subsequent to the date of last contact is similar to that for cases with complete follow-up data; the loss rate did not change during the interval; withdrawals and losses to follow-up were equally spaced throughout the interval (Cutler and Ederer 1958). This method was used in the study of RAF personnel records (Gray 1976).

The advantage of the method used in the present study was that when making comparisons between the lives of differing restoration types, the whole structures of the compared lifetables were used, and not just their values at one point in time.

Finally, Markov chain analysis (Lu 1966) has been used to calculate the time taken for a tooth to pass through a chain of states, e.g. erupted and sound, decayed, restored, restored and decayed, extracted. The method is unnecessarily complicated for the analysis of the durability of restorations, which may exist in one state alone.

SECTION BRESULTSIntroduction

This section, together with Section C, describes the results of the study. Firstly as a background, the distribution of the various types of treatment, received by the patients during the study, is described in Chapter 3. This distribution is then compared to what is known of treatment received by Scottish adults in general.

Secondly, since the life of a filling is the time elapsing between its placement and loss, the distribution of the ways in which a restoration may be lost, namely replacement, conversion and extraction, is described in Chapter 4.

CHAPTER 3THE DENTAL TREATMENT RECEIVED DURING THE STUDY3.1. Introduction

Compared to irregular attenders, those who attend a dentist regularly have been shown to have few missing and decayed teeth and many filled teeth. In Scotland, regularly attending adults had an average of 11.2 filled teeth compared to 3.2 for adults who only attended when having trouble (Gray et al 1970, Todd and Whitworth 1974). Little is known of the tooth types restored and the nature of conservative treatment received by regular attenders, whether it is simple fillings or advanced complex conservative procedures. The treatment received by the patients in this study gives an indication of the nature of the conservative treatment consumed by regular attenders, and forms the background to the life of restorations described later.

3.2. The Study Population

The study population consisted of 6,651 items of treatment received by 113 patients between 1949 and 1976. Of these patients, 41 were males, and 72 were females. Of the treatment given, 2,246 (34%) items were carried out for males and 4,405 were carried out for females. The mean age of the patients at the time of treatment was 37.6 years (S.E. = 0.207); for males, 35.4 years (S.E. = 0.381) and for females, 38.7 years (S.E. = 0.243). The age range was 5.4

years to 84.4 years. All of the patients had records of attendance exceeding 20 years. Fifty-eight patients had records spanning 28 years, and 27 patients had records spanning 27 years.

### 3.3. The Types of Treatment

The treatment received by the patients in this study was largely conservative and was organised into the following categories: Restorations; 1. occlusal, 2. proximal\*, 3. Buccal\*\*, 4. lingual\*\*\*, 5. mesio-occlusal and disto-occlusal (MO + DO), (including mesial-incisal and distal-incisal - MI + DI), 6. mesio-occlusal-distal (MOD), (including mesial-incisal-distal - MID), 7. other surface combinations, 8. crowns, 9. root treatments. In addition extractions were noted. In all, these categories accounted for 6,434 items of treatment. In addition, 217 items of miscellaneous treatment were provided. This last group included partial dentures (Appendix 3), apicectomies and gingivectomies. Since this group has no relevance to the life of fillings it will not be considered further.

\* includes restorations described as mesial or distal in the patient records

\*\* includes restorations described as buccal, labial, or cervical in the patient records

\*\*\* includes restorations described as lingual or palatal in the patient records

### 3.4. The Distribution of Types of Treatment (Table 2:3.4.)

Of the 6,434 items of treatment the commonest were MO + DO restorations (21.5%) and proximal restorations (20.5%). Occlusal, proximal, buccal, lingual, MO + DO, and MOD restorations together accounted for 80% of the treatment. The more complicated forms of treatment, crowns and root treatments, accounted for a total of less than 4%, and extractions accounted for only 10% of care.

In general there were not any important differences between males and females in the types of treatment received. Males received more occlusal restorations, and females received more proximal restorations and had a larger proportion of extractions.

### 3.5. The Distribution of Treatment according to Tooth Type (Tables 1:3.5.1-3; 2:3.5.1-4)

In general, there was twice as much treatment of posterior teeth than of anterior teeth. Although females received more treatment for front teeth than males and males received more treatment for posterior teeth, the difference was not large (Table 1:3.5.1.). There was one and a half times as much treatment for maxillary teeth compared to mandibular teeth in both sexes (Table 1:3.5.2.). Proximal, buccal and lingual restorations accounted for 73% of treatment of incisors and canines. In contrast, for premolars, buccal, lingual, MO + DO, and MOD restorations accounted for 70% of treatment. For molar teeth, occlusal restorations accounted for 27% of treatment and buccal,

Table 1:3.5.1.The Distribution of 6,434 items of treatment by tooth type and sex.

	Incisors and Canines		Premolars and Molars		All Teeth	
	Count	%	Count	%	Count	%
Males	647	29.4	1557	70.6	2204	100.0
Females	1461	34.5	2769	65.5	4230	100.0
All Patients	2108	32.8	4326	67.2	6434	100.0

Table 1:3.5.2.The Distribution of 6,434 items of treatment by dental arch and sex.

	Maxilla		Mandible		All Teeth	
	Count	%	Count	%	Count	%
Males	1369	62.1	835	37.9	2204	100.0
Females	2533	59.9	1697	40.1	4230	100.0
All Patients	3902	60.6	2532	39.4	6434	100.0

Table 1:3.5.3.

The Distribution of 6,434 items of treatment according to the type of tooth.

	Incisors and Canines		Premolars		Molars	
	Count	%	Count	%	Count	%
Occlusal or Incisal edge	26	1.2	154	9.5	718	26.5
Proximal	1185	56.2	62	3.8	72	2.7
Buccal and Lingual	354	16.8	349	21.6	526	19.4
MO + DO or MI + DI	97	4.6	554	34.3	731	27.0
MOD or MID	11	0.5	226	14.0	103	3.8
Other Surface Combinations	98	4.6	42	2.6	227	8.4
Crowns	91	4.3	30	1.9	1	0.0
Root Treatments	78	3.7	40	2.5	4	0.1
Extractions	168	8.0	160	9.9	327	12.1
Totals	2108	99.9	1617	100.1	2709	100.0

lingual and MO + DO restorations accounted for 46% of treatment.

#### 3.5.1. The Distribution of Occlusal Restorations

In both arches occlusal restorations were placed largely in molar teeth, to a much lesser extent in premolar teeth, and incisal edge restorations were rare. The largest proportions were placed in second molar teeth in both arches.

#### 3.5.2. The Distribution of Proximal Restorations

In contrast to occlusal restorations, most proximal restorations were placed in incisor and canine teeth. In maxillary teeth the largest proportions were in lateral incisors.

#### 3.5.3. The Distribution of Buccal and Lingual Restorations

No definite pattern could be seen in the distribution of buccal restorations in maxillary teeth in both sexes where the proportions were highest in canine and first premolar teeth. In contrast, in mandibular teeth of both sexes buccal restorations tended to be commonest in molar teeth.

There were few lingual restorations and they tended to be concentrated in maxillary and mandibular molars and maxillary incisors, in both sexes.

#### 3.5.4. The Distribution of MO + DO, and MOD Restorations

The commonest form of treatment, MO + DO restorations, was distributed mainly between first and second premolars and molars of both arches, in both sexes. In contrast, greater proportions of MOD restorations were placed in first premolars in both arches in females than males, while larger proportions were placed in first

molars of both arches in males compared to females. There was not an important difference between the sexes for the proportions of MOD restorations placed in other tooth types.

3.5.5. The Distribution of Other Surface Combination Restorations, Crowns, Root Treatments and Extractions.

Other surface combination restorations were concentrated in maxillary canines, and first and second molars of both arches, in both sexes.

Crowns, which accounted for only 2% of care, were commonest in maxillary incisors and mandibular second premolars in both sexes, as were root treatments with the inclusion of first premolars.

In maxillary teeth extraction of first molars and lateral incisors was commonest, but in general extractions were fairly evenly distributed about the upper arch. In contrast, for mandibular teeth, extractions were commonest in second premolar and molar teeth.

3.6. The Distribution of Treatment according to the age of the patient at the time of treatment (Tables 1:3.6.1; 2:3.6.1-2)

The ages of the patients at the time treatment was carried out were divided into seven groups: 10 years and younger, between 11 and 20 years, between 21 and 30 years, between 31 and 40 years, between 41 and 50 years, between 51 and 60 years, and 61 years and older.

In general, most treatment was carried out between 30 and 50 years of age (40%). For males most treatment was received in adolescence (26%) and between 41 and 50 years (19%). For females most treatment was received between 30 and 50 years (45%). In both sexes, treatment received in childhood accounted for least (Table 1:3.6.1.).

### 3.6.1. The Distribution of Occlusal Restorations

Occlusal restorations were most common in patients aged between 11 and 20 years and the proportions declined steadily with increasing age. They were commoner in males in the two youngest groups and commoner in females in the middle three age groups.

### 3.6.2. The Distribution of Proximal Restorations

The proportions of proximal restorations increased with age to a peak for patients aged between 41 and 50 years. Similar differences between the sexes were observed as for occlusal restorations.

### 3.6.3. The Distribution of Buccal and Lingual Restorations

No trend could be seen with buccal restorations, most being placed for patients aged between 41 and 50 years at the time of treatment. A higher proportion was provided for males between 11 and 20 years and for females between 31 and 40 years. A similar pattern was evident for lingual restorations.

### 3.6.4. The Distribution of MO + DO, and MOD Restorations

The majority of MO + DO restorations were distributed between patients aged between 11 and 50 years; more were placed in

Table 1:3.6.1.

The Distribution of 6,434 items of treatment according to the age of the patient at the time of treatment and sex.

Age (years)	Males		Females		All Patients	
	Count	%	Count	%	Count	%
10 and younger	124	5.6	125	3.0	249	3.9
11 - 20	571	25.9	612	14.5	1183	18.4
21 - 30	319	14.5	678	16.0	997	15.5
31 - 40	291	13.2	952	22.5	1243	19.3
41 - 50	410	18.6	957	22.5	1367	21.2
51 - 60	311	14.1	568	13.4	879	13.7
61 and older	178	8.1	338	8.0	516	8.0
All Ages	2204	100.0	4230	99.9	6434	100.0

males aged 10 years and younger, and between 11 and 20 years, and more placed in females in all the other age groups. The differences were largest in the 11 to 20 year and 31 to 40 year groups.

In females, the majority of MOD restorations were distributed relatively evenly between the 11 and 60 year old patients at the time of treatment, but in males MOD restorations were mainly placed in patients aged between 11 and 30 years.

#### 3.6.5. The Distribution of Other Surface Combination Restorations, Crowns, Root Treatments and Extractions.

No trend was apparent for other surface combination restorations. Higher proportions were seen in females aged between 21 and 30 years and 41 and 50 years, and in males in all other age groups.

Most crowns were made for females aged between 21 and 30 years and 41 and 50 years, while for males, most were made for patients aged between 51 and 60 years.

No trend was seen for root treatments, most of which, in both sexes, were carried out for patients aged between 11 and 60 years.

Only for males aged between 11 and 20 years were extractions more common than in females. In general, extractions increased with age to a plateau in patients aged more than 41 years.

### 3.7. The Distribution of Treatment according to Material

(Tables 2:3.7.1-2)

Five different types of materials were used for restorations; dental amalgam, silicate cement, acrylic resin, gold, and composite resin. Of these only acrylic resin was restricted to one brand (Sevriton\*); the others included an unknown number of different brands.

The most commonly used material was amalgam, accounting for 64% of restorations, followed by silicate cement (23%). Gold restorations accounted for only 1.5%, and sevriton and composite restorations 7.5% and 3% respectively. There was a higher proportion of tooth coloured materials used for females than males, and males received more amalgam restorations than females.

#### 3.7.1. The Distribution of Occlusal and Proximal Restorations

Amalgam accounted for 96% of occlusal restorations but only 13% of proximal restorations. The commonest material for proximal restorations was silicate cement (68%). There was not an important difference between the sexes.

#### 3.7.2. The Distribution of Buccal and Lingual Restorations

Amalgam accounted for 51% of buccal restorations, and silicate cement 29%. Males had a higher proportion of amalgam restorations

\* de Trey, A. G., Zurich, Switzerland.

than females, and females had a higher proportion of silicates. Amalgam accounted for 85% of lingual restorations, but again males had a higher proportion than females, who had a higher proportion of silicates.

### 3.7.3. The Distribution of MO + DO, and MOD Restorations

Amalgam accounted for over 90% of both restoration types and there was not an important difference between the sexes.

### 3.7.4. The Distribution of Other Surface Combination Restorations and Crowns\*

Over 90% of other surface combination restorations were made of amalgam. Males had a higher proportion of amalgams than females, while females had more tooth coloured material restorations. Males had more gold crowns than females, who had more sevriton crowns than males. Other materials (i.e. porcelain, and bonded porcelain) accounted for most crowns (46%) equally in both sexes.

### 3.8. The Crude frequency of treatment (Tables 1:3.8; 2:3.8)

The crude frequency of treatment can be described either as the number of treatments per patient per year, or as the number of patient years between treatments. In some cases the frequency of treatment was very low, e.g. crowns - 0.04 per patient per year, and therefore the frequency has been expressed as the number of years elapsing between each treatment for each patient. Expressed in this way, on average there were 25 years between each crown for each patient. Since the average duration of the study was 27 years,

\* see Preface to Appendices 2 and 3

the number of years between each treatment type for each patient is given by:

$$\frac{\text{Number of Patients (113)} \times \text{Duration of Study (27)}}{\text{Number of treatments during study}}$$

On average, each regularly attending patient consumed 2 items of care every year. Each patient received one occlusal restoration every 3.4 years, one proximal restoration every 2.3 years, and one buccal restoration every 3.1 years. A lingual restoration was placed once in 12 years, compared to the most frequently provided restoration, MO + DO, at a rate of one per patient every 2.2 years, while MOD restorations were placed at a rate of one per patient every 9 years. One other surface combination restoration was placed every 8.3 years and 25 years elapsed between each crown and root treatment. One tooth was extracted every  $4\frac{1}{2}$  years.

The most frequently treated teeth were mandibular molars at a rate of one treatment, per patient, per 2.2 years, followed by maxillary incisors and canines, and maxillary molars at a rate of one treatment, per patient, per 2.5 years. Maxillary premolars were treated at the rate of one treatment, per patient, per 3.5 years, mandibular premolars at the rate of once, per patient, per 4.2 years, and the least frequently treated teeth were mandibular incisors and canines at a rate of once, per patient, per 9.2 years.

The most frequent treatment was the provision of a proximal restoration in maxillary incisors and canines at a rate of one, per person, per 3 years, and the least frequent treatments were crowns and root treatments of maxillary molars.

Table 1:3.8.The Frequency of Treatment.

Treatment Type (Any Tooth)	Frequency** (years)	Tooth Type (Any Treatment)	Frequency** (years)
Occlusal	3.4	Maxillary Teeth	
Proximal	2.3	Incisors and Canines	2.5
Buccal	3.1	Premolars	3.5
Lingual	12.1	Molars	2.4
MO + DO	2.2		
MOD	9.0	Mandibular Teeth	
OSC*	8.3	Incisors and Canines	9.2
Crowns	25.0	Premolars	4.1
Root Treatments	25.0	Molars	2.1
Extractions	4.6		
All	0.5	All	0.5

\* OSC = Other Surface Combinations.

\*\* The number of years elapsing between each treatment =  

$$\frac{\text{Number of Patients} \times \text{Length of Study}}{\text{Number of Treatments}} = \frac{113 \times 27}{\text{No.}}$$

### 3.9. Discussion

Only one third of Scottish adults attend a dentist regularly (Todd and Whitworth 1974) and the patients whose records formed the basis of this study were all regular attenders. They cannot therefore be representative of all Scottish adults. However, when compared with the known characteristics of regular attenders in Scotland the patients in this study are not atypical.

Of the regularly attending Scottish adults a higher proportion was female than male, 58% compared to 42% (Todd and Whitworth 1974). In a study of patients attending a suburban practice in Leeds the proportions of female and male regular attenders were 57% and 43% respectively (Williams and Jackson 1978). In the present study a higher proportion of the patients was female than male, 66% compared to 34%. The relatively greater excess of females over males in this study is consistent with the location of the practice in an area having a higher proportion of females in the population than males, i.e. Morningside in Edinburgh (Keir 1966).

The data accumulated about this group of regularly attending patients is essentially a record of care consumed, as opposed to a survey of dental health. Nevertheless, the results provide an insight into the types of treatment received by Scottish regular attenders, information about which has not previously been available.

The best data to date may be found in the summary reports

of the Scottish Dental Estimates Board, the limitations of which have already been described (2.2.1). The summary reports differentiate between emergency care (form EC17A treatment) and routine care (form EC17 treatment). Care is described as the numbers of courses of treatment given, and the numbers of teeth treated. While patients who consumed routine care included both regular and irregular attenders, the care consumed by this group provides the best available approximation to that consumed by regular attenders alone.

The conservative treatment consumed by the patients in this study was not unlike the routine conservative care reported by the Scottish Dental Estimates Board. In Scotland over 95% of teeth treated conservatively were 'filled', i.e. a restoration other than an inlay, crown or bridge was provided (Table 1:3.9.1). Similarly in the present study 94% of conservative care was 'fillings'.\* In Scotland 2% of routine conservative care consisted of crowns, and 1.5%, root treatments. In the present study crowns and root treatments each accounted for 2% of care and inlays accounted for 1%. In Scotland inlays accounted for 0.6% of routine conservative care. The conservative care received by the patients in this study is therefore typical of the routine conservative care consumed by

\* (Occlusal + Proximal + Buccal + Lingual + MO+DO + MOD + Other Surface Combinations - Gold Restorations) ÷ (All Restorations + Root Treatments) = 5448 ÷ 5779 = 94%.

Table 1:3.9.1.

Numbers of Teeth Treated by General Dental Practitioners in  
Scotland under the National Health Service.

(Source: S.D.E.B. Summary Reports).

	<u>1973</u>		<u>1974</u>		<u>1975</u>		<u>1976</u>	
	Count	%	Count	%	Count	%	Count	%
Fillings	2949598	96.8	3059479	95.9	3065491	95.8	3129446	95.7
Inlays	21515	0.7	19791	0.6	18407	0.6	17316	0.5
R.T.*	39627	1.3	46656	1.5	52779	1.6	61354	1.9
Crowns	35857	1.2	64789	2.0	63025	2.0	63697	1.9
Total	3046597	100.0	3190715	100.0	3199702	100.0	3271813	100.0

\* R.T. = Root Treatments.

patients in Scotland, payment for which is authorised by the Scottish Dental Estimates Board.

The types of conservative procedure which comprise the 'fillings' component of the Scottish Dental Estimates Board annual reports, have not previously been reported. Data from the present study shows that over three quarters of this component of the conservative care given to a group of regularly attending patients consisted of occlusal, mesio-occlusal, disto-occlusal, buccal, lingual, proximal, and mesio-occlusal-distal restorations.

3.10. Summary

If extractions are excluded, 89% of the restorative dental care received by this group of regularly attending patients consisted of occlusal, proximal, buccal, lingual, MO + DO, and MOD restorations. Crowns and root treatments only accounted for 2% each. On average each patient received 2 items of treatment per year.

Premolars and molars accounted for twice as much treatment as incisors and canines.

Dental amalgam was used for 64% of restorations, while the most commonly used tooth coloured material was silicate cement, accounting for 23% of restorations. Gold only accounted for 1.5% of restorations.

CHAPTER 4THE FATE OF DENTAL RESTORATIONS4.1. Introduction

In Chapter 2 the life of a restoration was defined as the time elapsing between its placement and its loss. The ways in which restorations may be lost were described as replacement, conversion and extraction (2.4.1(b)), and in this chapter the distribution of these fates is described. Only those restorations which had been lost by the end of the study are included because restorations surviving beyond that date had not then suffered a fate. In addition, since occlusal, proximal, buccal, lingual, MO + DO, and MOD restorations together accounted for 80% of treatment, only their fates will be described. The remaining 20% consisted of other surface combination restorations, crowns, root treatments and extractions (Table 2:3.4.).

4.2. The Distribution of the fates of restorations

Of the 6,434 items of treatment provided during the study, 3,754 restorations were lost. Of these the six types of restorations described in 4.1. accounted for 87% (3,279). Replacement was the single most important fate accounting for 54% (1,774) of lost restorations. In comparison, 21% (690) and 25% (815) of the lost restorations were converted and extracted respectively.

4.3. The Fate of Restorations according to the tooth surfaces restored (Table 2:4.3.).

Restorations fell into two broad groups according to whether there was a high or low proportion of conversions. Occlusal, and MO + DO restorations had higher proportions lost by conversion, 57% and 30% respectively. Other types of restorations had 10% or less lost by conversion.

Occlusal restorations had the lowest proportion replaced (29%), followed by MO + DO restorations, 42% of which were replaced. In contrast 72% of proximal restorations, 64% of buccal restorations, 51% of lingual restorations and 68% of MOD restorations were replaced.

A relatively large proportion of lingual restorations was extracted, 46%, compared to only 14% of occlusal restorations. For the other types of restorations the proportions extracted varied between 21% and 32%.

Only for occlusal restorations was conversion the most important fate. For all others replacement was most important.

4.4. The Fate of Restorations according to the sex of the patient (Tables 2:4.4.1-2).

In general, equal proportions of restorations in both sexes were replaced, higher proportions were converted in males than females, and higher proportions were extracted in females than

males.

#### 4.5. The Fate of Restorations according to the type of tooth restored

##### 4.5.1. Introduction (Table 1:4.5.).

In general, the proportion of restorations replaced declined from anterior teeth towards posterior teeth, whereas the proportion of restorations extracted increased from the anterior teeth towards posterior teeth. Conversions accounted for only 5% of lost restorations in anterior teeth compared to almost one third in posterior teeth. For all teeth, the most important fate of restorations was replacement.

##### 4.5.2. Restorations of Incisors and Canines (Tables 2:4.5.1-2).

In maxillary incisors and canines replacement accounted for three quarters of lost restorations. Extractions accounted for almost one fifth of lost restorations, and conversion was an insignificant fate. In mandibular teeth rather more restorations were extracted at the expense of replacement. For mandibular restorations two thirds were replaced and one quarter was extracted.

Thus for all restoration types, replacement was most important, followed by extraction, and with the exception of MI + DI restorations conversion was of no importance.

Table 1:4.5.The Fate of 3,279 Restorations according to tooth type.

	<u>Replaced</u>		<u>Converted</u>		<u>Extracted</u>		<u>Total</u>	
	Count	%	Count	%	Count	%	Count	%
Incisors and Canines	888	75.1	65	5.5	229	19.4	1182	100.0
Premolars	394	47.6	244	29.5	189	22.9	827	100.0
Molars	492	38.7	381	30.0	397	31.3	1270	100.0
All	1774	54.1	690	21.0	815	24.9	3279	100.0

#### 4.5.3. Restorations of Premolars (Tables 2:4.5.3-4).

Premolar restorations followed the general trend in that replacement was the most important fate. In contrast to incisor and canine restorations, the proportions converted were large. This was mainly due to occlusal and MO + DO restorations. For these two restoration types, in premolar teeth, conversion was the most important fate. For proximal restorations, extraction accounted for the greatest proportion of lost restorations. The patterns were similar in both maxillary and mandibular teeth.

#### 4.5.4. Restorations of Molars (Tables 2:4.5.5-6).

Restorations of maxillary molars were the exception to the general trend. Extraction accounted for the highest proportion of lost restorations. However, like occlusal restorations of premolars, the most important fate of occlusal restorations of molars was conversion.

For mandibular molar restorations, replacement was the most important fate, following the general trend. As with premolars and maxillary molars, conversion accounted for the highest proportion of lost occlusal restorations.

#### 4.6. The Fate of Restorations according to the age of the patient at the time of treatment

##### 4.6.1. Introduction (Table 1:4.6.).

In general, the proportions of restorations replaced increased with age to early adulthood, and then remained largely



Table 1:4.6.

The Fate of Restorations according to the age of the patient  
at the time of treatment.

<u>Age</u> (years)	<u>Replaced</u>		<u>Converted</u>		<u>Extracted</u>		<u>Total</u>	
	Count	%	Count	%	Count	%	Count	%
10 and younger	70	36.1	69	35.6	55	28.4	194	100.1
11 - 20	309	48.7	251	39.6	74	11.7	634	100.0
21 - 30	266	59.9	110	24.8	68	15.3	444	100.0
31 - 40	427	59.6	134	18.7	156	21.8	717	100.1
41 - 50	422	54.0	95	12.1	265	33.9	782	100.0
51 - 60	207	58.0	22	6.2	128	35.9	357	100.1
61 and older	73	48.3	9	6.0	69	45.7	151	100.0

unchanged until age 61 years and older when they started to decline. In contrast, the proportion of conversions declined steadily with age while the proportions extracted reached a minimum in adolescence and then steadily increased with age.

