0300-5712(95)00076-3

Journal of Dentistry, Vol. 24, No. 5, pp. 309–315, 1996

Printed in Great Britain
0300-5712/96 $15.00 + 0.00

Ten years' clinical evaluation of three luting cements

A. Jokstad and I. A. Mjör*
Department of Prosthetic Dentistry and Stomatognathic Physiology, University of Oslo, Oslo, Norway, and NIOM, Scandinavian Institute of Dental Materials, Haslum, Norway

ABSTRACT

Objective: The aim of the present clinical longitudinal study was to observe, over 10 years, the prognosis of abutment teeth restored with fixed prostheses retained by two glass ionomer luting cements and one conventional zinc phosphate cement.
Methods: Three dentists prepared 135 abutment teeth in 61 patients to retain 81 fixed prostheses. The prostheses were retained by two glass ionomer luting cements (Ketac-Cem, Fuji Ionomer), or a conventional zinc phosphate cement (De Trey Zinc Zement Improved). The patients were examined yearly for 10 years.
Results: Post-operative hypersensitivity occurred in five teeth restored with glass ionomer luting cement. The prevailing reason for abutment tooth failure was secondary caries ($n = 21$) and pulp necrosis ($n = 5$). Non-parametric survival estimates indicated that 80–85% of the abutment teeth remained intact after 5 years and 71–81% after 10 years.
Conclusions: The 10-year results indicate that the prognosis of abutment teeth restored with fixed prostheses is good, regardless of whether a glass ionomer or a zinc phosphate luting cement is used.

KEY WORDS: Cements (luting), Prostheses (fixed), Clinical evaluation

J. Dent. 1996; **24**: 309–315 (