#### 4.6.2. Occlusal Restorations (Table 2:4.6.1.).

The proportions of occlusal restorations replaced showed no definite trend with age. The proportions converted reached a maximum in patients aged between 11 and 20 years (67%) and then declined with age while the proportions extracted reached a minimum in that age group (9%) and then increased with age.

#### 4.6.3. Proximal Restorations (Table 2:4.6.2.).

The proportions of replaced proximal restorations exceeded 85% up to age 30 years and then declined, the proportions converted remained below 10% always, and extractions increased with age.

#### 4.6.4. Buccal and Lingual Restorations (Tables 2:4.6.3-4).

The proportion of buccal restorations replaced rose to a peak of 76% in patients aged 31 - 40 years and then declined. The proportions converted never exceeded 8% and the proportions extracted tended to increase with age.

The numbers of lingual restorations were small. In patients aged 10 years and younger three quarters were extracted, while in adolescents only one quarter was extracted. Thereafter replacements and extractions were almost equal. Conversions were always unimportant.

#### 4.6.5. MO + DO, and MOD Restorations (Tables 2:4.6.5-6).

For MO + DO restorations those placed in patients 10 years and younger were again atypical of other ages; 43% restorations were extracted, 32% were converted and only 25% replaced. Thereafter for all other ages, replacements accounted for around 40%, while extractions increased with age and conversions decreased. The numbers of lost MOD restorations were small, but over all ages a consistently high proportion was replaced. No trend could be seen for extractions or conversions.

#### 4.7. The Fate of Restorations according to material

(Tables 2:4.7.1-3).

It was shown in Chapter 3 that restorations of anterior teeth were largely made from tooth coloured materials, while restorations of posterior teeth were largely made from amalgam. In general, the fate of restorations according to material reflected the tooth type in which the material was used. Hence the fate of silicate and sevriron restorations reflected the fate of incisor and canine restorations, while the fate of amalgam restorations reflected that of premolar and molar restorations.

#### 4.8. Discussion

In general replacement was the most important fate of the restorations in this study. In Chapter 2, the implications behind the way in which a restoration was lost, were described (2.4.1(b)).

For replacements, the implication was that the original had failed, whereas for conversions and extractions the implication was that, at the time of loss, failure had not then occurred. As replacements were failed restorations, they had completed their full potential lives. As conversions and extractions were assumed to have been lost before failure, they were lost prematurely, before their full potential lives had been completed.

From the distribution of fates, clearly restorations most likely to achieve their full potential survival are those of anterior teeth, while those most likely to be lost prematurely are MO + DO and occlusal restorations of premolars and molars in young people.

Clearly it is desirable that as many restorations as possible should complete their full potential lives and it is interesting to examine the fates of prematurely lost restorations to suggest possible mechanisms by which premature loss may be reduced.

Premature loss of a restoration in this study was due to one of two fates, i.e. conversion or extraction. Conversion may be considered to be almost wholly due to fresh caries attack on a surface remote from the restoration, but the reasons for extraction of teeth in regularly attending patients may not be only caries but other factors. These will be discussed later.

Conversion was the most important cause of premature loss in

young people, for occlusal and proximo-occlusal restorations, and restorations of premolar and molar teeth. For all other types of restorations conversion accounted for a very small percentage of losses. None of the patients in this study had consumed optimally fluoridated drinking water, and routine applications of topical fluoride preparations were not used. In addition fluoridated toothpastes only became widely available towards the end of the study. It is interesting to speculate on the reduction in the proportion of converted restorations had these patients been exposed to fluoride.

One of the earliest studies of the beneficial effects of drinking water containing optimum levels of fluoride showed a strikingly low level of proximal caries attack and also a low permanent first molar mortality in 12 - 14 year old children (Dean et al 1939). In the fluoridation study carried out at Tiel and Culemborg in Holland there was a 74% reduction in proximal caries attack after 13½ years (Kwant et al 1969). All smooth surfaces show a marked reduction in caries attack when fluoridated water is consumed and in a comparison of fluoridated and non-fluoridated towns in Holland and New Zealand, Backer-Dirks (1974) concluded that the relative importance of proximal and gingival lesions was markedly reduced in fluoridated towns. In addition there was an important shift towards less complicated restorations. The reduction in smooth surface caries attack has been shown to be life-long. In dentate adults aged 45 years and older, the frequency of smooth surface caries attack in

Hartlepool, where drinking water contained between 1.5 and 2.0 ppm fluoride, was 50% less than in a similar group in York, where the water contained 0.2 ppm (Jackson et al 1973A).

Clearly, if the patients in this study had consumed fluoridated water a much lower level of proximal and smooth surface caries attack would have occurred, with consequently a much reduced level of conversions of occlusal and proximo-occlusal restorations in molars and premolars of young people. For example in patients aged 10 years and younger at the time of treatment less than one quarter of occlusal restorations may be expected to have been converted compared to 50%, and in the 11 to 20 years group less than one third of occlusal restorations would have been converted instead of two thirds. For proximo-occlusal restorations in the younger age groups similar reductions could have occurred. These benefits assume that consuming fluoridated water would have no effect on the proportions extracted, which is unrealistic, and the benefits suggested above, therefore, are probably underestimates.

Support for these predictions comes from a study of the records of children aged less than 13 years treated by the New Zealand School Dental Service (Roder 1975). In a non-fluoridated community it was shown that 74.6% of first permanent molars restored with occlusal restorations, subsequently were restored with a proximo-occlusal restoration. In a fluoridated community the proportion of first permanent molars restored occlusally which subsequently were restored proximo-occlusally was 37.9%.

In the absence of fluoridated drinking water, a reduction in the number of restorations sacrificed in the treatment of new caries attack on proximal and bucco-lingual surfaces could have been achieved by the use of local applications of fluoride preparations, e.g. topical fluoride solutions or gels. Similarly if fluoride containing toothpastes had been available, reduction in proximal caries attack on premolars and molars could have been expected (Murray 1976).

The other cause of premature loss of restorations was extraction of teeth. The proportion of extracted restorations was more important in females than males, in the older patients than the younger ones, and for molar restorations than others. The practitioner did not record his reasons for extracting teeth and there is not any data in the literature relating to the causes of tooth loss in regularly attending Scottish patients. It has been shown in one small study that in excess of 40% of teeth extracted in Scottish adults are removed for non-disease reasons (Todd and Whitworth 1974).

In the present study, caries would have been the most important cause of tooth extraction, particularly in young patients, but in the older patients, the reasons for tooth extraction were almost certainly more complex. A study of adult dental health in fluoride and non-fluoride areas showed that in the non-fluoride areas, the percentage number of extracted teeth which were carious, for all tooth types, decreased steadily with age (Murray 1971). In the fluoride area the proportion of extracted

premolars and molars which were carious, also decreased with age. Clearly consumption of fluoridated water would have reduced the numbers of teeth extracted in younger patients in the present study, but may not have had such a marked effect on the numbers extracted in older patients, where extractions may not have been primarily due to caries.

In the present study of a group of patients who were not exposed to fluoride the overall proportion of restorations lost prematurely was 46%. It has been speculated that exposure to fluorides, particularly optimally fluoridated drinking water, would reduce this figure, perhaps to as low as 25%. Further research is required to show whether this hypothesis can be sustained, and to show the effect of any other methods of preventing premature loss of restorations.

The importance of reducing premature loss of restorations is that it would result in the life of restorations being prolonged.

#### 4.9. Summary

The fate of dental restorations has not previously been reported. In general replacement was the most important fate in this study, accounting for 54% of the lost restorations. Conversion and extraction accounted for 21% and 25% respectively. The important exception to this general trend was occlusal restorations, the majority of which were converted (57%).

For incisor and canine restorations, replacement was more important and conversion less important, than the general trend. For premolar and molar restorations, the converse was true. The proportions of restorations extracted increased from anterior to posterior teeth.

In general replacements varied little with increasing patient age, but conversions declined and extractions increased from adolescence.

If conversions and extractions are taken to be prematurely lost restorations, almost half of the lost restorations in this study did not complete their full potential lives.

SECTION CTHE LIFE OF DENTAL RESTORATIONSIntroduction

Having considered the way in which restorations were lost and the underlying implications, this section describes the life of the restorations considered in Chapter 4. Implicit in the fates of dental restorations was the concept of some achieving their full potential survival while others were lost prematurely. Firstly, in Chapter 5, the actual survival of the restorations is described by including in the lifetable analysis all lost restorations irrespective of fate. Secondly, in Chapter 6, an estimate of the latent durability of the restorations is made. This represents the life of the restorations if none had been lost prematurely. Latent durability was calculated by treating replacements as lost restorations in the lifetable analysis, while conversions and extractions were treated as having censored survival times. Thirdly, in Chapter 7, the difference between actual survival and latent durability is described. This represents the unused life of the restorations, and gives an estimate of how much longer they could have survived, if none had been lost prematurely.

The basis of Chapters 5, 6 and 7 is the lifetables describing actual survival and latent durability. Since they extend up to 28 years, two methods of summary for each lifetable

have been adopted. Firstly in Chapters 5 and 6, the proportions of restorations which survived 5, 10 and 25 years have been used and are given in parenthesis. For example, the actual survival of amalgam restorations is given in lifetable 2:1. The proportion surviving 5, 10 and 25 years were 68%, 48%, and 22% respectively. Similarly for the latent durability of amalgam restorations also given by lifetable 2:1, the proportions surviving 5, 10 and 25 years were 85%, 74%, and 59%. This method was adopted because survival distributions are not normal, and therefore measures of central tendency are inappropriate, and invariably highly unreliable descriptive statistics (Peto et al 1977). Nevertheless, this disadvantage is offset by the advantage of describing the life of restorations in years, when the difference between actual survival and latent durability is considered. In Chapter 7 therefore, the median actual survival times (MAST) and median latent durability times (MLDT) of restorations have been used to summarise lifetables.

In making comparisons between the life of different types of restorations, those made at one point in time can be misleading because the whole structures of the lifetables are not used. The whole structures of lifetables may be compared for two or more restoration types by using the Relative Loss Rate (RLR) for comparisons of actual survival and the Relative Replacement Rate (RRR) for comparisons of latent durability. The Relative Loss Rate is the ratio of the observed losses to the expected losses, while the Relative Replacement Rate is the ratio of the

observed replacements to the expected replacements. In each case the expected value is calculated assuming that there is no difference in either actual survival, or latent durability, between the compared restoration types (Appendix 1.5.). The lower the RLR or RRR for a particular restoration the better the actual survival or latent durability. Where paired comparisons have been made, the percentage reduction of the lower RLR or RRR to the greater has been used. If the Relative Loss Rate Ratio, or Relative Replacement Rate Ratio (expressed as a percentage reduction) for two types of restorations differs markedly from unity, and the numbers of restorations are large, the difference in survival is more likely to be statistically significant. A significant difference was noted when  $p$  was less than 0.05.

CHAPTER 5THE ACTUAL SURVIVAL OF RESTORATIONS5.1. Introduction

Dental restorations are commonly described by tooth surface and material. As an overview the actual survival of restorations according to tooth surface description has been described first. Subsequently the differences in survival of restorations between males and females is described in 5.3.. A second overview is then given by the actual survival of restorations according to material in 5.4..

Comparisons of the survival of the six tooth surface combinations in different tooth types is given in 5.5., and in 5.6. the variation in survival of these restorations with the age of the patient at the time of treatment is described.

5.2. The Survival of six types of Restorations according to the tooth surfaces restored

5.2.1. Introduction

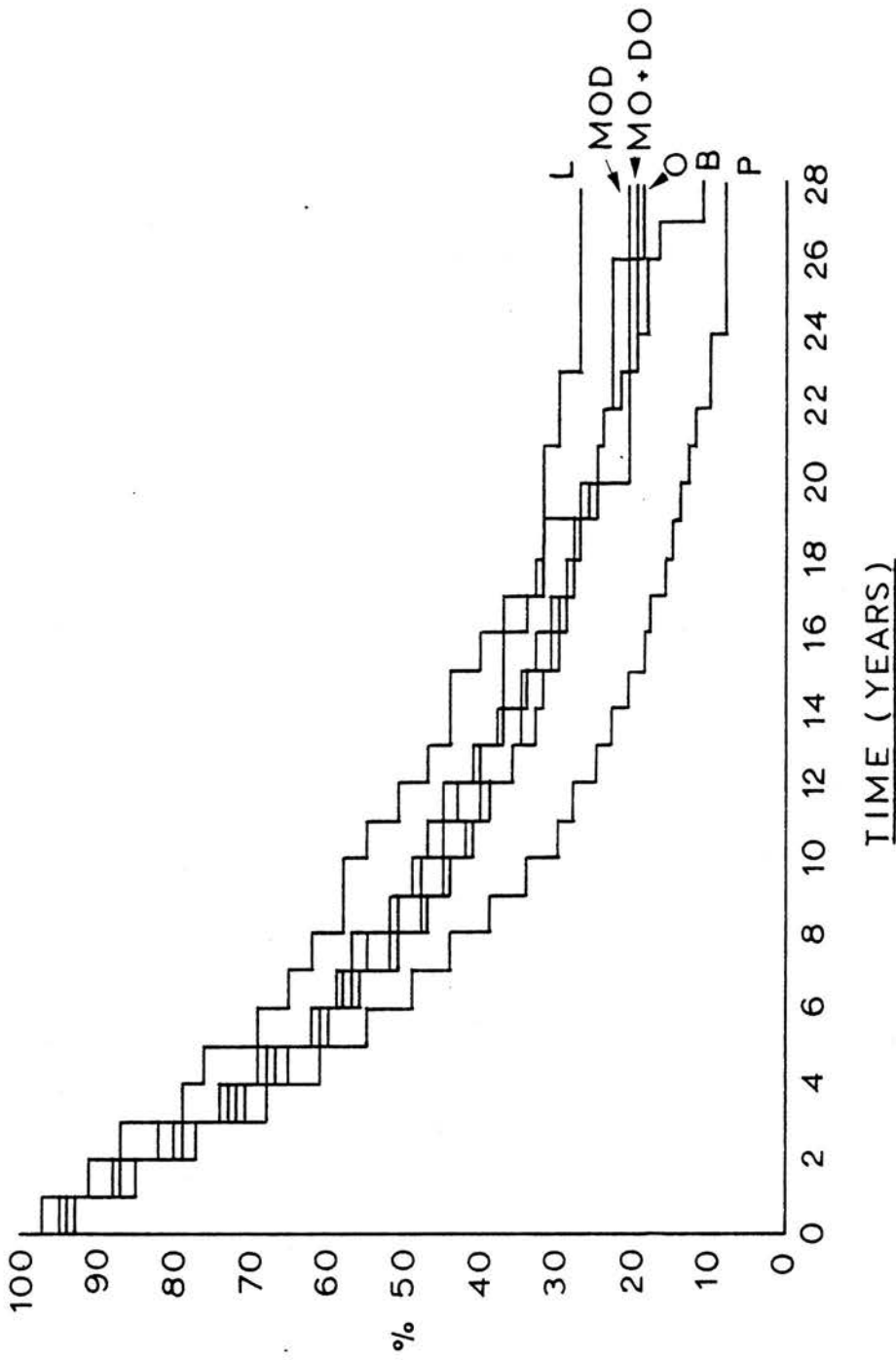
In this part the first overview of the actual survival of restorations is given. In Fig. 1:5.2.2A. a graphical representation of the six lifetables on which this part is based has been drawn. Fig. 1:5.2.2. shows graphically the six relative loss rates for the restorations and Table 1:5.2.2. shows paired comparisons of relative loss rates.

5.2.2. The Survival of six types of Restorations according to the tooth surfaces restored

(Figs. 1:5.2.2.; 1:5.2.2A.; Tables 1:5.2.2.; 2:5.2.2.; 2:5.2.2A.; Lifetables 2:6-11).

Of the six types of restorations, MOD restorations (76%, 58%, 21%) survived longest, and proximal restorations (61%, 34%, 8%) survived least well. Between these extremes and in descending order of survival were lingual (69%, 49%, 27%), MO + DO (67%, 48%, 20%), occlusal (65%, 45%, 23%) and buccal restorations (68%, 44%, 18%). Occlusal, buccal, lingual, MO + DO, and MOD restorations all survived significantly longer than proximal restorations. The respective RLR reductions were 26%, 26%, 33%, 29%, and 41%. In addition, MOD restorations also survived significantly longer than occlusal, buccal and MO + DO restorations, the RLR reductions being 24%, 24%, and 19% respectively.

Figure 1:5.2.2A.



THE SURVIVAL OF SIX TYPES OF DENTAL RESTORATIONS.

Figure 1:5.2.2.

THE SURVIVAL OF SIX TYPES OF  
DENTAL RESTORATIONS.

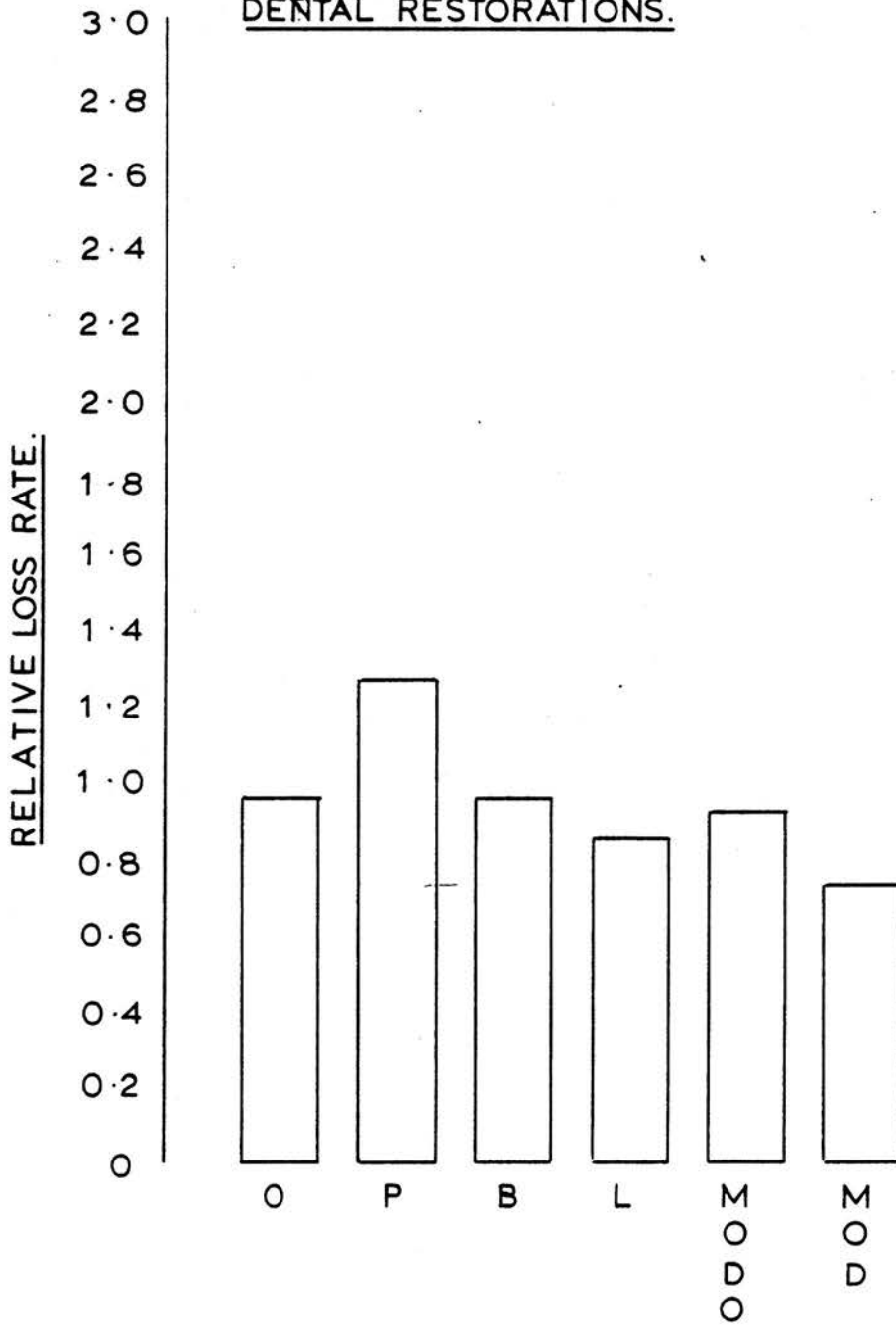


Table 1:5.2.2.The Survival of six types of Dental Restorations.

<u>BETTER</u>		<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1.	Occlusal	26%	p < 0.0001	Proximal
2.	Occlusal	0%	N.S.	Buccal
3.	Lingual	11%	N.S.	Occlusal
4.	MO + DO	4%	N.S.	Occlusal
5.	MOD	24%	p = 0.0022	Occlusal
6.	Buccal	26%	p < 0.0001	Proximal
7.	Lingual	33%	p < 0.0001	Proximal
8.	MO + DO	29%	p < 0.0001	Proximal
9.	MOD	41%	p < 0.0001	Proximal
10.	Lingual	11%	N.S.	Buccal
11.	MO + DO	4%	N.S.	Buccal
12.	MOD	24%	p = 0.0037	Buccal
13.	Lingual	7%	N.S.	MO + DO
14.	MOD	14%	N.S.	Lingual
15.	MOD	19%	p = 0.0143	MO + DO

### 5.2.3. Discussion

With respect to survival, the six restoration types fell broadly into 3 groups. The largest restoration type in terms of the number of surfaces restored was MOD and it survived longest. Next in survival came the group occlusal, buccal, lingual, and MO + DO restorations, a group which includes a wide heterogeneity of types of surface. The type with shortest survival was the proximal restoration.

Clearly the size of a restoration, expressed by the number of surfaces restored was not an important influence on actual survival. This is in contrast to the study of amalgam restorations placed in RAF personnel (Gray 1976) where the life of restorations decreased with an increase in number of tooth surfaces restored.

There are 3 important differences between the RAF study and the present study. Firstly, the RAF study included amalgam restorations only, whereas the present study included silicate, sevruton, gold and composite restorations, although amalgam restorations predominated. Secondly, the age range of the personnel whose restorations were followed up in the RAF study was not reported but a reasonable guess would be from late adolescence to late thirties. In contrast, in the present study the age range was from 5 to 84 years, and in Chapter 4 it was shown that the proportions of restorations lost by conversion and extraction was particularly dependent upon the age of the patient at the time of treatment. Thirdly, and as a consequence of the differing age ranges, it is likely that a higher proportion of restorations was

lost prematurely in the present study compared to the RAF study.

At first sight it might appear surprising that MOD restorations survived longest, particularly in the light of the RAF study. Nevertheless, the morphology of MOD restorations includes both proximal surfaces, thereby reducing the chance of conversion, which is one of the causes of premature restoration loss. Since MO + DO and occlusal restorations include only one proximal surface and none, respectively, their chances of being converted are greater. Therefore in posterior teeth, it would be expected that MOD restorations would survive longer than MO + DO restorations which would survive longer than occlusal restorations.

A large proportion of the remaining restoration types were placed in anterior teeth, particularly proximal restorations. Restorations of anterior teeth were made mainly from tooth coloured materials. Although lower proportions of these restorations were converted than occlusal, MO + DO, and MOD restorations, aesthetic constraints and the poorer properties of the materials probably led to a faster failure rate than that of restorations in posterior teeth. This high failure rate more than compensated for the premature losses of posterior restorations with the result that MOD, MO + DO and occlusal restorations actually survived longer than anterior tooth restorations.

In posterior teeth, the importance of tooth surfaces restored in determining restoration survival lies in the effect on the chance of conversion. It is of little importance in anterior

teeth where the overriding consideration is the material.

5.3. The Survival of six types of Restorations according to the sex of the patient

(Tables 1:5.3.; 2:5.3A.; Lifetables 2:12-23).

There were not any significant differences in the survival of restorations between males and females except for MOD restorations. MOD restorations in males (86%, 69%, 31%) had significantly better survival than restorations in females (68%, 49%, 17%). The RLR in males was 45% less than in females.

The difference between the survival of MOD restorations in males and females was probably the result of 2 factors. Firstly there was a different distribution according to tooth type (3.5.4.). Larger proportions were placed in premolars in females, while larger proportions were placed in first molars in males. Secondly there was a different age distribution (3.6.4.). In males most were placed between 11 and 30 years, while in females the restorations were distributed relatively evenly between 11 and 60 years.

Table 1:5.3.

The Survival of six types of Restorations according to the sex of the patient.

<u>Restoration</u>	<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1. Occlusal	Female	8%	N.S.	Male
2. Proximal	Male	3%	N.S.	Female
3. Buccal	Male	13%	N.S.	Female
4. Lingual	Female	18%	N.S.	Male
5. MO + DO	Male	5%	N.S.	Female
6. MOD	Male	45%	p = 0.0010	Female

#### 5.4. The Survival of Restorations according to material

##### 5.4.1. Introduction

Comparison of the actual survival of restorations according to material is constrained by two factors. Firstly, the patients in the study received overwhelmingly more amalgam restorations than any other material (3641). Silicate cement was the next commonly used material (1286), followed by sevricon (424). The numbers of gold and composite restorations were very small (87 and 163 respectively). Secondly, because amalgam is mainly used for restorations of premolars and molars, and tooth coloured materials are mainly used in incisors and canines, comparison of their survivals has little clinical relevance. In contrast, comparison of the survival of silicate cement and sevricon is clinically very important. With these comments in mind, the actual survival of all five materials has been compared in 5.4.2. as an overview.

5.4.2. The Survival of Restorations according to material

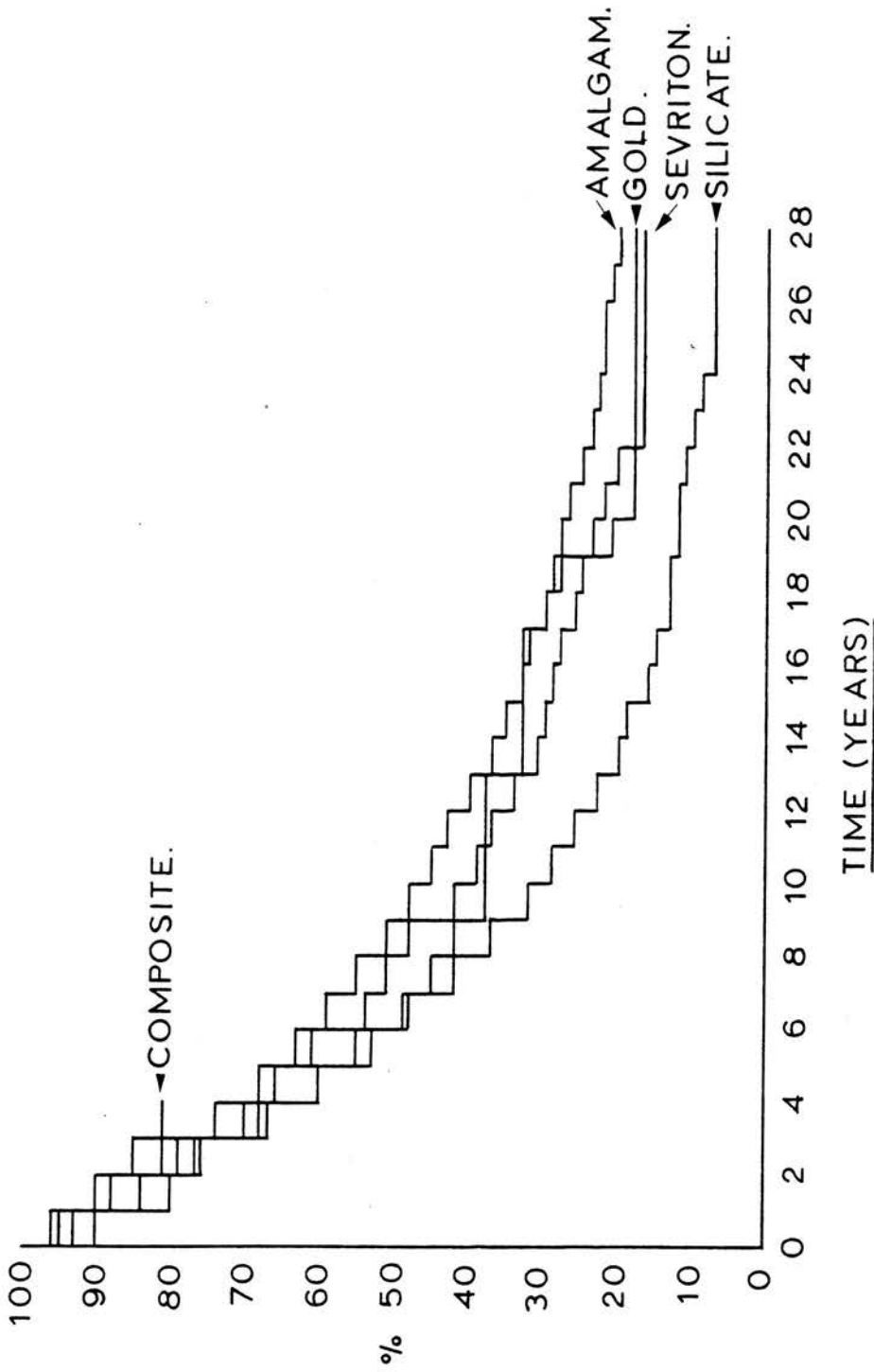
(Figs. 1:5.4.2.; 1:5.4.2A.; Tables 1:5.4.2 (a) & (b);  
2:5.4.2.; 2:5.4.2A.; Lifetables 2:1-5).

Amalgam was the most commonly used material and restorations made with it survived longest (68%, 48%, 22%), whereas silicate restorations (60%, 32%, 7%) were the shortest surviving restorations. In between were sevrton restorations (66%, 42%, 17%) and gold restorations (66%, 38%, 18%).

Amalgam restorations survived significantly longer than both silicate and sevrton restorations. The RLR reductions were 33% and 13% respectively. Sevrton restorations survived significantly longer than silicate restorations, the reduction in RLR being 23%.

During the last four years of the study the practitioner used composite resins. The estimates of the proportion of composite restorations which survived 4 years was 81% compared to 74%, 68%, 67%, and 70% for amalgam, gold, silicate and sevrton restorations respectively. Using the complete follow-up data composites survived significantly longer than silicates, the RLR reduction being 41%.

Figure 1:5.4.2A.



THE SURVIVAL OF RESTORATIONS ACCORDING TO MATERIAL.

Figure 1:5.4.2.

THE SURVIVAL OF RESTORATIONS  
ACCORDING TO MATERIAL.

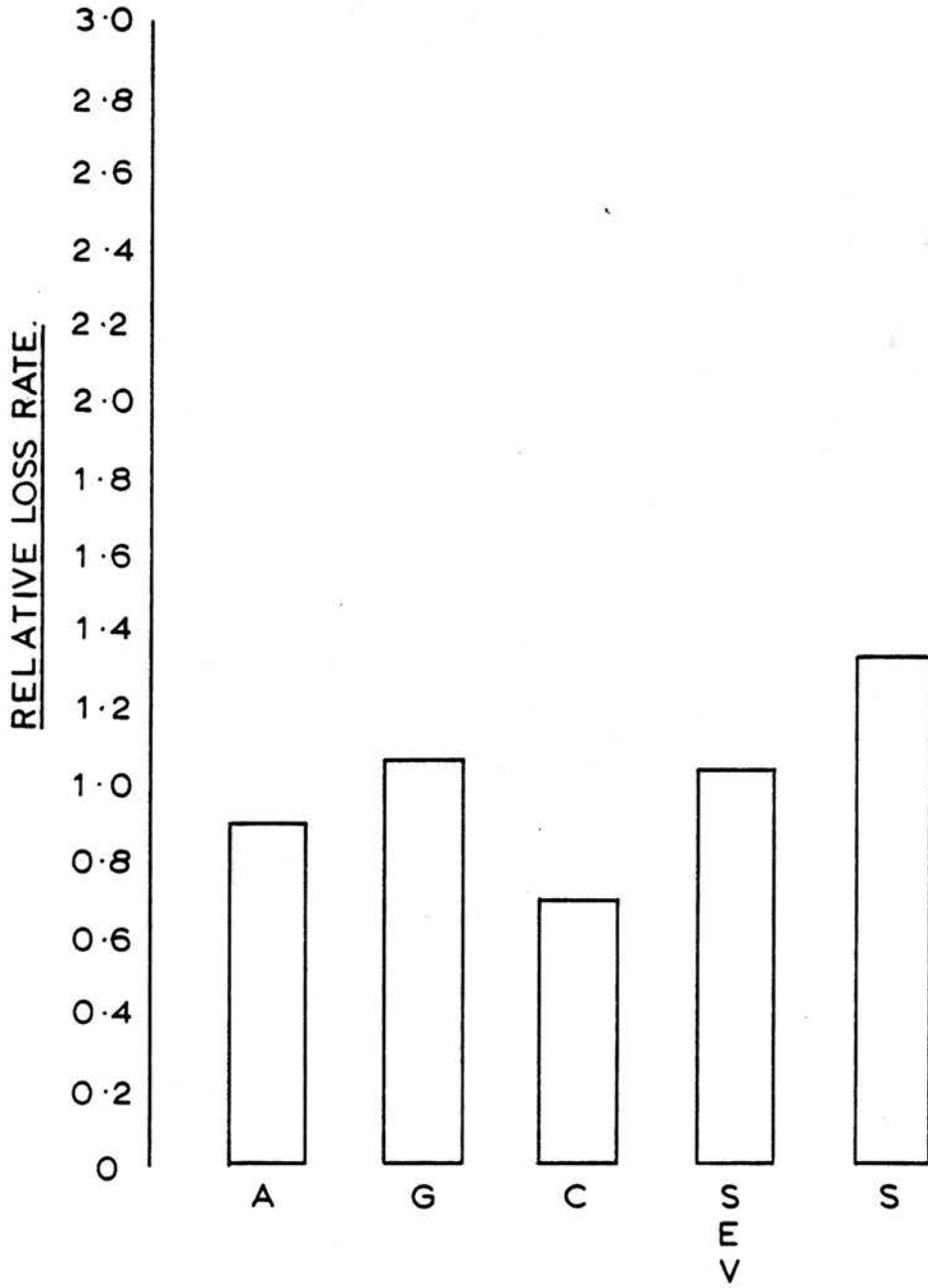


Table 1:5.4.2(a)

The Survival of Restorations\* according to material.

<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1. Amalgam	15%	N.S.	Gold
2. Amalgam	33%	p < 0.0001	Silicate
3. Amalgam	13%	p = 0.0195	Sevriton
4. Gold	21%	N.S.	Silicate
5. Sevriton	4%	N.S.	Gold
6. Sevriton	23%	p < 0.0001	Silicate

\* includes Other Surface Combinations and Crowns

Table 1:5.4.2(b)

The Survival of Restorations\* according to material.

<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1. Composite	24%	N.S.	Amalgam
2. Composite	33%	p = 0.0500	Gold
3. Composite	41%	p = 0.0152	Silicate
4. Composite	32%	N.S.	Sevriton

\* includes Other Surface Combinations and Crowns

#### 5.4.3. The Survival of six types of Amalgam Restorations

(Fig. 1:5.4.3.; Tables 1:5.4.3.; 2:5.4.3.; 2:5.4.3A.; Lifetables 2:24-29).

While the variation in survival over the six types of restorations was significant ( $p = 0.0032$ ) this was largely due to the good survival of MOD restorations and to a lesser extent, lingual restorations. The longest surviving restorations were MOD (78%, 61%, 25%), followed in order by lingual (72%, 55%, 31%), proximal (70%, 46%, 22%), MO + DO (68%, 50%, 21%), buccal (66%, 45%, 24%), and occlusal restorations (65%, 45%, 22%).

MOD amalgam restorations survived significantly longer than occlusal, buccal and MO + DO restorations. The RLR reductions were 31%, 29%, and 23% respectively. In addition lingual restorations survived significantly longer than occlusal restorations, the RLR reduction being 21%.

#### 5.4.4. The Survival of Silicate Restorations

(Tables 1:5.4.4.; 2:5.4.4.; 2:5.4.4A.; Lifetables 2:30-33).

Of the silicate restorations, 91% (1176) were proximal and buccal restorations and only their survival is described. Incisal, lingual, MI + DI, and MID restorations accounted for the remaining 9% (90) silicate restorations.

Buccal restorations survived significantly longer than proximal restorations, the RLR reduction being 28%.

Figure 1:5.4.3.

THE SURVIVAL OF SIX TYPES OF  
AMALGAM RESTORATIONS.

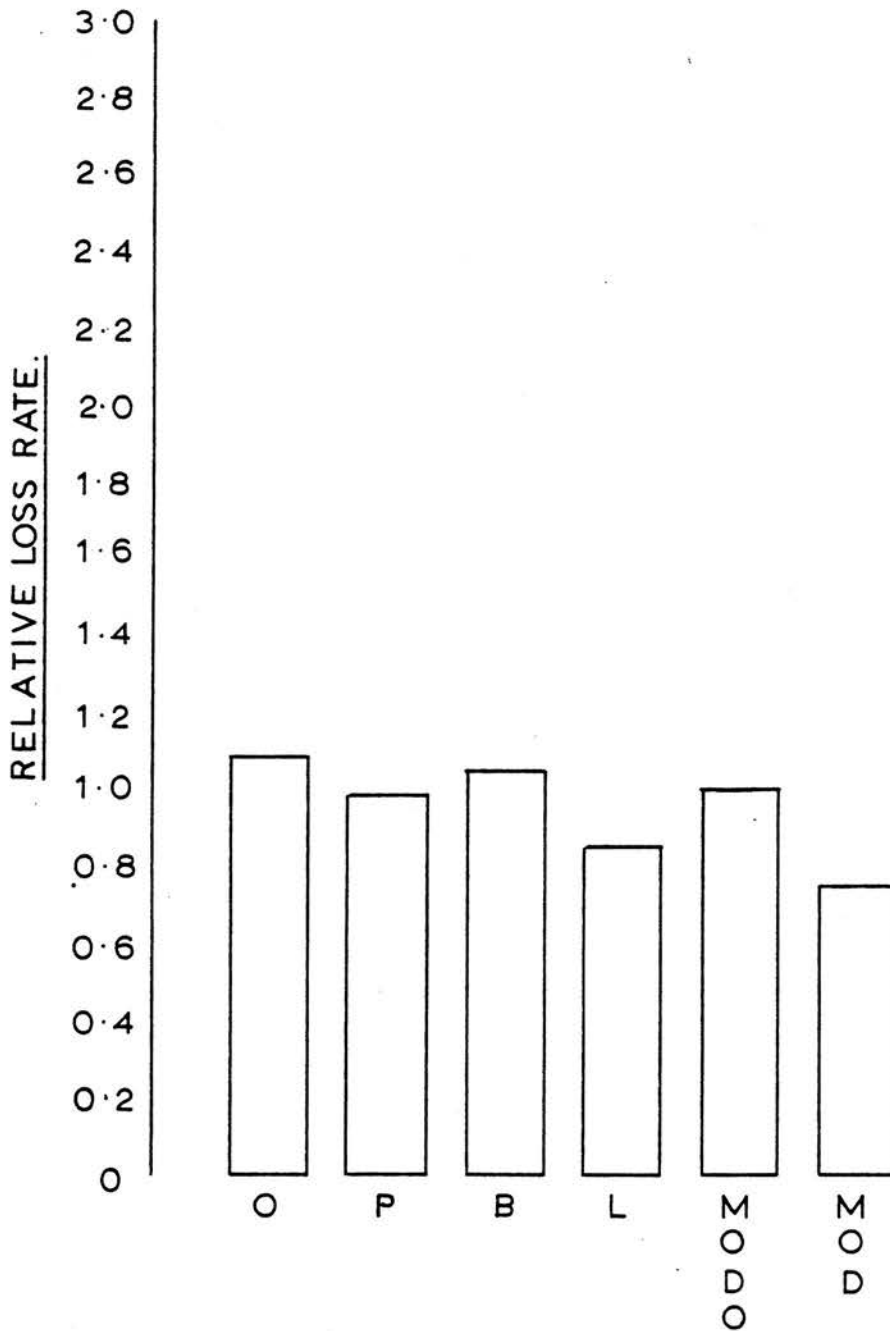


Table 1:5.4.3.The Survival of six types of Amalgam Restorations.

<u>BETTER</u>		<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1.	Proximal	15%	N.S.	Occlusal
2.	Buccal	4%	N.S.	Occlusal
3.	Lingual	21%	p = 0.0196	Occlusal
4.	MO + DO	8%	N.S.	Occlusal
5.	MOD	31%	p = 0.0001	Occlusal
6.	Proximal	4%	N.S.	Buccal
7.	Lingual	14%	N.S.	Proximal
8.	Proximal	1%	N.S.	MO + DO
9.	MOD	22%	N.S.	Proximal
10.	Lingual	18%	N.S.	Buccal
11.	MO + DO	5%	N.S.	Buccal
12.	MOD	29%	p = 0.0014	Buccal
13.	Lingual	15%	N.S.	MO + DO
14.	MOD	10%	N.S.	Lingual
15.	MOD	23%	p = 0.0077	MO + DO

Table 1:5.4.4.The Survival of Silicate Restorations.

<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
Buccal	28%	p < 0.0001	Proximal

5.4.5. The Survival of Sevriton Restorations

(Tables 1:5.4.5.; 2:5.4.5A.; Lifetables 2:34-36).

Only three comparisons were reasonable for sevriton restorations. Buccal restorations (70%, 49%, 22%) survived longest followed by proximal restorations (68%, 42%, 12%), and MI + DI restorations (51%, 19%, 0%).

Both proximal and buccal restorations survived significantly longer than MI + DI restorations, the RLR reductions being 36%, and 45% respectively.

Table 1:5.4.5.The Survival of Sevriton Restorations.

<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
1. Buccal	21%	N.S.	Proximal
2. Proximal	36%	p = 0.0094	MI + DI
3. Buccal	45%	p = 0.0008	MI + DI

#### 5.4.6. The Survival of differing materials used for the same Restorations

##### 5.4.6.1. Introduction

The constraints described in 5.4.1. apply, and therefore only clinically important comparisons are made. The survivals of silicate and sevricon are compared firstly for proximal and then for buccal restorations. Subsequently the survivals of amalgam and gold are compared for MO + DO, and MOD restorations (Table 1:5.4.6.).

##### 5.4.6.2. The Survival of Proximal and Buccal Restorations

(Tables 2:5.4.6A.; 2:5.4.7A.; Lifetables 2:25,26,30,31, 34,35).

Sevricon survived significantly longer than silicate in proximal restorations. The difference was not significant for buccal restorations. The RLR reductions were 26% and 18% respectively.

##### 5.4.6.3. The Survival of MO + DO, and MOD Restorations

(Tables 2:5.4.9A.; 2:5.4.10A.; Lifetables 2:28,29,36,37, 38).

Amalgam survived significantly longer than gold in MOD restorations but the difference was not significant in MO + DO restorations. The RLR reductions were 46% and 8% respectively.

Table 1:5.4.6.

The Survival of differing materials used for the same Restorations.

	<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
Proximal	Sevriton	26%	p = 0.0014	Silicate
Buccal	Sevriton	18%	N.S.	Silicate
MO + DO	Gold	8%	N.S.	Amalgam
MOD	Amalgam	46%	p = 0.0148	Gold

#### 5.4.7. Discussion

In common with the study of RAF personnel, a study of practice records by Robinson (1971) showed that 50% of amalgam restorations may be expected to survive 10 years, and the result of the present study (48%) is in good agreement. These results are in contrast to those of Allan (1977) who showed that in two cohorts of restorations placed in the same practice, 50% was lost in 8 years in one cohort and 5 years in the other cohort. It was not clear from the latter report what criteria of restoration loss had been used.

With respect to silicate restorations, previously reported retrospective follow-up studies have involved only small numbers of restorations. In a study of 23 silicate restorations, half failed in 20 years (Robinson 1971). In the second study, two cohorts of silicate restorations were followed up for 15 and 20 years respectively. All of the eleven restorations in the 15 year cohort had failed in 4 years, while half of the 42

restorations in the 20 year cohort had failed in 8 years, and all had failed in 14 years (Allan 1977). In the present study of 1286 restorations, 68% were lost in 10 years, and 93% in 25 years. Thus the variation in the life of silicate restorations between this and the other studies is much greater than that for amalgam restorations.

To date no other long term follow-up study of the survival of sevrison restorations has been reported. In the present study 42% of sevrison restorations survived 10 years compared to 32% of silicate restorations. This difference was seen when the survivals of the materials were compared in like restorations (5.4.6.). Both materials were used for anterior tooth restorations, and most of these were lost by replacement (4.5.), any difference between the life of restorations made of these materials largely reflects differences between their failure rates. Since the latent durability of restorations is wholly concerned with replaced restorations, the differences between silicate and sevrison will be discussed in greater detail in Chapter 6.

5.5. The Variation in the Survival of Restorations with the type of tooth restored  
(Lifetables 2:39-86).

5.5.1. Introduction

This section deals with the variation in actual survival of the restorations according to the type of tooth restored. The data was analysed firstly to show for each tooth type how the survival of different restoration types varied (Tables 2:5.5.2-7; 2:5.5.2A-7A). Secondly, it was analysed to show for each restoration type how survival varied between different tooth types restored (Tables 2:5.5.8A-13A).

5.5.2. The Variation in Survival of six types of Restorations in particular tooth types

The variation in survival of restorations in incisors and canines, and in premolars was significant. In maxillary incisors and canines buccal and lingual restorations survived longest. In mandibular incisors and canines the total number of incisal, lingual, MI + DI, and MID restorations was 33. Despite the small numbers, the significant variation in the survival of restorations in mandibular incisors and canines was due to the wide difference between, on the one hand incisal and MI + DI restorations which survived relatively well, and on the other, lingual and MID restorations, which had relatively poor survival. In both maxillary and mandibular premolar teeth, MOD restorations survived longest. There was no significant variation in the

survival of restorations of molars (Table 1:5.5.2.).

Table 1:5.5.2.

The Variation in Survival of six types of Restorations in particular tooth types.

	<u>Incisors and Canines</u>		<u>Premolars</u>		<u>Molars</u>	
	<u>Maxilla</u>	<u>Mandible</u>	<u>Maxilla</u>	<u>Mandible</u>	<u>Maxilla</u>	<u>Mandible</u>
	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>
Occlusal			0.91	1.32	1.11	1.10
Incisal	1.32	0.71				
Proximal	1.03	1.03	1.50	1.02	1.35	0.68
Buccal	0.76	0.84	1.14	1.10	0.85	0.98
Lingual	0.74	3.82	0.93	0.75	0.95	0.80
MO + DO			1.06	0.89	0.92	1.02
MI + DI	1.68	0.27				
MOD			0.72	0.72	0.88	0.76
MID	1.25	3.54				
p	< 0.0001	0.0001	0.0065	0.0460	N.S.	N.S.

5.5.3. The Variation in Survival of each Restoration type with the type of tooth restored

In general restorations of premolar and molar teeth survived longer than restorations of incisor and canine teeth (Table 1:5.5.3a.). The difference was least for buccal restorations and greatest for restorations which involved both proximal surfaces together with either the occlusal surface or the incisal edge (MOD and MID restorations).

Table 1:5.5.3a.

The Survival of Restorations in premolars and molars, and incisors and canines.

	<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
Occlusal (Incisal)	PM + M	10%	N.S.	I + C
Proximal	PM + M	29%	p = 0.0017	I + C
Buccal	PM + M	1%	N.S.	I + C
Lingual	PM + M	30%	p = 0.0441	I + C
MO + DO (MI + DI)	PM + M	55%	p < 0.0001	I + C
MOD (MID)	PM + M	67%	p < 0.0001	I + C

In general mandibular incisor and canine restorations survived longer than maxillary incisor and canine restorations. The exception was lingual restorations which survived significantly longer in maxillary incisors and canines. This was presumably due to the ease of restoring the lingual pit of maxillary incisors compared to the difficulty of restoring the lingual surfaces of mandibular incisors and canines. (Table 1:5.5.3b.).

Table 1:5.5.3b.

The Survival of Restorations of maxillary and mandibular incisors and canines.

	<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
Incisal	MND, I+C	39%	N.S.	MXL, I+C
Proximal	MND, I+C	34%	p = 0.0001	MXL, I+C
Buccal	MND, I+C	25%	N.S.	MXL, I+C
Lingual	MXL, I+C	68%	p = 0.0059	MND, I+C
MI + DI	MND, I+C	88%	p = 0.0091	MXL, I+C
MID	MXL, I+C	48%	N.S.	MND, I+C

Table 1:5.5.3c.The Survival of Restorations of premolars and molars.

	<u>BETTER</u>	<u>RELATIVE LOSS RATE</u> (% Reduction)		<u>WORSE</u>
Occlusal	MXL Molars	16%	N.S.	MXL Premolars
	MXL Molars	29%	p = 0.0174	MND Premolars
	MXL Molars	26%	p = 0.0006	MND Molars
Proximal	MND Molars	31%	N.S.	MXL Molars
	MND Molars	24%	N.S.	MND Molars
	MND Molars	56%	p = 0.0024	MXL Premolars
Buccal	MXL Molars	47%	p = 0.0013	MXL Premolars
	MXL Molars	35%	p = 0.0194	MND Premolars
	MXL Molars	36%	p = 0.0129	MND Molars
Lingual	MXL Molars	32%	N.S.	MXL Premolars
	MND Premolars	5%	N.S.	MXL Molars
	MXL Molars	13%	N.S.	MND Molars
MO + DO	MXL Molars	42%	p < 0.0001	MXL Premolars
	MXL Molars	20%	p = 0.0485	MND Premolars
	MXL Molars	34%	p < 0.0001	MND Molars
MOD	MXL Molars	18%	N.S.	MXL Premolars
	MXL Molars	4%	N.S.	MND Premolars
	MXL Molars	23%	N.S.	MND Molars

In posterior teeth, the life of restorations was longest in maxillary molars in general, but with the exception of lingual and proximal restorations. A trend was not seen with lingual restorations, and proximal restorations survived longest in mandibular molar teeth (Table 1:5.5.3c.).

#### 5.5.4. Discussion

There are two important differences between incisor and canine restorations, and premolar and molar restorations, which may be considered to influence actual survival. Firstly, anterior restorations in incisors and canines are made of tooth coloured materials and are subject to aesthetic scrutiny. Secondly, the proportions of restorations lost prematurely in posterior teeth are high compared to anterior teeth (Table 1:4.5.).

Over 80% of the restorations of incisors and canines were made from tooth coloured materials (Table 2:3.11.). Silicate cement and sevricon restorations accounted for over three quarters of the anterior restorations. Based on laboratory criteria the physical properties of these materials are even less suited to their use as filling materials than those of dental amalgam and gold (Guide to Dental Materials & Devices 1978), and it may be argued that the life of anterior restorations was shorter than that of posterior restorations on these grounds alone. Nevertheless, because conversion and extraction were more important fates for restorations of posterior teeth, it can also be argued that the higher risk of premature restoration loss in premolars and molars would more than offset the disadvantageous properties of the materials used for anterior restorations. Clearly this was not the case with respect to this group of patients.

It is more difficult to explain why mandibular incisor and canine restorations survived longer than maxillary restorations.

In general, operating conditions are less favourable with respect to mandibular incisors and canines, both in terms of access and moisture control. It may be argued that these disadvantageous conditions would lead to more frequent restoration failures. Yet, with the exception of a small number of lingual and MID restorations, this was manifestly not the case.

Another interpretation is that once having restored a mandibular incisor or canine tooth, the practitioner delayed for as long as possible any replacement precisely because the operating conditions were unfavourable. There is some support for this argument in that a higher proportion of mandibular incisor and canine restorations were extracted compared to restorations of maxillary teeth, suggesting that in some cases the practitioner waited too long before replacement (Tables 2:4.5.1-2).

Another view is that the mandibular incisor and canine restorations were placed in older patients, when the risk of extraction would be greater. The data supports this (Table 2:3.10.), since over one third of all mandibular incisor and canine treatment were placed in patients aged 61 years and older at the time of treatment.

The most tenable explanation is again aesthetics. Maxillary incisor and canine restorations are more frequently seen by the patient (and his or her family and friends) than mandibular incisor and canine restorations. In such circumstances, the pressure to replace aesthetically unacceptable restorations would

be much greater with respect to maxillary restorations compared to mandibular restorations. In contrast lingual restorations of maxillary incisors and canines (palatal pit restorations) are invisible to the patient and are relatively easy to fabricate compared to lingual restorations of mandibular incisors and canines. This is consistent with the life of maxillary incisor and canine lingual restorations being longer than that of mandibular incisor and canine lingual restorations.

For restorations of premolars and molars, aesthetics is a minor consideration. Of all posterior teeth, maxillary molars may be regarded as the most inaccessible, particularly with respect to the buccal surfaces. It can be argued therefore that because it is easier to diagnose and treat premolars and mandibular molars, the dentist would be more inclined to replace restorations of these teeth, compared to maxillary molar restorations. The major exception is the lingual surface of mandibular molars where access can be awkward. The finding that lingual restorations survived longer in mandibular molars over maxillary molars is consistent with this argument.

5.6. The Variation in the Survival of Restorations with the age of the patient at the time of treatment

(Lifetables 2:87-128).

5.6.1. Introduction

The data was organised into the same decennial age groups as in Chapters 3 and 4, ranging from 10 years and younger to 61 years and older. Firstly, it was analysed to show whether there was a significant variation in the survival of the six restoration types within each age group (Tables 2:5.6.2-8, 2:5.6.2A-8A). Secondly, the data was analysed to show how the survival of each restoration type varied with increasing patient age (Tables 2:5.6.9-14).

5.6.2. The Variation of the Survival of six types of Restorations in each age group

Except for patients aged 61 years and older there was a significant variation in the survival of the six types of restoration in each age group. In general, occlusal restorations survived longest in patients aged more than 30 years, while in patients aged between 11 and 30 years MOD restorations survived longest, and in children (patients aged 10 years and younger) lingual restorations survived longest (Table 1:5.6.2.).

Table 1:5.6.2.

The Relative Survival of six types of Restorations in each of seven age groups.

	10 years and younger	11-20 years	21-30 years	31-40 years	41-50 years	51-60 years	61 years and older
	RLR	RLR	RLR	RLR	RLR	RLR	RLR
Occlusal	1.23	1.19	0.94	0.65	0.62	0.55	0.52
Proximal	0.89	1.10	1.58	1.25	1.26	1.27	1.10
Buccal	0.85	0.79	0.97	0.93	0.97	1.07	0.86
Lingual	0.52	0.98	0.83	0.90	0.84	0.67	1.20
MO + DO	0.80	0.91	0.91	1.01	0.93	0.96	1.04
MOD	1.04	0.50	0.51	1.29	1.03	0.68	0.79
p	0.0120	0.0001	0.0001	0.0001	0.0001	0.0003	N.S.

5.6.3. The Variation in Survival of the Restorations with increasing age

In general, the actual survival of the restorations improved from childhood into adolescence, and then deteriorated with increasing patient age. This trend was highly significant. There were two exceptions, namely occlusal and lingual restorations. The actual survival of occlusal restorations continued to improve after adolescence to a plateau in patients aged over 30 years, and this trend was highly significant. There was no significant variation in the survival of lingual restorations with increasing patient age (Table 1:5.6.3.).

Table 1:5.6.3.The Variation in Survival of Restorations with increasing age.

Age (years)	O RLR	P RLR	B RLR	L RLR	MO+DO RLR	MOD RLR
10 and younger	2.03	1.10	1.38	0.97	1.36	2.43
11 - 20	1.08	0.74	0.72	0.99	0.87	0.58
21 - 30	0.87	1.12	0.92	0.86	0.90	0.61
31 - 40	0.65	0.88	0.89	0.99	1.00	1.55
41 - 50	0.71	1.04	1.08	1.06	1.07	1.45
51 - 60	0.63	1.14	1.25	0.87	1.17	1.09
61 and older	0.78	1.43	1.42	1.89	1.70	1.71
p (trend)	<0.0001	<0.0001	0.0004	N.S.	0.0082	0.0002

#### 5.6.4. Discussion

There is no other comparable data in the dental literature with which these results may be compared. An indirect comparison, however, may be made with data from the study of amalgam restorations of RAF personnel (Gray 1976). In that study a distinction was made between first restoration and subsequent 'replacements'. It was shown that the 'durability' of the restorations decreased with each subsequent 'replacement'. (A replacement was defined as a new restoration involving the same number or a greater number of tooth surfaces). At each subsequent 'replacement', the patient would have been older than at the time of placing its predecessor, and therefore it can be argued that the life of these restorations decreased as the patients increased in age. This interpretation of the results of the RAF personnel study is in broad agreement with the general

results of the present study. The results of the RAF study in relation to subsequent 'replacements' were not analysed with respect to individual restorations according to tooth surface description. It is not known therefore whether occlusal restorations in that study showed an improvement in survival with patient age, as in the present work.

Any explanation of these trends must take into account the change in the risks of replacement, conversion and extraction, with increasing patient age. From the results described in Chapter 4, in general, no trend could be seen with respect to replacement. For occlusal and MO + DO restorations, conversions declined with increasing age while for others conversion was not an important fate. Extractions increased with increasing patient age (Tables 2:4.6.1-6).

It is reasonable to argue that, if there was no general trend with respect to replacements with increasing patient age, there would be no consistent change in the latent durability of the restorations. This will be described in the next chapter. Under these circumstances the changes in actual survival of restorations with patient age would have been the result of change in the balance between conversions and extractions.

For all types of restorations, extractions were at a minimum in adolescence and then steadily increased with age. A direct relationship may be seen therefore between the increasing importance of extractions and the declining survival of restorations, with increasing patient age, with the exception of occlusal and MO + DO restorations.

The survival of occlusal restorations improved with age up to patients aged between 31 and 40 years at the time of treatment, and then levelled off. Up to and including this age group, extractions were relatively unimportant as conversion was overwhelmingly the dominant fate for occlusal restorations (Table 2:4.3.). In the older groups, extractions balanced and then dominated conversion as the most important fate.

This change with age in the balance between conversions and extractions for occlusal restorations may be seen to match almost exactly the change in the pattern of survival of occlusal restorations. As conversions declined and extractions remained unimportant in younger patients, so survival of restorations improved. When extractions became more important in the older patients, so the improvement in survival of occlusal restorations ceased.

A similar argument may be made for MO + DO restorations, but here, unlike occlusal restorations, extractions were never relatively unimportant. The net result was that as patients aged and the proportions of extractions increased so survival decreased, despite there being a gradual reduction in the proportions converted.

In conclusion it appears that the main factor determining the variations in restoration survival with increasing patient age at the time of treatment, is the increasing number of teeth extracted. The principal exception is occlusal restorations where the decline

in conversion with increasing age leads to an improvement in survival.

Finally, in general there was a marked improvement in the survival of all restorations from childhood to adolescence. Clearly, if the need for restorations could be delayed until adolescence, the restorations would have a longer life.

### 5.7. Summary

Chapter 5 described the actual survival of the restorations in the study and contains much new information. Only the life of amalgam restorations has previously been reported, and the actual survival of amalgam restorations reported in Chapter 5 (48% surviving 10 years) is in good agreement. The present study describes the actual survival of the largest number of silicate restorations reported to date (1286), 32% of which survived 10 years. The actual survival of sevruton restorations has not previously been reported; 42% survived 10 years.

Considering tooth surfaces restored, the actual survival of proximal restorations was shortest (34% survived 10 years) and MOD restorations survived longest (58% survived 10 years). The proportions of occlusal, buccal, lingual, and MO + DO restorations which survived 10 years varied between 45% and 48%.

Restorations of premolars and molars survived longer than restorations of incisors and canines. Of the posterior tooth restorations, those in maxillary molars survived longest and those in maxillary premolars survived shortest. Mandibular incisor and canine restorations survived longer than those in maxillary incisors and canines. This variation in the life of restorations with tooth type has not previously been reported.

The age of the patient at the time of treatment had a marked influence on the actual survival of restorations. In general, survival declined with increasing age (e.g. the proportion of

MO + DO restorations surviving 10 years ranged from 54% in patients aged between 11 and 20 years, to 38% in patients aged 61 years and older). Occlusal restorations were the exception. Their survival improved with age from 18% surviving 10 years, in patients aged 10 years and younger, reaching a plateau of around 60% surviving 10 years, in patients aged 31 years and older. All restorations showed an improvement in survival with increasing age from patients aged 10 years and younger to those aged between 11 and 20 years. This variation in restoration survival with increasing patient age has not previously been reported.

In general the two most important influences on the actual survival of restorations are the fate and the material.

CHAPTER 6THE LATENT DURABILITY OF RESTORATIONS6.1. Introduction

In the previous chapter the actual survival of the restorations was described. In this chapter an estimate is made of their full latent durability by re-analysing the data in the manner described in the introduction to Section C, and Appendix 1.

The chapter follows the same pattern as Chapter 5. Firstly two overviews of latent durability are given, according to tooth surface description and material (6.2. and 6.4.). In the latter parts of the chapter (6.5. and 6.6.), latent durability of restorations placed in differing tooth types and at differing ages, is given.

It was shown in Chapter 5 that the two most important influences on the actual survival of restorations were the fate and the material. The calculation of latent durability is based on one fate alone, i.e. replacement, and therefore the principal influence on latent durability will be the failure rate of the restorations. An important factor contributing to the failure rate of restorations is material. This is reflected throughout this chapter since where tooth coloured materials were used for restorations, durability was low, and where dental amalgam was used, durability was good.

6.2.1. The Durability of six types of Restorations according to the tooth surfaces restored

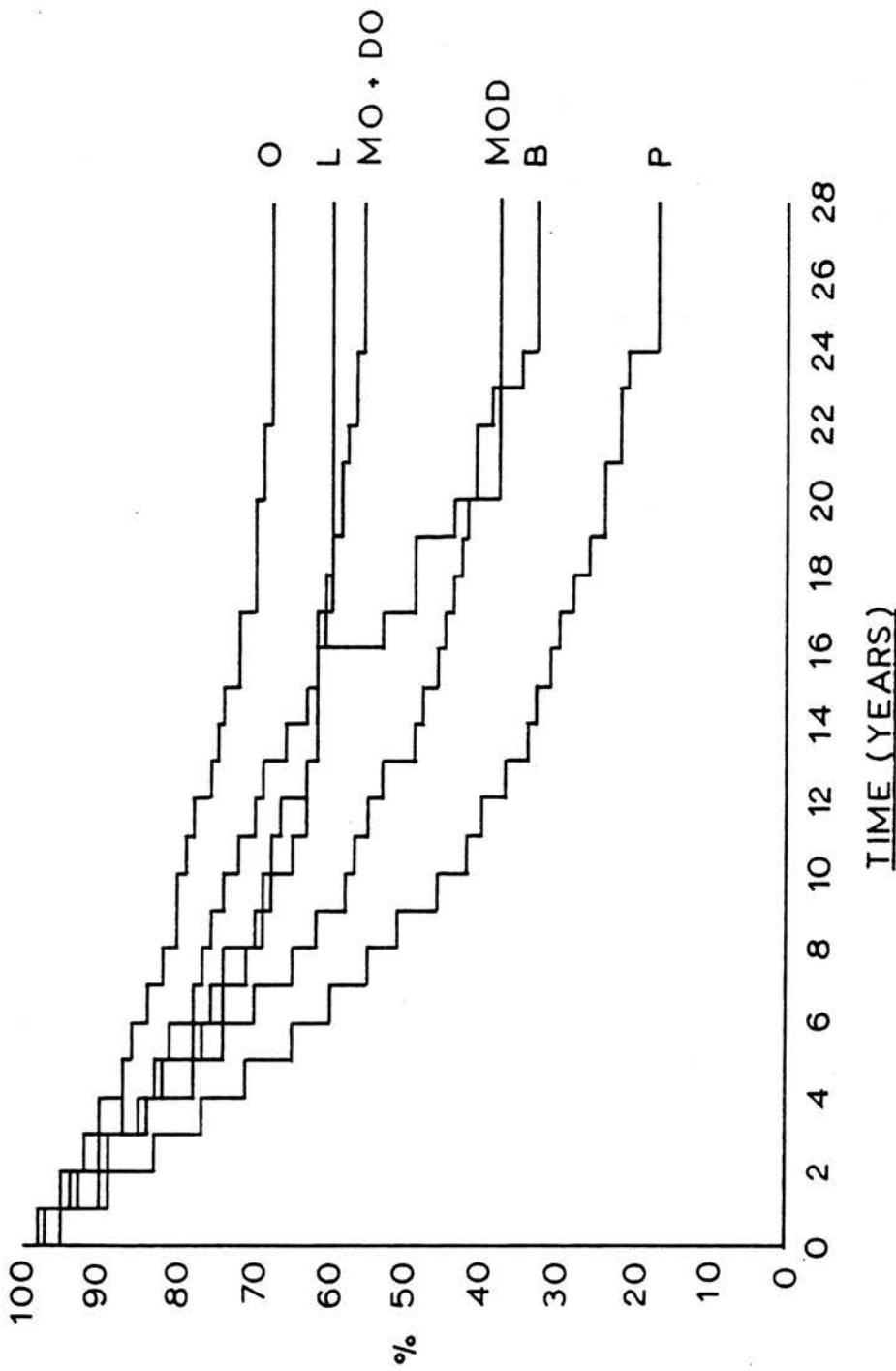
(Figs. 1:6.2.1.; 1:6.2.1A.; Tables 1:6.2.1.; 2:6.2.1.; 2:6.2.1A.; Lifetables 2:6-11).

There was a wide and significant variation in the durability of restorations. Overall, occlusal restorations (87%, 80%, 68%), had best durability followed in order by MO + DO (83%, 74%, 56%), lingual (82%, 69%, 60%), MOD (83%, 68%, 38%), buccal (78%, 58%, 33%) and proximal restorations (71%, 46%, 17%). Occlusal restorations' durability was significantly longer than proximal, buccal, lingual, MO + DO, and MOD restorations. The R.R.R. reductions were 70%, 55%, 35%, 28% and 41% respectively. In addition to occlusal restorations the durability of buccal, lingual, MO + DO, and MOD restorations was significantly longer than that of proximal restorations. The R.R.R. reductions were 33%, 53%, 58% and 45% respectively. In addition to occlusal restorations the durability of lingual and MO + DO restorations was significantly longer than that of buccal restorations, the R.R.R. reductions being 24% and 37% respectively. Thus the durability of occlusal restorations was significantly longer than all of the others, and the durability of proximal restorations was significantly shorter than all of the others.

6.2.2. Discussion

In general, two patterns may be seen in this overview. Firstly, the least durable restorations were those where the majority were made of tooth coloured materials. For example,

Figure 1:6.2.1A.



THE DURABILITY OF SIX TYPES OF DENTAL RESTORATIONS.

Figure 1:6.2.1.

THE DURABILITY OF SIX TYPES OF  
DENTAL RESTORATIONS.

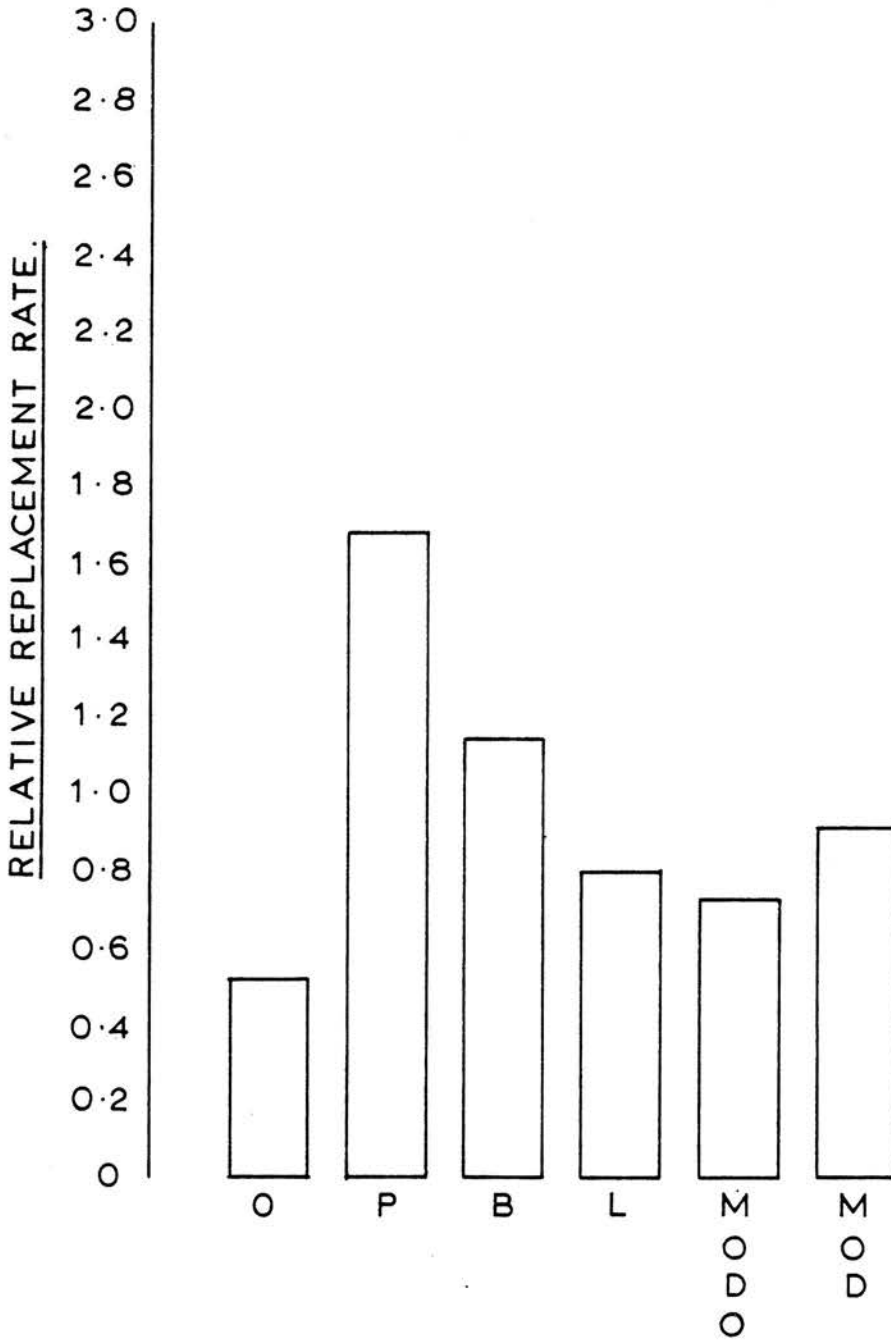


Table 1:6.2.1.The Durability of six types of Dental Restorations.

<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
1. Occlusal	70%	p < 0.0001	Proximal
2. Occlusal	55%	p < 0.0001	Buccal
3. Occlusal	35%	p = 0.0024	Lingual
4. Occlusal	28%	p = 0.0003	MO + DO
5. Occlusal	41%	p < 0.0001	MOD
6. Buccal	33%	p < 0.0001	Proximal
7. Lingual	53%	p < 0.0001	Proximal
8. MO + DO	58%	p < 0.0001	Proximal
9. MOD	45%	p < 0.0001	Proximal
10. Lingual	29%	p = 0.0070	Buccal
11. MO + DO	37%	p < 0.0001	Buccal
12. MOD	19%	N.S.	Buccal
13. MO + DO	10%	N.S.	Lingual
14. Lingual	10%	N.S.	MOD
15. MO + DO	20%	N.S.	MOD

80% of proximal restorations were made of tooth coloured materials. The most durable were those where the majority were made of dental amalgam. For example over 90% of occlusal, MO + DO, and MOD restorations were made of amalgam (Tables 2:3.7.1-2).

Secondly, and in contrast to actual survival, for those restorations where the majority were made of amalgam, durability declined with an increase in the number of tooth surfaces restored e.g. occlusal restorations were more durable than MO + DO restorations, which were more durable than MOD restorations. This second generalisation is in accord with the study of amalgam restorations placed in R.A.F. personnel (Gray 1976).

Two explanations are that the tooth coloured restorations in this study failed earlier than the amalgam restorations, and that the bigger the amalgam restoration the more likely that failure would occur. These associations, between material, and the number of tooth surfaces restored, with latent durability are examined in detail in 6.4..

6.3. The Durability of six types of Restorations according to the sex of the patient

(Tables 1:6.3.; 2:6.3A.; Lifetables 2:12-23).

There was not a significant difference between the sexes with respect to the durabilities of the six types of dental restorations, with the exception of MOD restorations. The R.R.R. for MOD restorations in males was 40% less than that for females ( $p = 0.0173$ ). Since the majority of lost MOD restorations was replaced (Table 2:4.3.) the reasons given in 5.3. for differences between the life of MOD restorations in males and females apply here.

Table 1:6.3.

The Durability of six types of Restorations according to sex.

<u>Restoration</u>	<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)	<u>WORSE</u>
1. Occlusal	Female	7%	N.S. Male
2. Proximal	Male	4%	N.S. Female
3. Buccal	Male	6%	N.S. Female
4. Lingual	Female	31%	N.S. Male
5. MO + DO	Male	2%	N.S. Female
6. MOD	Male	41%	$p = 0.0173$ Female

#### 6.4. The Durability of Restorations according to material

##### 6.4.1. Introduction

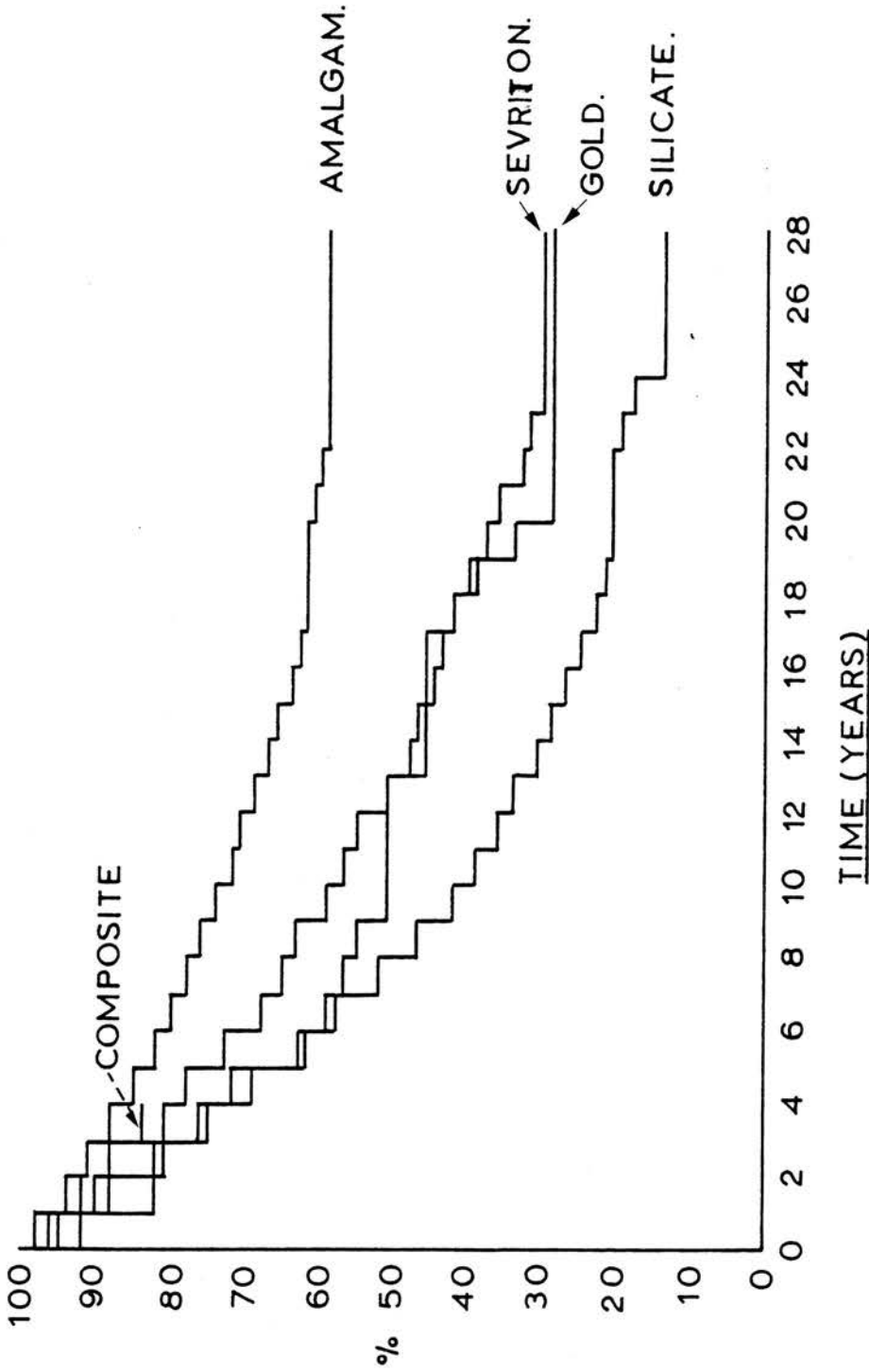
In 5.4.1. the constraints which apply to a comparison of the actual survival of restorations according to material were described. These constraints also apply when latent durabilities are compared. In particular it should be restated that amalgam is used for restorations of premolars and molars, while tooth coloured materials are used for anterior teeth. Any comparison made in general between their durabilities therefore has little clinical relevance.

##### 6.4.2. The Durability of Restorations according to material

(Figs. 1:6.4.2.; 1:6.4.2A.; Tables 1:6.4.2a & b;  
2:6.4.2.; 2:6.4.2A.; Lifetables 2:1-5).

There was a large and significant difference between the durabilities of the 5 dental materials, amalgam, gold, silicate, sevricon and composite resin. The principal characteristic of the differences was the relatively excellent durability of amalgam and the relatively poor durabilities of all of the others. Amalgam restorations (85%, 74%, 59%) had better durability than, in order, sevricon (78%, 59%, 30%), gold (72%, 51%, 29%) and silicate restorations (69%, 42%, 14%). Amalgam restorations had significantly better durability than gold, silicate and sevricon restorations. The reductions in RRR were 53%, 63% and 45% respectively. In addition sevricon restorations were significantly more durable than silicate restorations (RRR reduction = 34%).

Figure 1:6.4.2A.



THE DURABILITY OF RESTORATIONS ACCORDING TO MATERIAL.

Figure 1:6.4.2.

THE DURABILITY OF RESTORATIONS  
ACCORDING TO MATERIAL.

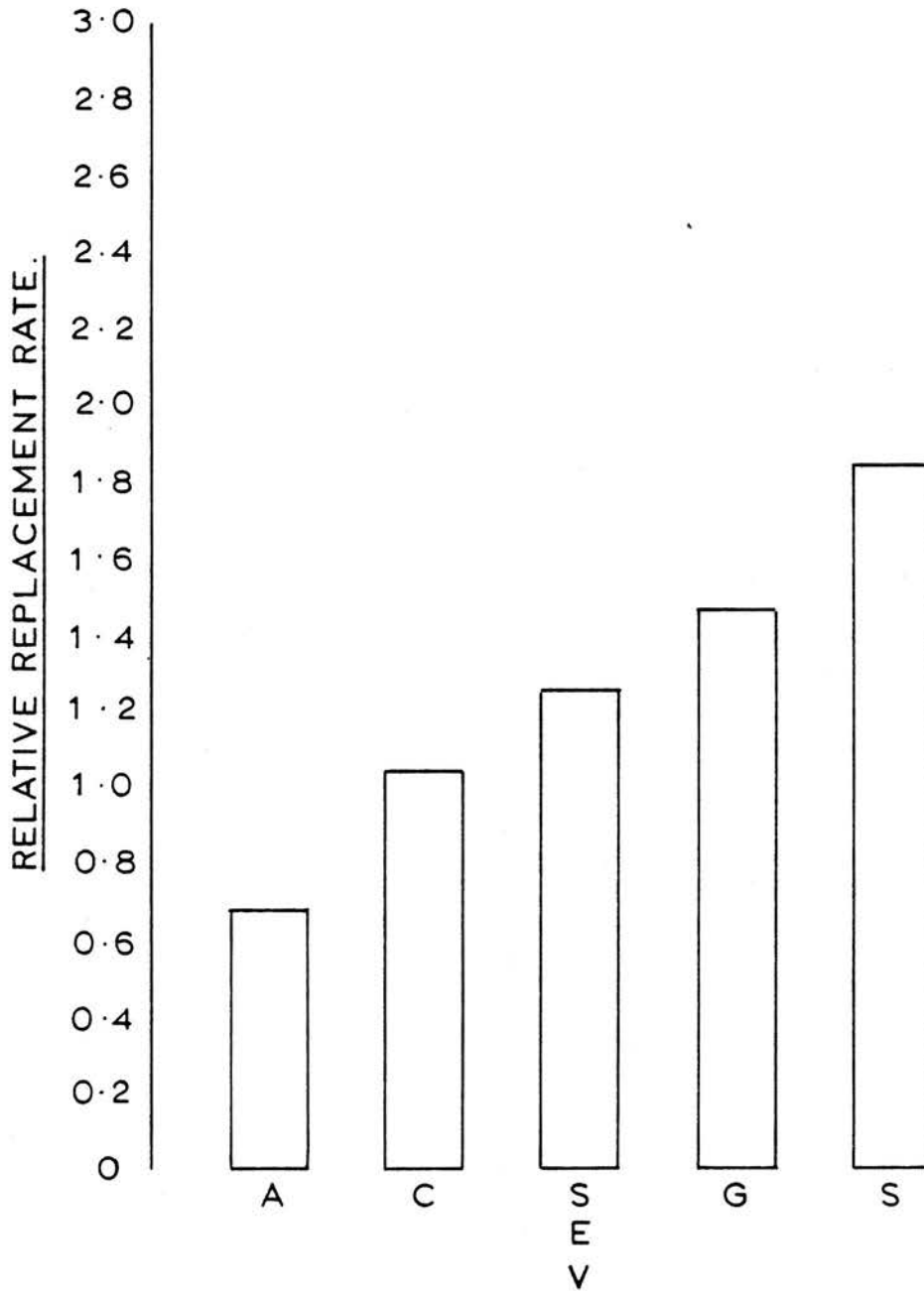


Table 1:6.4.2a.

The Durability of Restorations\* according to material.

<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Amalgam	53%	p < 0.0001	Gold
Amalgam	63%	p < 0.0001	Silicate
Amalgam	45%	p < 0.0001	Sevriton
Gold	22%	N.S.	Silicate
Sevriton	16%	N.S.	Gold
Sevriton	34%	p < 0.0001	Silicate

\* includes Other Surface Combination Restorations and Crowns

After 4 years of follow-up 84% of composite restorations had not been replaced compared to 88% of amalgam, 75% of gold, 76% of silicate, and 82% of sevriton restorations. None of the differences were significant.

Table 1:6.4.2b.

The Durability of Restorations\* according to material.

<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Amalgam	26%	N.S.	Composite
Composite	31%	N.S.	Gold
Composite	33%	N.S.	Silicate
Composite	9%	N.S.	Sevriton

\* includes Other Surface Combination Restorations and Crowns

#### 6.4.3. The Durability of six types of Amalgam Restorations

(Fig. 1:6.4.3.; Tables 1:6.4.3.; 2:6.4.3.; 2:6.4.3A.; Lifetables 2:24-29).

There was wide and significant variation in the durability of amalgam restorations, principally due to the relatively poor durability of buccal and MOD restorations. Occlusal restorations were most durable (88%, 81%, 68%), followed in order by proximal (88%, 78%, 64%), lingual (86%, 76%, 66%), MO + DO (85%, 77%, 60%), MOD (85%, 71%, 36%) and buccal restorations (77%, 62%, 49%).

Occlusal amalgam restorations had significantly better durability than buccal, MO + DO, and MOD restorations. The RRR reductions were 49%, 20% and 37% respectively. In addition to occlusal, proximal, lingual, and MO + DO amalgam restorations were all significantly more durable than buccal restorations, the respective RRR reductions being 42%, 37% and 36%.

#### 6.4.4. The Durability of Silicate Restorations

(Tables 1:6.4.4.; 2:6.4.4.; 2:6.4.4A.; Lifetables 2:30-33).

Buccal restorations were significantly more durable than proximal restorations, the RRR reduction being 32%.

Figure 1:6.4.3.

THE DURABILITY OF SIX TYPES OF  
AMALGAM RESTORATIONS.

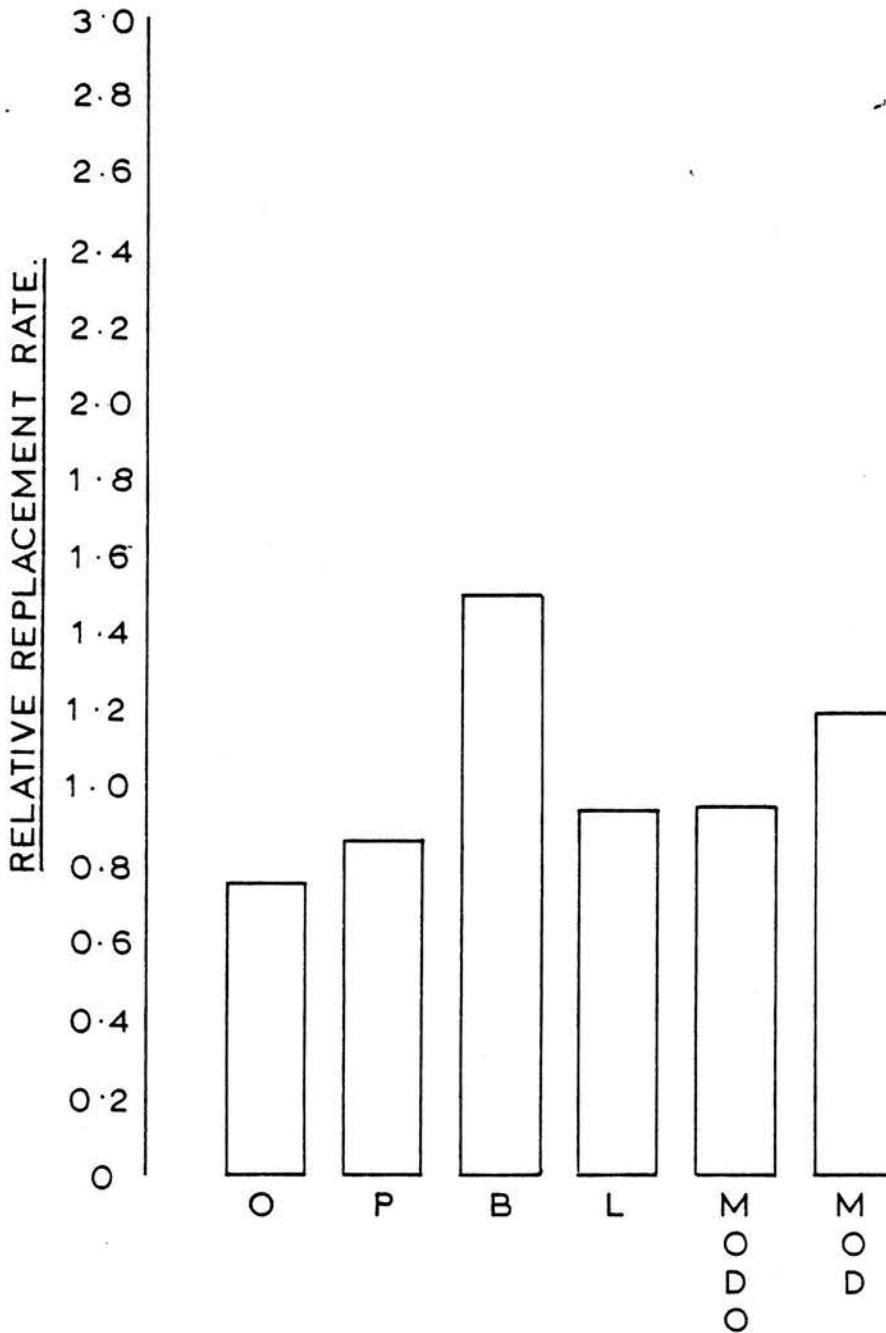


Table 1:6.4.3.The Durability of six types of Amalgam Restorations.

<u>BETTER</u>		<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
1.	Occlusal	13%	N.S.	Proximal
2.	Occlusal	49%	$p < 0.0001$	Buccal
3.	Occlusal	19%	N.S.	Lingual
4.	Occlusal	20%	$p = 0.0167$	MO + DO
5.	Occlusal	37%	$p = 0.0007$	MOD
6.	Proximal	42%	$p = 0.0025$	Buccal
7.	Proximal	7%	N.S.	Lingual
8.	Proximal	10%	N.S.	MO + DO
9.	Proximal	29%	N.S.	MOD
10.	Lingual	37%	$p = 0.0038$	Buccal
11.	MO + DO	36%	$p < 0.0001$	Buccal
12.	MOD	21%	N.S.	Buccal
13.	Lingual	1%	N.S.	MO + DO
14.	Lingual	23%	N.S.	MOD
15.	MO + DO	21%	$p = 0.0539$	MOD

Table 1:6.4.4.The Durability of Silicate Restorations.

<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Buccal	32%	p < 0.0001	Proximal

6.4.5. The Durability of Sevricon Restorations

(Tables 1:6.4.5.; 2:6.4.5A.; Lifetables 2:34-36).

Buccal restorations (84%, 65%, 37%) were more durable than proximal (77%, 55%, 24%) restorations, which were more durable than MI + DI restorations (72%, 53%, 0%). The RRR for buccal restorations was significantly less than that for proximal, and MI + DI restorations (31% and 39% reductions respectively).

Table 1:6.4.5.The Durability of Sevricon Restorations.

<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Buccal	31%	p = 0.0280	Proximal
Proximal	15%	N.S.	MI + DI
Buccal	39%	p = 0.0437	MI + DI

6.4.6. The Durability of differing materials used for the same Restorations

6.4.6.1. The Durability of Proximal and Buccal Restorations

(Tables 2:6.4.6A.; 2:6.4.7A.; Lifetables 2:25,26,30,31,34, 35).

Sevriton was significantly more durable than silicate for both proximal and buccal restorations. The RRR reductions were 33% and 29% respectively (Table 1:6.4.6.).

6.4.6.2. The Durability of MO + DO, and MOD restorations

(Tables 2:6.4.9A.; 2:6.4.10A.; Lifetables 2:28,29,36,37, 38).

Amalgam was significantly more durable than gold for both MO + DO, and MOD restorations. The RRR reductions were 53% and 52% respectively (Table 1:6.4.6.).

Table 1:6.4.6.

The Durability of differing materials used for the same

Restorations.

	<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Proximal	Sevriton	33%	p = 0.0004	Silicate
Buccal	Sevriton	29%	p = 0.0186	Silicate
MO + DO	Amalgam	53%	p = 0.0031	Gold
MOD	Amalgam	52%	p = 0.0098	Gold

#### 6.4.7. Discussion

Latent durability was calculated by including only replaced restorations as lost in the lifetable analysis. It was therefore determined by the replacement rate of the restorations which in turn depended upon the failure rate of the restorations (2.4.1b.).

The practitioner did not record his reasons for replacing restorations on the patient record card. The causes of failure of the restorations in this study are unknown and cannot be compared with other studies of the causes of failure of restorations.

In a review of the literature relating to the causes of failure of restorations, Elderton (1976) concluded that a wide variety of reasons has been reported to explain the failure of restorations. In addition the author concluded that research workers had not always distinguished between the true causes of failure, e.g. inadequate retention, and manifestations of the failure, e.g. recurrent caries. Poor contour or adaptation of the restoration in one form or another were frequently seen as a cause of failure, while inadequate extension for prevention, faulty restoration margins and poor retention form of the cavity are cited quite often. The same author has also concluded in relation to occlusal amalgam restorations, that reasons for failure are not related to morphological characteristics but to the individual propensity of the operator (Elderton 1975).

An important use of the results of laboratory tests of the

properties of restorative materials is to assist practitioners in their choice of material. The durability of restorations, such as that calculated in this section may be used to validate those results.

In Table 1:6.4.7. four commonly cited physical properties of acrylic resin (sevriton) and silicate cement, together with those for enamel and dentine, are given. In the present study sevriton restorations have been shown to be more durable than silicate restorations, yet this could not have been predicted from the laboratory tests. Firm conclusions cannot be drawn without a more detailed comparison of the properties of these materials, nevertheless, the evidence of the present study tends to support the view of Reisbick (1979), that the clinical performance of a material cannot be predicted from laboratory tests alone.

Table 1:6.4.7.

Some Physical Properties of enamel, dentine, silicate cement and acrylic resin.\*

		Enamel	Dentine	Silicate Cement	Acrylic Resin
Coefficient of Thermal Expansion	( $\times 10^{-6}/^{\circ}\text{C}$ )	11.4	8.3	8	81
Thermal Conductivity	(W/mK)	0.88	0.59	0.8	0.2
Tensile Strength	(Mn/m <sup>2</sup> )	200	300	15	30
Compressive Strength	(Mn/m <sup>2</sup> )	35	60	200	70

\* Combe, E. C., 1975

6.5. The Variation in the Durability of Restorations with the type of tooth restored.

(Lifetables 2:39-86).

6.5.1. Introduction

As in Chapter 5, this section deals with the variation in latent durability of the restorations, according to the type of tooth restored. The data was analysed firstly to show, for each tooth type, how the durability of the six types of restorations varied (Tables 2:6.5.2-7, 2:6.5.2A - 7A.). Secondly the data was analysed to show, for each restoration type, how durability varied between the different types of tooth restored (Tables 2:6.5.8A - 13A.).

6.5.2. The Variation in Durability of six types of Restorations in particular tooth types

Excepting maxillary molars, the variation in durability of the six types of restorations was highly significant in each tooth type. Nevertheless no pattern could be seen. In maxillary incisors and canines, buccal and lingual restorations were most durable. In mandibular incisors and canines, and despite the low numbers of incisal, lingual, MI + DI, and MID restorations, the variation was due to the relatively good durability of incisal and MI + DI restorations against the relatively poor survival of lingual and MID restorations. In maxillary premolars occlusal restorations were most durable and buccal restorations were least durable.

Table 1:6.5.2.

The Variation in Durability of six types of Restorations in particular tooth types.

	<u>Incisors and Canines</u>		<u>Premolars</u>		<u>Molars</u>	
	<u>Maxilla</u>	<u>Mandible</u>	<u>Maxilla</u>	<u>Mandible</u>	<u>Maxilla</u>	<u>Mandible</u>
	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>	<u>RLR</u>
Occlusal			0.48	0.75	0.79	0.86
Incisal	1.16	0.65				
Proximal	1.06	0.92	1.33	0.55	1.05	0.39
Buccal	0.68	1.07	1.69	1.40	1.03	1.38
Lingual	0.73	3.44	1.28	0.00	1.01	0.51
MO + DO			0.83	0.79	1.16	0.91
MI + DI	1.58	0.40				
MOD			1.10	1.01	1.18	1.22
MID	0.98	6.06				
p	<0.0001	0.0001	0.0001	0.0027	N.S.	0.0002

In mandibular premolars, excepting the 5 lingual restorations, proximal restorations were most durable, and like maxillary premolars buccal restorations were least durable. The variation in durability of the six restoration types in maxillary molars was not significant. In mandibular molars, like mandibular premolars, proximal restorations were most durable, and like all premolars, buccal restorations were least durable.

### 6.5.3. The Variation in the Durability of each Restoration type, with the type of tooth restored

In general, restorations of premolars and molars were more durable than restorations of incisors and canines (Table 1:6.5.3a.). The difference was least for buccal restorations and

greatest for proximal restorations and restorations involving both a proximal and either an occlusal or incisal surface.

Table 1:6.5.3a.

The Durability of Restorations of incisors and canines compared to premolars and molars.

	<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Occlusal (Incisal)	PM + M	59%	p = 0.0125	I + C
Proximal	PM + M	72%	p < 0.0001	I + C
Buccal	PM + M	16%	N.S.	I + C
Lingual	PM + M	63%	p < 0.0001	I + C
MO + DO (MI + DI)	PM + M	74%	p < 0.0001	I + C
MOD (MID)	PM + M	71%	p = 0.0020	I + C

Except for proximal restorations and proximo-incisal restorations, there was not an important difference between the durabilities of restorations of mandibular and maxillary incisors and canines. For the two exceptions, mandibular restorations were more durable than maxillary restorations (Table 1:6.5.3b.).

Table 1:6.5.3b.

The Durability of Restorations of maxillary and mandibular incisors and canines.

	<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Incisal	MND	44%	N.S.	MXL
Proximal	MND	48%	p < 0.0001	MXL
Buccal	MND	4%	N.S.	MXL
Lingual	MXL	54%	N.S.	MND
MI + DI	MND	85%	p = 0.0420	MXL
MID	MXL	54%	N.S.	MND

Except for proximal and lingual restorations, restorations of maxillary molars were more durable than in any other posterior tooth type. Proximal restorations were most durable in mandibular molars and there was not a significant variation in the durability of lingual restorations in posterior teeth (Table 1:6.5.3c).

Table 1:6.5.3c.

The Durability of Restorations of premolars and molars.

	<u>BETTER</u>	<u>RELATIVE REPLACEMENT RATE</u> (% Reduction)		<u>WORSE</u>
Occlusal	MXL Molars	18%	N.S.	MXL Premolars
	MXL Molars	41%	N.S.	MND Premolars
	MXL Molars	41%	p = 0.0003	MND Molars
Proximal	MND Molars	27%	N.S.	MND Premolars
	MND Molars	75%	p = 0.0050	MXL Premolars
	MND Molars	33%	N.S.	MXL Molars
Buccal	MXL Molars	70%	p < 0.0001	MXL Premolars
	MXL Molars	60%	p = 0.0010	MND Premolars
	MXL Molars	57%	p = 0.0025	MND Molars
Lingual	MND Premolars	100%	N.S.	MND Molars
	MND Premolars	100%	N.S.	MXL Premolars
	MND Premolars	100%	N.S.	MXL Molars
MO + DO	MXL Molars	30%	p = 0.0207	MXL Premolars
	MXL Molars	19%	N.S.	MND Premolars
	MXL Molars	29%	p = 0.0287	MND Molars
MOD	MXL Molars	47%	N.S.	MXL Premolars
	MXL Molars	38%	N.S.	MND Premolars
	MXL Molars	50%	N.S.	MND Molars

#### 6.5.4. Discussion

Restorations of incisors and canines were predominantly made from tooth coloured filling materials, while restorations of premolars and molars were almost exclusively made from dental amalgam (Table 2:3.11.). Under these circumstances it is hardly surprising that, without exception, restorations of premolar and molar teeth were more durable than restorations of incisors and canines. These two distinct types of restorations will therefore be discussed separately.

##### 6.5.4.a. Premolar and Molar Restorations

A constant relationship existed between occlusal, MO + DO, and MOD restorations irrespective of which type of posterior tooth was considered. Occlusal restorations were more durable than MO + DO restorations, which were more durable than MOD restorations. At first sight therefore it may appear that an association between the number of tooth surfaces restored and the durability of restorations exists, i.e. that durability decreases with an increase in the number of surfaces restored. A similar result was reported by Gray (1976) in his study of R.A.F. personnel. Nevertheless, when buccal, proximal and lingual restorations are introduced, the association breaks down. Clearly, for these last three restorations, the type of tooth restored plays a more important role in determining durability than the tooth surfaces restored.

One possible explanation for these variations is the

accessibility of the cavity. Access to the buccal surface of maxillary molars is difficult because of the close proximity of the coronoid process of the mandible when the mouth is open and because of the soft tissues of the cheek when the mouth is closed. Once a buccal carious lesion of a maxillary molar had been restored the practitioner may have been much less disposed to diagnosing failure because of the difficult operating conditions. The data lends support to this hypothesis in that buccal restorations of maxillary molars were significantly more durable than those of other posterior teeth (Table 1:6.5.3c.).

A similar argument may be made for restorations of the lingual surfaces of mandibular premolars and molars where access can be impeded by the tongue. A definite conclusion cannot be drawn from the data because of small numbers. Similarly because the numbers of proximal restorations of posterior teeth were small, definite conclusions cannot be drawn, although the relatively poor durability of maxillary premolar proximal restorations might have been the result of aesthetic considerations.

#### 6.5.4.b. Incisor and Canine Restorations

If the very few incisal, and MID restorations of maxillary teeth are ignored, then the restorations fall into three categories. Buccal and lingual restorations were very durable, MI + DI restorations were least durable and proximal restorations were in between.

MI + DI restorations correspond to Class IV cavities in Black's Classification and proximal and buccal restorations

correspond to Class III and V cavities. Clearly the site of the restoration plays an important role in determining durability, particularly if the incisal edge is involved. In addition the restorations involving the largest number of tooth surfaces, MI + DI, had the poorest durability.

In mandibular teeth definite inference may only be drawn in relation to proximal and buccal restorations because the other types were present in very small numbers. Their relative durabilities were reversed compared to maxillary proximal and buccal restorations. There was little difference in durability of buccal restorations in mandibular and maxillary teeth, but proximal restorations were significantly more durable in mandibular teeth. The principal factors influencing the durability of restorations of anterior teeth are aesthetics and operating conditions, and these have already been discussed (5.5.4.).

6.6. The Variation in the Durability of Restorations with the age of the patient at the time of treatment

(Lifetables 2:87-128).

6.6.1. Introduction

The data was organised into the same age groups as in Chapter 5, ranging from 10 years and younger to 61 years and older. Firstly it was analysed to show the variation in durability of the six types of restorations in each age group (Tables 2:6.6.2-8, 2:6.6.2A-8A.). Secondly the data was analysed to show how durability varied with increasing patient age (Tables 2:6.6.9-14).

6.6.2. The Variation of the Durability of the six types of Restorations in each age group

Except for patients aged 61 years and older, there was a significant variation in the durability of the six types of restorations in each age group. In general, the durability of occlusal restorations was longest, and the durability of proximal restorations was shortest (Table 1:6.6.2.), except for patients aged 10 years and younger when the durability of occlusal restorations was relatively poor.



6.6.3. The Variation in Durability of the Restorations with increasing patient age at the time of treatment

In general, no consistent variation in durability with increasing patient age could be seen. The exceptions were occlusal restorations, whose durability improved up to patients aged between 21 and 30 years at the time of treatment and then declined, and MO + DO restorations whose durability declined significantly with increasing age (Table 1:6.6.3.).

Table 1:6.6.3.

The Variation in the Durability of Restorations with increasing patient age at the time of treatment.

Age (years)	O RRR	P RRR	B RRR	L RRR	MO+DO RRR	MOD RRR
10 and younger	2.09	1.32	0.58	0.58	0.80	1.73
11 - 20	0.90	0.97	0.80	1.30	0.83	0.67
21 - 30	0.83	1.33	1.03	0.98	0.96	0.64
31 - 40	0.59	0.93	1.05	0.83	1.10	1.60
41 - 50	1.07	0.89	1.01	1.06	0.97	1.58
51 - 60	1.34	1.08	1.05	0.75	1.28	0.80
61 and older	1.61	0.98	1.11	1.58	1.53	1.18
p (trend)	N.S.	N.S.	N.S.	N.S.	0.0355	0.0430

6.6.4. Discussion

In general, no consistent pattern could be seen in the variation of the latent durability of the six types of restorations with increasing patient age.

It was shown in Chapter 5 that the two most important direct

influences on the actual survival of restorations were the fate and the material. The calculation of latent durability is based on one fate alone, i.e. replacement. From this it follows that variation in latent durability with age, will directly reflect variation in the replacement rate of restorations with age. The rate of replacement is governed by the rate of failure of the restorations which are replaced (2.4.1b.). Since the dentist did not record the reasons for replacing a restoration a direct comparison of the reasons for replacement against the age of the patient cannot be made.

In a review of the causes of failure of restorations, Elderton (1976) listed 22 reasons for failure. These are shown in Table 1:6.6.4..

Of these reasons, only tooth extraction may be expected to vary with age, and that reason does not apply here. Assuming that some or all of these reasons were applicable to the replaced restorations in the present study, the replacement rate would not be expected to vary consistently with increasing patient age. It follows that latent durability also would not be expected to vary consistently with increasing age and the results of this section are in accord with this argument.

The age of the patient at the time of treatment does not appear to be an important influence on the latent durability of restorations.

Table 1:6.6.4.Reasons given for Failure of Restorations.

1. Poor contour, occlusion, carving or contact of restoration.
2. Overhang or overlap of restoration.
3. Faulty restoration margin.
4. Inadequate extension of cavity for prevention.
5. Incorrect cavity wall or retention form; or mobile restoration.
6. Fractured or cracked restoration.
7. Fractured tooth.
8. Caries (residual or recurrent).
9. Sensitivity, pulp problem, lack of lining.
10. Incorrect cavity margin.
11. Failure of restorative material.
12. Poor aesthetics.
13. Incorrect manipulation of restorative material.
14. Insufficient bulk of amalgam.
15. Damage to adjacent tooth.
16. Cavity too narrow.
17. Solubility of restorative material.
18. Poor surface finish of restoration.
19. Corrosion of amalgam.
20. Poor technique.
21. Extraction of tooth for another reason.
22. "Don't know".

### 6.7. Summary

Latent durability was calculated by including only replaced restorations in the analysis, and represents how long the restorations could have survived if none had been converted or extracted.

The patterns of latent durability were similar to those for actual survival, but with three qualifications. Firstly, the range in latent durability of materials (74% of amalgam, 42% of silicate, 59% of sevricon restorations surviving 10 years) was much greater than for actual survival. Secondly and in contrast to actual survival, occlusal restorations were most durable (81% survived 10 years), but like actual survival, proximal restorations were least durable (46% survived 10 years). Thirdly no clear trend in latent durability with increasing patient age could be seen.

The pattern of latent durability according to tooth type, was similar to that for actual survival but not as well defined.

In general the most important influence on the latent durability of restorations was the material.

CHAPTER 7THE DIFFERENCE BETWEEN THE ACTUAL SURVIVAL AND  
THE LATENT DURABILITY OF RESTORATIONS7.1. Introduction

The difference between the actual survival and the latent durability of restorations represents the difference between how long a restoration actually survives in the mouth and how long it may potentially survive in the mouth. It represents the excess or unused durability of restorations.

In this chapter, the excess or unused durability of restorations is given in years. It was calculated by subtracting the median actual survival time (M.A.S.T.) from the median latent durability time (M.L.D.T.). Using median survival and durability times has the disadvantage of being unreliable if the loss rate around the 50% level is low. This is offset by the advantage of allowing survival and durability to be expressed as a number of years, and hence the difference between MLDT and MAST can be expressed as a number of years. For example occlusal restorations in patients aged 10 years and younger could have survived 9 years\* longer than they actually did. Median actual survival and median

\*  $MLDT - MAST = 13 - 4 = 9$  years (Table 1:7.5.1.).

latent durability times have been taken to the nearest whole year.

7.2. The Difference between Actual Survival and Latent Durability for six types of Restorations

In general occlusal, lingual, and MO + DO restorations could all have survived at least 19 years longer than they actually did. Buccal and MOD restorations could have survived 6 years longer than they actually did. The smallest difference between MLDT and MAST was for proximal restorations which in general could only have survived 2 years longer (Table 1:7.2.).

Table 1:7.2.

The Difference between actual survival and latent durability for six types of Restorations.

	<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Occlusal	8	> 28	> 20
Proximal	7	9	2
Buccal	8	14	6
Lingual	9	> 28	> 19
MO + DO	9	> 28	> 19
MOD	12	18	6

7.3.1. The Differences between Actual Survival and Latent Durability of Restorations according to material.

The difference between actual survival and latent durability of amalgam restorations showed that they could have survived at least 19 years longer. In contrast, silicate restorations could only have survived 1 year longer. Between these extremes, sevricon restorations and gold restorations could have survived 5 and 6 years longer respectively (Table 1:7.3.1.).

Table 1:7.3.1.

The Difference between actual survival and latent durability of Restorations according to material \*.

	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
Amalgam	9	> 28	19
Gold	7	13	6
Silicate	7	8	1
Sevricon	8	13	5

\* includes Other Surface Combinations and Crowns

7.3.2. The Difference between Actual Survival and Latent Durability of six types of amalgam Restorations

Occlusal and proximal restorations could have survived at least 19 years longer. MO + DO and lingual restorations could have survived at least 18 and 16 years longer respectively. Buccal and MOD restorations could have survived 10 and 4 years longer respectively (Table 1:7.3.2.).

Table 1:7.3.2.

The Difference between actual survival and latent durability of six types of amalgam Restoration.

	<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Occlusal	8	> 28	> 20
Proximal	9	> 28	> 19
Buccal	8	18	10
Lingual	12	> 28	> 16
MO + DO	10	> 28	> 18
MOD	13	17	4

7.3.3. The Difference between Actual Survival and Latent Durability of Silicate Restorations.

In contrast to amalgam restorations the potential additional survival of silicate restorations was much less. The maximum difference was 3 years for buccal restorations (Table 1:7.3.3.).

Table 1:7.3.3.

The Difference between actual survival and latent durability of silicate restorations.

	<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Proximal	6	8	2
Buccal	8	11	3

7.3.4. The Difference between Actual Survival and Latent Durability of three types of sevrison Restorations

For sevrison restorations, the potential extra survival was greater than for silicate restorations. It was less than that for amalgam restorations with the exception of buccal sevrison restorations. These had a similar potential extra survival time compared to buccal amalgams (Table 1:7.3.4.).

Table 1:7.3.4.

The Difference between actual survival and latent durability of three types of sevrison Restorations.

	<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Proximal	8	11	3
Buccal	10	19	9
MI + DI	5	11	6

7.4. The Difference between Actual Survival and Latent Durability according to tooth type

The difference between actual survival and latent durability in different tooth types was a reflection of the differences described in 7.3. for materials. In general the differences in anterior teeth were small, whereas the differences in posterior teeth were relatively large. In addition, the differences also reflected those described in 7.2. for the six types of restorations. The detailed differences between actual survival and latent

durability of six types of restorations in incisors and canines, premolars, and molars are given in Tables 1:7.4.1-3.

Table 1:7.4.1.

The Difference between the actual survival and latent durability of six types of incisor and canine Restorations.

		<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
Incisal	MXL	4*	> 20*	> 16*
	MND	7*	> 27*	> 20*
Proximal	MXL	7	8	1
	MND	10	16	6
Buccal	MXL	8	12	4
	MND	10	13	3
Lingual	MXL	8	13	5
	MND	3*	5*	2
MI + DI	MXL	4	6	2
	MND	16*	16*	-
MID	MXL	7*	7*	-
	MND	3*	3*	-

\* based on less than 50 restorations

Table 1:7.4.2.

The Difference between actual survival and latent durability of six types of premolar Restorations.

		<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Occlusal	MXL	8	> 28	> 20
	MND	9	> 25	> 16
Proximal	MXL	6*	13*	7*
	MND	12*	> 23*	> 11*
Buccal	MXL	7	9	2
	MND	9	15	6
Lingual	MXL	6*	13*	7*
	MND	18*	18*	-
MO + DO	MXL	7	> 28	> 21
	MND	12	> 27	> 15
MOD	MXL	11	17	6
	MND	16	> 19	> 3

\* based on less than 50 restorations

Table 1:7.4.3.

The Difference between actual survival and latent durability of six types of molar Restorations.

		<u>MAST</u> YEARS	<u>MLDT</u> YEARS	<u>(MLDT-MAST)</u> YEARS
Occlusal	MXL	10	> 28	> 18
	MND	7	> 28	> 21
Proximal	MXL	6*	> 26*	> 20*
	MND	11*	> 27*	> 16*
Buccal	MXL	15	> 28	> 13
	MND	8	14	6
Lingual	MXL	12	> 28	> 16
	MND	10*	> 24*	> 14*
MO + DO	MXL	13	> 28	> 15
	MND	8	> 28	> 20
MOD	MXL	13	> 28	> 15
	MND	11	17	6

\* based on less than 50 restorations

7.5. The Difference between Actual Survival and Latent Durability of Restorations according to the age of the patient at the time of treatment

7.5.1. Occlusal Restorations

The potential improvement in survival of occlusal restorations increased from 7 years in childhood to more than 18 years for patients aged between 11 and 30 years, and then declined (Table 1:7.5.1.).

Table 1:7.5.1.

Occlusal Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	4	13	7
11 - 20	8	> 26	> 18
21 - 30	10	> 28	> 18
31 - 40	16	> 28	> 12
41 - 50	14	> 27	> 13
51 - 60	15*	> 22*	> 7*
61 and older	21*	21*	-

\* based on less than 50 restorations

7.5.2. Proximal Restorations

In contrast to occlusal restorations, the difference between actual survival and latent durability of proximal restorations never exceeded 3 years (Table 1:7.5.2.).

Table 1:7.5.2.Proximal Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	6*	7*	1*
11 - 20	9	10	1
21 - 30	7	7	-
31 - 40	8	10	2
41 - 50	7	10	3
51 - 60	6	9	3
61 and older	5	8	3

\* based on less than 50 restorations

7.5.3. Buccal Restorations

The difference between actual survival and latent durability of buccal restorations declined to 3 years in patients aged between 21 and 40 years and then increased to more than 10 years in patients aged more than 60 years (Table 1:7.5.3.).

Table 1:7.5.3.Buccal Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	4*	> 23*	> 17*
11 - 20	12	> 25	> 13
21 - 30	10	13	3
31 - 40	10	13	3
41 - 50	8	13	5
51 - 60	7	14	7
61 and older	7	> 17	> 10

\* based on less than 50 restorations

7.5.4. Lingual Restorations

The potential extra survival of lingual restorations was more than 13 years except for patients older than 50 years when it declined (Table 1:7.5.4.).

Table 1:5.7.4.Lingual Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	5*	> 24*	> 19*
11 - 20	9	> 22	> 13
21 - 30	10*	> 25*	> 15*
31 - 40	9*	> 25*	> 16*
41 - 50	11*	> 28*	> 17*
51 - 60	12*	> 21*	> 9*
61 and older	4*	> 7*	> 3*

\* based on less than 50 restorations

7.5.5. MO + DO Restorations

With the exception of patients aged 61 years and older the potential extra survival of MO + DO restorations was always greater than 13 years (Table 1:7.5.5.).

Table 1:7.5.5.MO + DO Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	8*	> 21*	> 13*
11 - 20	11	> 28	> 17
21 - 30	11	> 28	> 17
31 - 40	9	> 28	> 19
41 - 50	9	> 27	> 18
51 - 60	7	> 27	> 20
61 and older	5*	12*	7*

\* based on less than 50 restorations

7.5.6. MOD Restorations

The potential extra survival of MOD restorations was minimal in patients aged less than 20 years. There was a sudden increase to a difference between actual survival and latent durability of more than 13 years in patients aged between 21 and 30 years reaching a peak of more than 19 years in patients aged between 31 and 40 years. Thereafter it declined with age (Table 1:7.5.6.).

Table 1:7.5.6.MOD Restorations.

<u>Age</u> <u>YEARS</u>	<u>MAST</u> <u>YEARS</u>	<u>MLDT</u> <u>YEARS</u>	<u>(MLDT-MAST)</u> <u>YEARS</u>
10 and younger	6*	> 7*	> 1*
11 - 20	> 24	> 24	-
21 - 30	13	> 28	> 15
31 - 40	6	> 25	> 19
41 - 50	7	15	8
51 - 60	13	> 16	> 3
61 and older	> 8*	> 8*	-

\* based on less than 50 restorations

7.6. Discussion

Care must be exercised in interpreting the differences between latent durability and actual survival for the following reasons. Firstly, median survival times can be unreliable particularly if the loss rate of restorations at the 50% level is low (Peto et al 1977). Secondly, analysis of the data involved several assumptions which could have affected the calculations of the actual survival and latent durability of restorations.

The first assumption was that the three fates of restorations (2.4.1b., 2.5.3.), were mutually exclusive. For replacements no bias is introduced, since replacement would be superseded by either of the other two fates. For conversions, it was not possible to tell at the time of loss whether the restoration was also in need of replacement. Nevertheless, clinical

experience suggests that in most cases converted restorations are sacrificed before failure has occurred. For extractions, it was not possible to tell whether the extracted restoration was in addition either in need of replacement, or conversion, or both. While it was not possible to validate the assumption that replacement, conversion, and extraction were mutually exclusive, any bias introduced is unlikely to have been large, but would have operated to increase the latent durability of the restorations.

Secondly, the calculation of latent durability treated conversions and extractions as lost to follow-up. It was assumed that converted and extracted restorations would have survived as long as replaced restorations, if they had not been converted or extracted. There is no evidence to suggest that this assumption is unreasonable, and that bias was introduced.

Thirdly, in treating extractions and conversions as lost to follow-up, in the calculation of latent durability, it is assumed that they were totally prevented. In Chapter 4 it was argued that this is unrealistic. Even in a fluoridated community, some restorations will be converted (Roder 1975) (4.8.), and while the most important reason for tooth extraction is dental caries, other reasons have been shown to account for a significant proportion of extracted teeth (Abramowsky & Buchner 1967, Allen 1944, Brekhus 1929, Johansen & Johansen 1977, Krogh 1958, Lundqvist 1967, Todd & Whitworth 1974). These will not necessarily be reduced in a fluoridated community. It is unlikely therefore that the calculated latent durability could

ever be achieved in reality.

The net result is that the full potential durability of these restorations lies somewhere between the actual survival and the latent durability. Without knowing the proportions of extracted and converted restorations which had failed at the time of loss, the real full potential durability of restorations cannot be determined, and the calculated latent durability remains the best estimate. As a consequence the difference between MLDT and MAST is an over-estimate of the additional time the restorations in this study could have survived.

The importance of a difference between MLDT and MAST lies in showing the benefit of preventing premature loss or restorations. If premature losses cannot be reduced significantly, it can be argued that amalgam is a material whose excellent durability is waster in MO + DO and occlusal restorations. For these restorations, a case can be made for using a less durable material, and this will be considered in the next chapter.

#### 7.7. Summary

In general the greatest difference between MLDT and MAST was seen for MO + DO restorations, and for occlusal restorations in young people. The difference tended to increase from anterior teeth to posterior teeth.

SECTION D

DISCUSSION, PRINCIPAL FINDINGS,  
CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

CHAPTER 8DISCUSSION8.1. The Study in Perspective

At the present time no other detailed study of the life of restorations placed in general practice has been published. There have been 3 previous studies analysing the life of small numbers of amalgam and silicate restorations placed in general practice but the effects of patient related factors, sex and age, and restoration related factors, tooth type, tooth surfaces restored and fate, were not reported. Only the material was considered (Robinson 1971, Lavelle 1976, Allan 1977). To date the best information on the life of amalgam restorations may be found in an unpublished study of restorations placed by many dentists in R.A.F. personnel (Gray 1976). This study, in addition, used lifetable analysis to determine the life of fillings, and also described the amalgam restorations by tooth surface.

The present study contains new information and gives a valuable insight into an important aspect of dental practice, namely the restoration of teeth, but it also has certain limitations. Firstly, all of the data was drawn from the records of one practice alone, secondly, all of the patients were regular attenders, and thirdly, only the work of one dentist is included, who not only placed the restorations but also diagnosed

their condition at subsequent recall visits. Inevitably, these limitations mean that the results cannot be regarded as representative of the life of fillings in Scottish adults. However, when compared to what is known of the dental condition of regularly attending Scottish adults, the patients in this study are not atypical (Chapter 3).

## 8.2. Comparison with Other Studies

### 8.2.1. General Practice Studies

The results of the present study for the actual survival of amalgam restorations are in good agreement with the results of studies of the life of amalgam restorations placed in other general practices (Robinson 1971, Allan 1977). The concensus is that about 50% of amalgam restorations may be expected to survive between 8 and 10 years. There is no similar agreement about the life of silicate restorations, and the numbers in earlier practice studies were very small. The life of silicate restorations varied between 50% surviving 10 years (Robinson 1971) to none surviving 4 years (Allan 1977).

### 8.2.2. R.A.F. Study

Comparison with the study of Gray (1976) is important because the work of many dentists was included. Treatment and diagnosis were not necessarily carried out by the same dentist and inevitably one dentist assessed another's work. Comparison with the R.A.F. study is difficult because the tooth types restored were not reported, and no distinction between differing restoration

fates was made. In addition the patients were R.A.F. personnel, who were required to be maintained at a high level of dental fitness, and their ages were not reported.

Similarities between the actual survival of the restorations in the present study and the R.A.F. study were that approximately 50% of amalgam restorations survived 10 years, and the life of restorations decreased with increasing patient age (In the R.A.F. study the life decreased with each subsequent 'replacement'. Since the patient would have been older at each subsequent 'replacement' this has been taken as increasing patient age.).

An important difference between the studies was that actual survival of restorations improved with an increase in the number of tooth surfaces restored (i.e. occlusal, MO + DO, and MOD restorations) in the present study, while in the R.A.F. study the converse was shown. This difference can be explained in terms of the differing age ranges of the patients. In the present study the ages of the patients at the time of treatment ranged from 5 to 84 years (3.2.). Although the age range of the patients in the R.A.F. study was not reported, it is reasonable to assume that it approximated to between 20 and 40 years. Thus it is likely that the present study included more converted and extracted restorations than the R.A.F. study, because much younger and much older patients were included. This is a probable explanation for the opposite trends in restoration survival with increasing numbers of restored surfaces, found in the two studies. Support for this explanation comes from comparing the latent durability of

amalgam restorations in the present study (calculated by treating conversions and extractions as having censored survival) with the R.A.F. study. Under these circumstances, in both studies, the life of restorations (i.e. occlusal, MO + DO, and MOD restorations) deteriorated with an increase in the number of surfaces restored.

### 8.3. The Effect of attending a Dentist regularly

The present study was wholly concerned with care received by regularly attending patients. In Scotland only one third of adults claim to attend regularly (Todd & Whitworth 1974), but it is unlikely that this proportion was constant throughout the period of the study (1949 - 1976). Although no data is available for the earlier part of the study, the proportion is unlikely ever to have been greater than that reported in the Scottish survey of 1972 (Todd & Whitworth 1974).

The condition of natural teeth in regularly attending adults has been shown to be quite different from that of adults who do not attend regularly. On average, Scottish regular attenders have been shown to have 4 fewer missing teeth, 2 fewer decayed teeth, 8 more restored teeth, and 2 fewer sound teeth (Todd & Whitworth 1974). In England and Wales regular attenders have been shown to have 5 fewer missing teeth, 2 fewer decayed teeth, 8 more restored teeth, and 2 fewer sound teeth (Gray, Todd, Slack & Bulman 1970).

Similar differences were evident in the 1978 survey of adult dental health (Todd & Walker 1980), which also showed that in regular attenders the greatest treatment need was in teeth that had previously been restored, whereas in irregular attenders it was in teeth that had not previously been restored. Regular attenders have also been shown to have a higher level of restorative care compared to irregular attenders in a study of York and Hartlepool adults (Jackson et al 1973 B).

In these studies the types of fillings present in participants' teeth have not been reported. It is interesting therefore to look at the types of fillings in the group of regularly attending adults in the present study and to speculate how they would differ from those who only go to a dentist when having trouble.

Proximal restorations were the commonest type of filling in both maxillary and mandibular incisors and canines. In both maxillary and mandibular premolars, MO + DO restorations accounted for the largest proportions and in mandibular premolars, buccal restorations were equally frequent. In maxillary molars, both occlusal and MO + DO restorations were important, while in mandibular molars, occlusal, MO + DO, and MOD restorations accounted equally for almost one quarter of the fillings (Tables 2:3.5.2-5). Overall proximal and MO + DO restorations were commonest.

There is no evidence to suggest that the types of restorations placed in teeth of patients who only attend when

having trouble would be different, only that fewer premolars and first and second molars would be restored (Gray, Todd, Slack & Bulman 1970; Todd & Walker 1980). The main advantage of regular attendance is that it allows the dentist to make an earlier diagnosis of caries lesions, and of course to diagnose the state of any restorations.

The patient who attends at least once per year is likely to have restorations which do not survive as long as those in a patient who does not attend regularly, for two reasons. Firstly, the dentist will be able to diagnose failure earlier, and replacements and repairs might be expected to be more frequent. Secondly, the dentist will also be able to diagnose earlier, caries attack on a surface remote from an existing restoration which may result in conversion.

Against these arguments must be weighed the dentists' knowledge of the best interests of the patient. A restoration may be diagnosed as less than perfect, but the clinical circumstances may not permit its replacement by a better restoration. This alternative is perhaps more likely if the dentist himself inserted the less than perfect restoration. Contrast this with a new patient attending the dentist for the first time. Under these circumstances where the dentist does not know the patient, he may be more readily inclined to replace a less than perfect restoration.

In summary, regular attendance may lead to more frequent

repair and replacement of restorations when clinical conditions are favourable, whereas the more difficult replacement or repair may be left and its less than perfect state accepted, particularly if extraction is the only reasonable alternative. In addition, conversions are likely to be more frequent. For the irregular attender his restorations will probably survive longer, but when he does attend, the dentist may be less tolerant of failed restorations, and extraction may be more likely.

#### 8.4. Implication for Dental Materials

It was shown in Chapter 7 that there was a difference between the actual survival of the restorations in this study and their latent durability. It was argued that the full potential life of a filling lay somewhere between its actual survival and the calculated latent durability, because of the assumptions made in calculating the latter. Nevertheless, the latent durability remains the best estimate of the full potential life of a filling. When the actual survival is much less than the latent durability of a restoration there are important implications for dental materials, as some of the life of that filling is unused, or wasted. If the difference is very large then it can be argued that the material used for the restoration was too durable for the clinical circumstances in which it was used. From the results of the present study, restorations which had high durability were predominantly MO + DO restorations, and occlusal restorations in young people. They were almost all amalgam restorations.

The results of this study indicate that dental amalgam is a very durable material. Apart from the general restriction of its use to posterior tooth restorations, it is used in a non-specific way, i.e. for all types of restorations at all ages. The opinion has been stated that with the predicted world shortage of mercury and the greater awareness of its toxicological hazards, there is little doubt that dentistry will need to look for alternative materials (McLean 1978, 1980). A case can be made therefore for using dental amalgam specifically for those restorations which may be expected to make full use of its long durability, i.e. those restorations where the difference between actual survival and latent durability is least, i.e. MOD restorations.

The other side of this argument is that in circumstances where the difference between actual survival and latent durability is large, i.e. where there is a high chance of the restoration being lost prematurely, a less durable material than amalgam could be considered, e.g. MO + DO restorations, and occlusal restorations placed in patients aged 30 years and younger.

At the present time there are two possible material systems that may be considered as substitutes for amalgam in occlusal cavities. These are restoration of the cavity using composite resin and fissure sealant (Simonsen & Stallard 1977; Raadal 1978; Simonsen 1980) and glass ionomer cements (McLean & Wilson 1974; Wilson & Kent 1972).

Conventional methods of obtaining mechanical retention are not necessarily required for either system, hence cavity preparation may be reduced to the minimum required for removal of caries. The combination of fissure sealant and composite resin makes use of the acid etched enamel technique to obtain retention, while glass ionomer cements exhibit chemical adhesion to tooth tissue. Since both systems incorporate an element of fissure sealing, the need for extension for prevention is eliminated. Such combined preventive restorations should reduce to a minimum the iatrogenic destruction of sound tooth tissue, implicit in Black's principles of cavity preparation (Black 1955).

Against those techniques are the exacting clinical standards of cleanliness and isolation which must be achieved with both the acid etched enamel technique and for chemical adhesion. These two techniques are less likely to be tolerant of variations in clinical procedures compared to dental amalgam. This last factor is in general likely to have been the principal factor determining the high latent durability of amalgam reported in the present study.

The only material that may be considered as a substitute for amalgam for MO + DO restorations (Class II cavities) is composite resin. At present the problem of using composite resins in Class II cavities is not only related to their inadequate physical and mechanical properties, but also their technique of insertion. Because the unset material lacks 'body' it is difficult to establish accurate contact areas and correct

anatomical countour (McLean 1980).

In the development of new restorative materials, comprehensive laboratory investigations of their properties are made. It is implicit that the results of such laboratory tests are valid predictors of the clinical performance of new materials. In contrast, it was the opinion of the American Dental Association that laboratory tests are apt to be too conventional or artificial (Guide to Dental Materials and Devices 1978), and it has been stated that " ..... the clinical performance of a new material or system cannot be reliably predicted from laboratory data alone." (Reisbick 1979). If laboratory tests were valid predictors of clinical performance of materials it might be expected that more rapid development of new materials would occur.

Predictions of a restoration's clinical performance based on laboratory tests, pre-suppose that the dentist works with a standard batch of material, follows the manufacturers instructions exactly, and uses it in an optimum situation. Even if these conditions are fulfilled there remains the frequent inspection and assessment of the restoration, which occurs with regular attendance at a dentist, when a failure may be diagnosed. In a review of the literature on the causes of failure of restorations Elderton (1976) lists 22 reasons given in studies of restorations failure. The commonest reasons were poor contour, carving or contact of restoration; inadequate extension of the cavity for prevention; faulty restoration margin; overhang or overlap of restoration. The author concluded that reasons

given for restoration failure were largely subjective.

The only assessment technique which accounts for all the variables which may affect the clinical performance of restorations, is either retrospective or prospective study of durability. The technique used in this study has an important use in validating laboratory tests predicting clinical performance of materials.

When all the variables influencing the life of a filling are considered, the durability of dental amalgam is remarkable. When the actual survival is considered, restorations have a longer life than most dentists credit.

#### 8.5. The Life of Occlusal Restorations and Fissure Sealants

Occlusal surfaces of premolars and molars are highly susceptible to dental caries (Backer Dirks 1961; Barr, et al 1957; Berman & Slack 1973; Parfitt 1955), and various techniques have been tried to prevent the attack. Hyatt (1923) advocated prophylactic odontotomy which consisted of placing an occlusal amalgam restoration as soon as possible after the eruption of the tooth. Silver nitrate has been used as a method of occluding fissures (Miller 1905; Prime 1937; Klein & Knutson 1942; Miller 1950) but with little success. In addition, precipitating zinc ferrocyanide into fissures, and occluding them with black copper cement have been tried (Ast et al 1950; Miller 1950).

At the beginning of the 1970's Buonocore reported

spectacularly successful results in the prevention of occlusal caries attack, by occluding the anatomical pits and fissures of premolar and molar teeth with a bis GMA resin polymerised using ultra-violet light (Buonocore 1971). The material was retained on the surface of the tooth by etching the enamel first. After two years only one of 113 treated surfaces had become carious. Since that time trials of occlusal sealants carried out by other workers have shown widely varying results. For example, in a study of an ultra-violet light polymerised resin in 6 year old children in Scotland, the authors reported that in a fluoride area (Wigtownshire) only 19% of first permanent molars retained the sealant in whole or part for one year, and 21% of the teeth became carious compared to 33% of the control teeth. In a non-fluoride area (Kircudbrightshire) the same authors showed that only 0.5% of permanent first molars retained sealant for one year and 31% became carious compared with 54% of control teeth (Stephen et al 1976). Using the same material in patients aged between 11 and 13 years Rock showed that at the end of 3 years 70% of treated fissures were still fully sealed and 22% partially sealed. Of the test teeth 7% became carious compared to 21% of the control teeth (Rock 1977).

The differences between these studies is probably the result of testing the material on different types of teeth in different age groups and varying operator skill. This last reason probably played a major part in the poor retention rates achieved in the Scottish study, since the operators who applied

the resin only received one day's training in the technique. In the study by Rock the majority of sealed teeth were premolars which were probably easier to seal than the first permanent molars of the six year old children in the Scottish study. The 3 studies mentioned suffer from a disadvantage common to all studies of fissure sealants to date, and that is they are short term studies. Only two studies have reported the results of sealing occlusal surfaces even 5 years after a single application of sealant (Horowitz et al 1977; Meurman et al 1978).

Of 156 permanent teeth of Finnish children aged between 6 and 12 years at the time of sealing, 59.6% retained the sealant in good condition, 14.7 retained it in fair condition, and 25.6% had lost the sealant totally, 5 years after a single application of sealant (Meurman et al 1978). Of the 115 sealed teeth with paired controls, 61 retained sealant in good condition, 23 retained it in fair condition, and 31 had totally lost the sealant. Only 3.3% of the teeth retaining sealant in good condition were carious, compared to 78.7% of the controls. Of the teeth retaining sealant in fair condition, 26.1% were carious, compared to 82.6% of the paired controls. Of the teeth where sealant was totally missing, 93.5% were carious compared to 80.6% of the paired controls. The sealant was calculated to be 59.8% effective in preventing decay.

In the study of children aged between 5 and 8 years and 10 and 14 years at Kalispell, Montana, 42% of initially sealed

sites wholly retained the sealant and 14% had sealant partly missing after 5 years (Horowitz et al 1977). In the older children 49% of the sites retained all the sealant, but in the younger group only 7% sites retained all the sealant. Of the sites where sealant was totally retained less than 1% were carious whereas in the teeth which had totally lost sealant 52% were carious. The corresponding proportions for the paired control unsealed sites were 18% and 60%. Regardless of retention status the sealant was shown to be 39% effective in preventing decay after 5 years. In this study, the sites with compound restorations (proximo-occlusal restorations) were regarded as sealant failures.

Fissure sealing is a clinical technique used in an unselective manner. In sealing newly erupted teeth, it is assumed that all occlusal surfaces will decay in the future. Despite high susceptibility to caries, not all occlusal surfaces decay, and clearly some surfaces will be sealed unnecessarily. The greater the delay between eruption and sealing the more likely it will be that the sealing will be valueless. The alternative approach is to wait until caries is diagnosed and to place an occlusal restoration. This is a specific form of care applied only to occlusal surfaces which have decayed. Both approaches have the common aim of prolonging the life of the tooth.

If it is assumed that both types of treatment are equally effective in achieving the long term aim, the cheaper technique will appear attractive. The cost of a particular technique is related to, among others; salaries of operating and supporting staff, cost

of equipment, and the cost of maintenance and repairs (Horowitz & Heifitz 1979). Additionally, the more frequently a technique is repeated the higher the cost, i.e. the shorter the life of the occlusal restoration or sealant the greater its cost.

In an analysis of the cost effectiveness of pit and fissure sealants, Horowitz (1980A) concluded that "the concensus of opinion ..... seems to be that the procedure (sealants) is expensive, perhaps more expensive than the alternative of restoring decayed occlusal tooth surfaces." Using preliminary data from the State of Kentucky's caries prevention programme Horowitz (1980A) estimated that the cost of placing each sealant approaches the cost of placing a single surface restoration. At a workshop on the relative efficiency of methods of caries prevention (Burt 1978), a working group on oral hygiene procedures and pit and fissure sealants concluded that the cost of placing sealants is one half that of placing amalgams if dentists perform both services.

In comparing the cost of occlusal restorations and fissure sealants, the intangible and indirect benefits of one over the other are difficult to assess. When an item cannot easily be assigned a market price it is likely to be omitted from calculations of cost-benefit, even though it is likely to be important. Such items are usually subjective and often patient-related, e.g. the avoidance of trauma or pain, improved aesthetics or time saved (Horowitz 1980B).

The intangible benefits of fissure sealing compared to

occlusal restorations are that sealing is a non-surgical technique whereas an occlusal restoration requires a surgical procedure. However carefully the cavity for an occlusal restoration is prepared some loss of sound tooth tissue must occur, and at replacement, further loss of sound tooth tissue has been shown to occur (Elderton 1975). Further, the placing of a sealant, while demanding exacting standards of moisture control, is less unpleasant than placing an occlusal restoration.

If the concensus view given by Horowitz is correct, that the cost of placing a sealant is roughly equal to the cost of an occlusal amalgam restoration then the difference between the techniques will depend upon the cost of resealing teeth compared to the cost of replacing occlusal restorations. While data on the long-term benefits of pit and fissure sealants are not available, using the data relating to the survival of occlusal restorations in Chapter 5, a crude comparison may be made with the 5 year retention rates for sealants as reported by Horowitz and his colleagues (1977).

Caution must be observed in interpreting this comparison since the data come from two wholly different sources. The data relating to occlusal restorations comes from patients whose parents elected to take them, as children, for regular dental treatment in the 1950's, to an urban Scottish practice. The data on fissure sealants comes from a controlled clinical trial, conducted in the 1970's in the U.S.A.. Almost certainly, the caries experience of the two groups of patients were different. The methods of

analysis used in the two studies were different. Nevertheless, the comparison gives the best information available on the life of occlusal restorations and sealants, and how often they are likely to need replacing.

Comparison of the lifetable estimates of occlusal restorations' survival placed in patients aged 10 years and younger may be made with the Kalispell Age Group 1 children (aged between 5 and 8 years) and the survival of occlusal restorations placed in patients aged between 11 and 20 years may be made with the Kalispell Age Group 2 (aged between 10 and 14 years). Clearly in the older groups restorations are included that were placed in late adolescence and it is likely that this will favour the survival of occlusal restorations. The proportion of occlusal restorations placed in patients aged 10 years and younger which survived 5 years was 6 times greater than the proportion of sites totally retaining sealant in 5 to 8 year old children in Kalispell, (44% compared to 7%). In the older groups the difference was much less, 64% compared to 49% respectively.

The Kalispell study showed that sites where sealant was only partly retained were still protected against caries, therefore a more meaningful comparison between occlusal restorations and sealants would be to include the figures for partial retention. In the 5 to 8 years age group in Kalispell after 5 years 22% of sites still retained sealants in whole or part, i.e. half the proportion of occlusal restorations which survived 5 years in patients aged 10 years and younger at the time of treatment. In

the older group the corresponding percentages were 64% for restorations and 63% for sealants.

If the data for both totally and partially retained sealants are considered, in the younger groups, occlusal restorations would have been cheaper, and in the older groups the costs would have been similar. If the views of the working group on oral hygiene procedures and pit and fissure sealants are correct (Burt 1978) however, then costs would be equal in the younger groups, and sealants would be cheaper in the older groups, if a dentist provided both services.

Earlier in this discussion it was argued that fissure sealants have important intangible benefits which are difficult to cost. Another important intangible benefit is that they may delay the date of first restoration of a tooth.

In a study of the records of children aged less than 13 years treated by the New Zealand School Dental Service, it was shown that 74.6% of first permanent molars restored with occlusal restorations subsequently were restored with a proximo-occlusal restoration in a non-fluoridated community. The comparable proportion in a fluoridated community was 37.9% (Roder 1975). In the non-fluoridated community use of occlusal sealants would only have eliminated the need for restorations for 25% of teeth, whereas in the fluoridated community in 62.1% of cases sealants would have eliminated the need for restorations. In the non-fluoridated community, sealants would have delayed the date of

first restoration of a tooth in up to three quarters of cases. In the present study the results in Chapter 4 show that sealants could have delayed the date of first restoration in 50% of cases, in patients aged 10 years and younger and 67% of cases in patients aged between 11 and 20 years. The results of the present study show that by delaying the date of first restoration of a tooth into adolescence (between 11 and 20 years), that restoration will have a longer life (5.6.3.).

In summary, in patients younger than 10 years, occlusal restorations appear to survive longer than sealants, but in adolescents, the survivals appear to be about equal. As a consequence, the cost of sealants is either equal to or less than the cost of occlusal restorations. Sealants appear to prevent the need for restorations in a large proportion of teeth in fluoridated areas and to delay the date of first restoration in non-fluoridated areas. On balance, the intangible benefits of fissure sealants appear to outweigh the better survival of occlusal restorations.

#### 8.6. The Quality of Dental Care and the Performance of Dentists

In the fifth monograph of a series on the assessment of the quality of dental care (Allred 1977), it was concluded that where care is mainly of a restorative nature the manner in which a dentist is remunerated appears to have a marked effect upon the cost of providing care and the time taken when working with a Dental Surgery Assistant (D.S.A.) only. Times and costs were

similar for salaried dentists and for those working to private contract. A dentist working for a fee per item of service was shown to provide the same restorative care at one third of the cost and in one third of the time. The question was posed whether the restorations placed by a dentist working under a fee per item of service system would last as long or longer than those placed by a dentist working at a slower pace but at greater cost.

In the present study all of the restorations were placed by one dentist working with one D.S.A. for a fee per item of service. The results show that the life of restorations placed under this system of payment can be surprisingly long, and compares favourably with the life of restorations placed by dentists working in a salaried service, ie. the R.A.F. (Gray 1976). Clearly, if quality of restorative care is measured by the life of restorations, then the quality of National Health Service restorative care can be good. In addition it has been suggested that the life of restorations might be of value in assessing the performance of dentists (Hunter 1980). The results of this study set a bench mark against which the care provided by other dentists working in the same and other health care systems may be compared.

#### 8.7. The Success of Restorative Dentistry

In the present study, part of the difference between how long restorations actually survived in the mouth and how long they were potentially capable of surviving (Chapter 7), resulted

from teeth being extracted. The loss of teeth, despite regular attendance, is a feature common to both this study and the surveys of adult dental health in the United Kingdom (Gray et al 1970; Todd & Whitworth 1974; Todd & Walker 1980). Whilst at first it may appear that the available restorative techniques are not capable of maintaining a dentition throughout life in regular attenders, the latent durability of restorations described in the present study shows that they are potentially able to achieve this aim.

The loss of a significant proportion of restorations before their full potential survival has been achieved (principally in premolars and molars - Chapter 4) reinforces the need for water fluoridation and a better understanding of why teeth are extracted, particularly in regular attenders, who are presumably well motivated. Despite water fluoridation remaining a matter of public debate, there is evidence that attitudes towards tooth extraction in both regular and irregular attenders are improving (Todd & Walker 1980). In the light of this trend it may be anticipated that more restorations will achieve their full potential life and the maintenance of a functional dentition throughout life will become a reality for a greater number of patients.

CHAPTER 9SUMMARY OF PRINCIPAL FINDINGS, CONCLUSIONS, AND  
SUGGESTIONS FOR FURTHER RESEARCH9.1. Principal Findings

Comparatively uncomplicated restorations accounted for 89% of the restorative care received by this group of regularly attending patients. On average each patient received two items of treatment per year.

In general, the commonest fate of restorations was replacement (54%). The important exception was occlusal restorations, 57% of which were converted to restorations involving a larger number of tooth surfaces. The proportions replaced decreased, and the proportions extracted and converted increased from anterior to posterior teeth. Conversions decreased and extractions increased with increasing patient age at the time of treatment.

The actual survival of the restorations varied from 48% of amalgam to 32% of silicate restorations surviving 10 years. Forty-two per cent of sevricon restorations survived 10 years. The actual survival of silicate restorations is based on the largest number reported to date, and the life of sevricon restorations has not previously been reported.

With respect to the tooth surfaces restored, actual

survival ranged from 54% of MOD restorations to 34% of proximal restorations surviving 10 years.

With respect to the teeth restored, restorations of premolars and molars actually survived longer than restorations of incisors and canines, and maxillary molar restorations survived longest.

With respect to the age of the patient at the time of treatment, actual survival improved with age from those placed in patients aged 10 years and younger to those placed in patients aged between 11 and 20 years. Thereafter, with the important exception of occlusal restorations, actual survival decreased with age. The actual survival of occlusal restorations continued to improve and reached a plateau in patients aged over 30 years.

The variation in the actual survival of restorations with tooth type and with the age of the patient at the time of treatment has not previously been reported.

In general the patterns of latent durability of restorations followed those of the actual survival of restorations, but with three qualifications. Firstly, the differences between the materials were much greater, ranging from 74% of amalgam, to 59% of sevricon, to 42% of silicate restorations surviving 10 years. Secondly, with respect to the tooth surfaces restored, occlusal restorations were most durable (81% surviving 10 years), but like the actual survival of restorations, proximal restorations were least durable (46% surviving 10 years). Thirdly, no clear trend

could be seen in the variation of the latent durability with increasing patient age.

The latent or potential durability of restorations has not previously been reported.

The latent durability of restorations was greater than their actual survival. The difference was greatest for MO + DO restorations and occlusal restorations in young people, and least for proximal restorations.

## 9.2. Conclusions

The restorative techniques described in this study have the potential to maintain the permanent dentition of a regularly attending patient throughout life. The actual survival of restorations is, however, less than their latent durability, indicating that some of the potential life of restorations is not used. The realisation of the full potential survival of restorations depends primarily upon the availability of optimally fluoridated drinking water and on altering the pattern of tooth extraction.

The actual survival of restorations is influenced by their fate and material, and fate is influenced by the type of tooth restored, the tooth surfaces restored and the age of the patient at the time of treatment. The latent durability is influenced by the material, the type of tooth and the tooth surfaces restored.

Dental amalgam is a remarkably durable material but is

frequently used in clinical circumstances where its excellent durability may not be needed. Less durable substitutes could be considered, particularly if they offered improved aesthetics and less sound tooth tissue destruction. With this in mind, the design of restorations should be re-examined, particularly in young people.

Restorations may be required very early in the life of the permanent dentition, yet considerable improvement in the actual survival of restorations may be achieved by delaying the date of first restoration into adolescence. Fissure sealants have an important role to play in achieving a delay in the date of first restoration of the tooth if caries attack is inevitable.

Finally, all of the restorations in this study were provided by a general practitioner working for a fee per item of service, under the terms and conditions of service of the General Dental Service of the National Health Service. If the life of restorations is used as an index, a dentist working under these conditions can provide care of a very high quality.

### 9.3. Suggestions for Further Research

The present study was restricted to the treatment received by a group of loyal patients, who only ever attended one practice throughout the study, and were only treated by one practitioner working for a fee per item of service. None of the patients had consumed optimally fluoridated drinking water throughout life. Further research is required to show:-

1. how the life of restorations varies between patients who have benefitted from a lifetime's consumption of optimally fluoridated drinking water and patients who have not consumed fluoridated drinking water,
2. the variation in the life of restorations between operators and between practices,
3. how the life of restorations varies with frequency of attendance and with regular attendance at one practice and regular attendance with migration between practices.
4. how the life of restorations varies with the method of paying the dentist.

In calculating the fate and life of the restorations in this study, certain assumptions were made because the patient record did not contain sufficient details, for example, those restorations which were described ambiguously (2.4.2.), and the reasons for tooth extraction. Further research is required to:-

5. develop a system of recording dental treatment which is acceptable to practitioners, but which contains more

detailed information of use in epidemiological studies,

6. show the reasons why regular attenders lose teeth, and why restorations are replaced,
7. show the proportions of converted and extracted restorations which had failed at the time of loss.

Finally, the methods used in this study can be applied to other aspects of dental care. For example:-

8. to show the life of restorations in deciduous teeth,
9. to compare the life of restorations of new materials to dental amalgam,
10. to investigate the life of dentures, crowns, and bridges.

SECTION E

APPENDICES

APPENDIX 1ANALYSIS OF SURVIVAL1.1. Introduction

In long term follow-up studies of the actual duration of survival of patients, lifetable analysis is the appropriate statistical method. If the course of a disease is particularly rapid and it is not important whether a dying patient lives a few days longer or not, a count of the numbers of deaths and survivors in differing treatment groups is all that is required. If an appreciable proportion live for a considerable time, a more sensitive assessment of the value of treatments is gained by counting not only how many died, but also how long it took them to die. This assessment may be made not only for patients receiving different treatments but also for different prognostic factors, e.g. age and sex.

These methods are also appropriate to the analysis of the survival of restorations. An appreciable proportion of restorations take a considerable time before being lost, either through failure, tooth extraction, or sacrifice during other treatment of the tooth. Lifetable analysis may be used to show the effect of various prognostic factors on the survival of restorations. Factors which may influence the survival of restorations include the age of the patient at the time of treatment, sex, type of tooth restored, tooth surfaces restored

and materials.

## 1.2. The Lifetable

From the practice records it was known whether or not a restoration was lost by the end of the study, and the time it was at risk of being lost. Time at risk is effectively the life of the restoration and was measured as the time elapsing either between the placement and loss of the restoration, or placement and the end of the study (31:12:76) (2.4.1a). If all of the restorations had been lost by the end of the study, a graph of proportions surviving against time would form a simple lifetable.

The survival time of a restoration surviving beyond the end of the study is effectively censored, i.e. the complete survival is hidden because the study closed before the restoration was lost. Lifetable analysis gives an estimate of the proportion of a group of restorations that survived different periods after placement, and an important feature is that survival data which is arbitrarily censored may be readily incorporated.

Other forms of censorship of survival data include patient migration and loss of restorations through causes other than those being investigated. It is assumed that causes of censorship operate independently of the cause of loss, and no distinction is made between them.

In this study all the patients were regular attenders, and none migrated away, and therefore there were not any restorations

lost to follow-up in this way. In the calculation of latent durability, losses to follow-up were artificially created by treating extracted and converted restorations as having censored survival times.

### 1.3. Compilation of a Lifetable

For a restoration to survive 5 years it had to survive each of the preceding 4 years and then one more year, i.e. the proportion surviving 5 years equals the cumulative proportion surviving 4 years multiplied by the proportion which survived one more year. In general terms, if the cumulative proportion surviving  $(t - 1)$  years is given by:

$$P_1 \times P_2 \times P_3 \dots \dots \dots \times P_{(t - 1)}$$

where  $P$  = the proportion surviving any one year, then the cumulative proportion surviving  $t$  years is given by:

$$P_1 \times P_2 \times P_3 \dots \dots \dots \times P_{(t - 1)} \times P_t$$

Due to censorship the values of  $P$  were unknown but could be estimated from the proportion of restorations known to have survived a given year. If  $p_5$  equals the observed proportion of restorations at risk during year 5 which survived the whole of year 5, then the estimate of the cumulative proportion surviving 5 years is given by:

$$P_1 \times P_2 \times P_3 \times P_4 \times P_5$$

1.4. Calculation of proportions surviving allowing for incomplete follow-up (censorship)

The proportion of restorations lost between  $t - 1$  and  $t$  is given by:

$$d_t / r_t$$

where  $d_t$  = the number of restorations lost during  $t$ , and  $r_t$  = the number at risk during  $t$ . The proportion surviving  $t$  is given by:

$$1 - d_t / r_t$$

The proportion of restorations at risk during  $t + 1$  is given by:

$$r_t - (d_t + c_t)$$

where  $c_t$  = the number of restorations with censored survival times during  $t$ . The estimate of the cumulative proportion surviving until  $t$  is given by:

$$p_1 \times p_2 \times p_3 \dots \times p_t$$

The facility to use censored data allowed separate fates to be studied. Restorations may be lost by replacement, conversion or extraction. In the ideal world, conversion and extraction would be totally prevented. An estimate of the survival of restorations when loss occurs by replacement alone may be made by treating converted and extracted restorations as lost to follow-up, i.e. on the date of extraction or conversion the survival data is censored.

1.5. Calculation of the standard error of the proportion surviving.

$$\text{S.E. of } p = p \times \sqrt{\frac{1-p}{m}}$$

$$= \sqrt{\frac{p(1-p)}{m}}$$

where  $p$  is the estimated proportion surviving a given time and  $m$  is the number of restorations known to have survived that long.

1.6. Comparison of Lifetables1.6.1. Loss rates

In general the loss rate amongst a group of surviving restorations is not constant, but varies with the length of time at risk. If the time at risk is divided into infinitesimally small units, so that the loss rate does not vary within each unit, then two groups' survival may be compared by the ratio of their loss rates within each interval. The RELATIVE LOSS RATE for a group approximates to the ratio of the interval loss rate for the group to the interval loss rate for both groups combined. The ratio of two relative loss rates estimates the average loss rate ratio for the groups over all intervals, and represents the excess mortality of one group over the other.

1.6.2. Calculation of Relative Loss Rate

If in a particular year after placement  $\frac{2}{3}$  restorations are at risk in group A and  $\frac{1}{3}$  of restorations are at risk in group B, then on average  $\frac{2}{3}$  losses in that year would be expected from group A and  $\frac{1}{3}$  from group B. The expected losses in the year from group A,

$$e_A = \frac{r_A}{r_A + r_B} \times (o_A + o_B)$$

and the expected losses from group B,

$$e_B = \frac{r_B}{r_A + r_B} \times (o_A + o_B)$$

where  $r$  = number of restorations at risk,  $o$  = number of restorations observed lost. If over many years the survival in the two groups is equivalent, then  $\sum e_A = \sum o_A$  and  $\sum e_B = \sum o_B$ . Let  $O = \sum o$  and  $E = \sum e$ , then if  $O_A$  exceeds  $E_A$  and  $O_B$  is less than  $E_B$ , restorations in group B have better survival than restorations in group A.

The relative loss rate for group A is given by  $O_A/E_A$  and

the relative loss rate for group B is given by  $O_B/E_B$ .

The ratio of relative loss rates =  $O_A/E_A \div O_B/E_B$ .

With respect to the two groups, a test of the Null Hypothesis is more likely to be significant if the relative loss rate ratio differs markedly from unity or the numbers of restorations involved are large. If the relative loss rate ratio approximates to unity but does not equal it then the logrank test is more likely to detect the difference between groups than any other rank-invariant test procedure, and is asymptotically fully efficient.

### 1.6.3. The Logrank Test

For 2 groups of restorations having respectively observed and expected numbers lost during given intervals, the data can be represented as several 2 x 2 contingency tables, one for each interval of observation. For example in the  $i$  th interval:

	Lost	Survived	Total
Group A	$O_{Ai}$	$N_{Ai} - O_{Ai}$	$N_{Ai}$
Group B	$O_{Bi}$	$N_{Bi} - O_{Bi}$	$N_{Bi}$
Total	$M_{Ai}$	$M_{Bi}$	$T_i$

where  $N_{Ai}$  = total number of group A restorations at risk.

$N_{Bi}$  = total number of group B restorations at risk.

$M_{Ai}$  = total number of lost restorations from both groups.

$M_{Bi}$  = total number of restorations surviving in both groups.

$T_i$  = total number of restorations at risk.

Then  $E_{Ai} = M_{Ai} \times N_{Ai} / T_i$  ; (the expected number of group A restorations lost)

and  $V_i = N_{Ai} \times N_{Bi} \times M_{Ai} \times M_{Bi} / T_i^2 (T_i - 1)$  ; (the variance)

A chi-square test with one degree of freedom permitting simultaneous comparison over all of the contingency tables of the differences in loss or survival probabilities for the two groups is given by:

$$\frac{(\sum O_A - \sum E_A)^2}{\sum V_A}$$

or where a continuity correction is used:

$$\frac{(|\sum O_A - \sum E_A| - \frac{1}{2})^2}{\sum V_A}$$

(Peto et al 1977).

The use of a simpler test, which is much easier to compute manually and is conservative, was justified by Peto and Pike (1973).

For each group of restorations being compared, the term

$$\frac{(\sum O - \sum E)^2}{\sum E}$$
 is calculated.

Then Chi Square =

$$\frac{(\sum O_A - \sum E_A)^2}{\sum E_A} + \frac{(\sum O_B - \sum E_B)^2}{\sum E_B} + \dots \dots \dots \frac{(\sum O_K - \sum E_K)^2}{\sum E_K}$$

where there are K groups, with K - 1 degrees of freedom.

#### 1.6.4. Computation

In this study, a computer programme was used which produced lifetables, logrank test statistics, and relative loss rates (Pike et al 1976). The programme used the methods of analysis described by Mantel (1966) and Peto and Pike (1973), which were reviewed by Breslow (1975) and Peto et al (1976 and 1977). The programme was used to generate all of the lifetables in Volume 2 of this thesis, and the comparisons of lifetables. Output from the programme summarising the statistical analysis consisted of an overall chi square value testing for heterogeneity (df = K - 1; K = number of groups compared) and a chi square test of trend (df = 1) (Mantel 1963) which incorporates a continuity correction. Where 2 or more groups were compared, but did not fall into a natural order, the overall chi square is quoted. Where groups fell into a natural order (e.g. age groups) both the overall and the trend chi squares are quoted. Where only 2 groups of restorations were compared the continuity corrected chi square test for trend is quoted as it is more conservative than the overall chi square.

PREFACE TO APPENDICES 2 and 3THE LIFE OF CROWNS, ROOT TREATMENTS AND PARTIAL DENTURES

The information in the patient record cards on crowns, root treatments and partial dentures was incomplete. For crowns, only the tooth treated was recorded. The practitioner recalled that before around 1960, anterior crowns were constructed from sevriton, and thereafter porcelain, or porcelain bonded to gold was used. He recalled that posterior crowns were made of gold. For root treatments only the tooth treated was recorded. The practitioner recalled always using gutta percha to fill root canals, with a variety of sealing agents. For partial dentures, in some cases the number of teeth replaced was recorded, in others it was not. The design (including for example information on the use of clasps, or whether the denture was tooth or tissue borne) was never recorded.

In view of such constraints, the information in appendices 2 and 3 is included for its intrinsic value alone.

APPENDIX 2THE LIFE OF CROWNS AND ROOT TREATMENTS

(Lifetables 2:129 + 130).

2.1. Crowns

Of the 6,434 items of treatment received by the patients in this study, only 122 were crowns. Almost three quarters (71%) were made for maxillary incisors and canines, 14% for maxillary premolars, 0.8% for maxillary molars, 3% for mandibular incisors and canines, 11% for mandibular premolars and none for mandibular molars. Crowns were placed in all age groups, except for patients aged 10 years and younger, but mainly after age 20 years. Based on the practitioner's recall, males had more gold crowns than females, who had more sevriton crowns than males. Other materials (i.e. porcelain, and bonded porcelain) accounted for most crowns (46%) equally in both sexes, (2:3.7.1-2). Forty eight crowns were lost; none were converted, 36 were replaced (75%) and 12 (25%) were extracted. The lifetable estimates of the proportions surviving 5, 10 and 25 years were 74%, 48%, and 27% for actual survival (MAST = 10 years) and 78%, 59%, and 40% for latent durability (MLDT = 12 years).

## 2.2. Root Treatments

In all of the 122 root treatments, gutta percha was used to fill the root canal, but with a variety of sealing agents. The sealing agent was not noted in the patient record. Over half (57%) were maxillary incisors and canines, 11% were maxillary premolars, 0.8% were maxillary molars, 7% were mandibular incisors and canines, 21% were mandibular premolars, and 2% were mandibular molars. None of the root treatments was carried out in patients aged 10 years and younger. Thirty six root treatments were 'lost'; 11 were retreated (replaced), and 25 (69%) were extracted. The lifetable estimates of the proportions surviving 5, 10 and 25 years were 89%, 74%, and 48% (MAST = 23 years). It is not reasonable to apply the assumptions behind latent durability to root treatments.

APPENDIX 3THE LIFE OF PARTIAL DENTURES

During the period of the study 165 partial upper dentures and 52 partial lower dentures were made. Of the partial upper dentures, 49 were made for males and 116 for females. Of the partial lower dentures, 9 were made for males and 43 for females. All of the dentures except 3 were made of acrylic. The smallest number of teeth replaced was one. The life of a partial denture was taken to be the time elapsing between its insertion and either a repair, addition or replacement. In calculating survival a distinction was not made between them. The lifetable estimates of the proportions of partial upper dentures surviving 5, 10 and 25 years were 33%, 14%, and 0% respectively. The median survival time was 3 years. For partial lower dentures the proportions were 43%, 24%, and 13% respectively, and the median survival time was 4 years.

The Survival of Partial Dentures

	N	OL	EL	RLR	RLR % reduction
Partial lower dentures	165	128	120.30	1.06	
Partial upper dentures	52	35	42.70	0.82	23%

Chi Square = 2.00, d.f. = 1, p = 0.1569

APPENDIX 4ABBREVIATIONS4.1. Restorations

O	= Occlusal	MID	= Mesial-incisal-distal
I	= Incisal	O.S.C.	= Other surface combinations
P <sup>*</sup>	= Proximal	Cr	= Crowns
B <sup>**</sup>	= Buccal	R.T.	= Root Treatments
L <sup>***</sup>	= Lingual	Ext.	= Extractions
MO	= Mesial-occlusal	A	= Amalgam
DO	= Distal-occlusal	C	= Composite
MI	= Mesial-incisal	G	= Gold
DI	= Distal-incisal	S	= Silicate
MOD	= Mesial-occlusal-distal	Sev.	= Sevriton

4.2. Teeth

I + C	= Incisors and Canines	MXL	= Maxillary
PM	= Premolars	MND	= Mandibular
M	= Molars		

- \* includes restorations described as mesial or distal in the patient records.
- \*\* includes restorations described as buccal, labial or cervical in the patient records.
- \*\*\* includes restorations described as lingual, or palatal in the patient records.

4.3. Statistics

T	= time at risk
N	= number at risk
O	= observed
E	= expected
L	= losses
R	= replacements
C	= restorations with censored survival times
O.L.	= observed losses
E.L.	= expected losses
O.R.	= observed replacements
E.R.	= expected replacements
R.L.R.	= relative loss rate
R.R.R.	= relative replacement rate
M.A.S.T.	= median actual survival time
M.L.D.T.	= median latent durability time
N.S.	= not significant (null hypothesis sustained)
p	= chance of null hypothesis being sustainable
d.f.	= degrees of freedom
S.E.	= standard error

APPENDIX 5REFERENCES

- ABRAMOWSKY, Z. L. & BUCHNER, A., 1967. Causes of Tooth Extraction: Part II - A Statistical Study. N. Y. J. Dent., 37, 16-19.
- ALLAN, D. N., 1962. An Evaluation of Dental Conservative Restorations. University of Durham Medical Gazette, 56, 114-118.
- ALLAN, D. N., 1969. The Durability of Conservative Restorations. Brit. Dent. J., 126, 172-177.
- ALLAN, D. N., 1977. A Longitudinal Study of Dental Restorations. Brit. Dent. J., 143, 87-89.
- ALLEN, E. F., 1944. Statistical Study of the Primary Causes of Extractions. J. Dent. Res., 23, 453-458.
- ALLRED, H., 1977. The Assessment of the Quality of Dental Care. The London Hospital Medical College, University of London, 1977.
- AST, D. B., BUSHEL, A. & CHASE, H. C., 1950. Clinical Study of Caries Prophylaxis with Zinc Chloride and Potassium Ferrocyanide. J. Am. Dent. Assoc., 41, 437-442.
- BACKER DIRKS, O., 1961. Longitudinal Dental Care Study in Children 9 - 15 Years of Age. Archs. Oral. Biol., 6, 94-108.
- BACKER DIRKS, O., 1974. The Benefits of Water Fluoridation. Caries Res. 8, suppl., 2-15.
- BARR, J. H., DIODATI, R. R., STEPHENS, R. G., 1957. Incidence of Caries at Different Locations on the Teeth. J. Dent. Res., 36, 536-545.
- BERMAN, D. S. & SLACK, G. L., 1973. Susceptibility of Tooth Surfaces to Carious Attack. A Longitudinal Study. Brit. Dent. J., 134, 135-139.
- BLACK, G. V., 1955. Operative Dentistry. 9th Edition. Medico-Dental Publishing Co. Chicago.
- BREKHUS, P. J., 1929. Dental Disease and its Relation to the Loss of Human Teeth. J. Am. Dent. Assoc., 16, 2237-2247.
- BRESLOW, N. E., 1975. Analysis of Survival Data under the Proportional Hazards Model. Int. Stat. Rev., 43, 45-58.

- BUONOCORE, M. G., 1971. Caries Prevention in Pits and Fissures Sealed with an Adhesive Resin Polymerised by Ultra-violet Light: a Two Year Study of a single Adhesive Application. *J. Am. Dent. Assoc.*, 82, 1090-1093.
- BURT, B. A. (Ed), 1978. The Relative Efficiency of Methods of Caries Prevention in Dental Public Health. Proceedings of a Workshop at the University of Michigan.
- CARLOS, J. P. & GITTELSON, A. M., 1965. Longitudinal Studies of the Natural History of Caries - II. A Life Table Study of Caries Incidence in the Permanent Teeth. *Arch. Oral Biol.*, 10, 739-751.
- COMBE, E. C., 1975. Notes on Dental Materials. 2nd Ed. Churchill Livingstone.
- CUTLER, S. J. & EDERER, F., 1958. Maximum Utilisation of the Lifetable Method in Analysing Survival. *J. Chron. Dis.*, 8, 669-712.
- DEAN, H. T., JAY, P., ARNOLD, F. A. jun., McCLURE, F. J. & ELVOVE, E., 1939. Domestic Water and Dental Caries, including certain Epidemiological Aspects of Oral L. Acidophilus. *Public Health Rep.*, 54, 862-888.
- ELDERTON, R. J., 1975. An in vivo Morphological Study of Cavity and Amalgam Margins on the Occlusal Surfaces of Human Teeth. Ph.D. Thesis, University of London.
- ELDERTON, R. J., 1976. The Causes of Failure of Restorations: a Literature Review. *J. Dent.*, 4, 257-262.
- FRYKHOLM, K. O. & LYSELL, L., 1962. Different Systems for Recording Teeth and Tooth Surfaces. *Int. Dent. J.*, 12, 194-207.
- GRAY, J. C., 1976. An Evaluation of the Average Lifespan of Amalgam Restorations. M.Sc. dissertation. Dept. of Community Dental Health, The London Hospital Medical College Dental School, University of London.
- GRAY, P. G., TODD, J. E., SLACK, G. L. & BULMAN, J. S., 1970. Adult Dental Health in England and Wales - 1968. H.M.S.O. London.
- GUIDE TO DENTAL MATERIALS AND DEVICES. 8th Ed., 1978. American Dental Association, Chicago.
- HOLLOWAY, P. J., 1975. The Success of Restorative Dentistry. *Int. Dent. J.*, 25, 26-30.

- HOROWITZ, H. S., 1980 A. Pit and Fissure Sealants in Private Practice and Public Health Programmes: Analysis of Cost Effectiveness. *Int. Dent. J.*, 30, 117-126.
- HOROWITZ, H. S., 1980 B. Cost Value Analysis in Dentistry. In "Proceedings of a Workshop on Assessing the Performance of Dentists". Edited by Elderton, R. J., Campbell, M. L. & Nuttall, N. M., pp 8-13. University of Dundee.
- HOROWITZ, H. S. & HEIFETZ, S. B., 1979. Methods for Assessing the Cost Effectiveness of Caries Preventive Agents and Procedures. *Int. Dent. J.*, 29, 106-117.
- HOROWITZ, H. S., HEIFETZ, S. B. & POULSEN, S., 1977. Retention and Effectiveness of a Single Application of an Adhesive Sealant in Preventing Occlusal Caries: Final Report after 5 years of a Study in Kalispell, Montana. *J. Am. Dent. Assoc.*, 95, 1133-1139.
- HUNTER, B., 1980. Analysis of the Durability of Restorations as an Indicator of Dentist Performance. In "Proceedings of a Workshop on Assessing the Performance of Dentists". Edited by Elderton, R. J., Campbell, M. L. & Nuttall, N. M., pp 42-44. University of Dundee.
- HYATT, T. P., 1923. Prophylactic Odontotomy: the Cutting into the Tooth for the Prevention of Disease. *Dental Cosmos*, 65, 234-241.
- JACKSON, D., MURRAY, J. J. & FAIRPO, C. G., 1973 A. Life-long Benefits of Fluoride in Drinking Water. *Brit. Dent. J.*, 134, 419-422.
- JACKSON, D., MURRAY, J. J. & FAIRPO, C. G., 1973 B. Regular Dental Care in Dentate Persons. *Brit. Dent. J.*, 135, 59-63.
- JOHANSEN, S. B. & JOHANSEN, J. R., 1977. A Survey of Causes of Permanent Tooth Extraction in South Australia. *Austral. Dent. J.*, 22, 238-242.
- KEIR, D. (Ed), 1966. *The Third Statistical Account of Scotland The City of Edinburgh*. Collins, Glasgow.
- KLEIN, H. & KNUTSON, J. W., 1942. Studies on Dental Caries. XIII Effect of Ammoniacal Silver Nitrate on Caries of the First Permanent Molar. *J. Am. Dent. Assoc.*, 29, 1420-1426.
- KROGH, H. W., 1958. Permanent Tooth Mortality: a Clinical Study of Causes of Loss. *J. Am. Dent. Assoc.*, 57, 670-675.

- KWANT, G. W., HOUWINK, B., DIRKS, O. BACKER. & BANER, L., 1969. Fluoride and Oevoeging aan Drinkwater, III. Resultaten ven het Onderwoek Tiel-Culemborg na 13 jaar. Tijdschr. Tandheelk, 76, 281-302.
- LAVELLE, C. L. B., 1976. A Cross-sectional Longitudinal Survey into the Durability of Amalgam Restorations. J. Dent., 4, 139-143.
- LU, K. H., 1966. An Analysis of the Caries Process by Finite Absorbing of Markov Chains. J. Dent. Res., 45, 998-1015.
- LUNDQUIST, C., 1967. Tooth Mortality in Sweden. A Statistical Survey of Tooth Loss in the Swedish Population. Acta. Odont. Scand., 25, 298-322.
- MANTEL, N., 1963. Chi-square Tests with one Degree of Freedom; Extensions of the Mantel-Haenszel Procedure. J. Am. Stat. Assoc., 58, 690-700.
- MANTEL, N., 1966. Evaluation of Survival Data, and two new Rank Order Statistics arising in its Consideration. Cancer Chemother. Rep., 50, 163-170.
- McLEAN, J. W., 1978. Restorative Dentistry - Past and Future. Brit. Dent. J., 145, 179-183.
- McLEAN, J. W., 1980. Aesthetics in Restorative Dentistry: the Challenge for the Future. Brit. Dent. J., 149, 368-373.
- McLEAN, J. W. & WILSON, A. D., 1974. Fissure Sealing and Filling with an Adhesive Glass-ionomer Cement. Brit. Dent. J., 136, 269-276.
- MEURMAN, J. H., HELMINEN, S. K. J. & LUOMA, H., 1978. Caries Reduction over 5 years from a Single Application of a Fissure Sealant. Scand. J. Dent. Res., 86, 153-156.
- MILLER, J., 1950. A Clinical Investigation in Preventive Dentistry. Dent. Pract. Dent. Rec., 1, 66-75.
- MILLER, W. D., 1905. The Preventive Treatment of Teeth with Special Reference to Nitrate of Silver. Dent. Cosmos, 47, 913-922.
- MOSER, C. A., GALES, K. E. & MORPUGO, P. W. R., 1962. Dental Health and Dental Services - An Assessment of Available Data. Oxford University Press for the Nuffield Provincial Hospitals Trust.
- MURRAY, J. J., 1971. Adult Dental Health in Fluoride and Non-fluoride Areas. Part 2 - Caries Experience in Each Tooth Type. Brit. Dent. J., 131, 437-442.

- MURRAY, J. J., 1976. Fluorides in Caries Prevention. John Wright & Sons Ltd., Bristol.
- PARFITT, G. J., 1955. The Distribution of Caries on Different Sites of the Teeth in English Children from the age of 2 - 15 Years. *Brit. Dent. J.*, 99, 423-427.
- PETO, R. & PIKE, M. C., 1973. Conservatism of the Approximation  $(O-E)^2/E$  in the Logrank Test for Survival Data or Tumour Incidence Data. *Biometrics*, 29, 579-584.
- PETO, R., PIKE, M. C., ARMITAGE, P., BRESLOW, N. E., COX, D. R., HOWARD, S. V., MANTEL, N., McPHERSON, K., PETO, J., & SMITH, P. G., 1976. Design and Analysis of Randomised Clinical Trials, requiring Prolonged Observation of each Patient. Part I. *Brit. J. Cancer*, 34, 585-612.
- PETO, R., PIKE, M. C., ARMITAGE, P., BRESLOW, N. E., COX, D. R., HOWARD, S. V., MANTEL, N., McPHERSON, K., PETO, J., & SMITH, P. G., 1977. Design and Analysis of Randomised Clinical Trials requiring Prolonged Observation of each Patient. Part II. *Brit. J. Cancer*, 35, 1-39.
- PIKE, M. C., HOWARD, S. V. & SMITH, P. G., 1976. Survival Analysis Computer Programme (Surv-C). DHSS Cancer Epidemiology and Clinical Trials Unit, 9 Keble Road, Oxford, England.
- PRIME, J. M., 1937. Controlling Dental Caries. *J. Am. Dent. Assoc.*, 24, 1950-1961.
- RAADAL, M., 1978. Follow-up Study of Sealing and Filling with Composite Resins in the Prevention of Occlusal Caries. *Community Dent. Oral. Epidemiol.*, 6, 176-180.
- REISBICK, M. H., 1979. Predicting the Clinical Success of Restorative Dental Materials. *Biomat., Med. Dev., Art. Org.*, 7, 89-98.
- ROBINSON, A. D., 1971. The Life of a Filling. *Brit. Dent. J.*, 130, 206-208.
- ROCK, W. P., 1977. Fissure Sealants. *Brit. Dent. J.*, 142, 16-18.
- RODER, D. M., 1975. The Treatment of First Permanent Molars in a School Dental Programme; Implications for Fissure Sealants, *Aust. Dent. J.*, 20, 94-100.
- SCOTTISH DENTAL ESTIMATES BOARD (SDEB), 1976. Summary Report 1976 NHS Circular No. 1977 (GEN)60. Scottish Home & Health Dept., St. Andrews House, Edinburgh.

- SIMONSEN, R. J., 1980. Preventive Resin Restorations: Three Year Results. J. Am. Dent. Assoc., 99, 38-41.
- SIMONSEN, R. J. & STALLARD, R. E., 1977. Sealant Restorations Utilizing a Diluted Filled Composite Resin: One Year Results. Quint. Int., 6, 77-84.
- STEPHEN, K. W., SUTHERLAND, D. A. & TRAINER, J., 1976. Fissure Sealing by Practitioners. Brit. Dent. J., 140, 45-51.
- SUTCLIFFE, P. & HUNTER, B., 1976. A 2 Year Retrospective Study of Demand for Dental Care from Scottish School Leavers. Community Dent. Oral. Epidemiol., 4, 171-175.
- THYLSTRUP, A. & ROLLING, I., 1975. The Lifetable Method of Clinical Dental Research. Community Dent. Oral Epidemiol., 3, 5-10.
- TODD, J. E. & WALKER, A. M., 1980. Adult Dental Health - Volume 1, England and Wales 1968-1978. H.M.S.O. London.
- TODD, J. E. & WHITWORTH, A., 1974. Adult Dental Health in Scotland - 1972. H.M.S.O. London.
- WILLIAMS, S. A. & JACKSON, D., 1978. Distribution of Regular Patients Attending a Dental Practice. Probe, 20, 200-207.
- WILSON, A. D. & KENT, B. E., 1972. A New Translucent Cement for Dentistry. Brit. Dent. J., 132, 133-135.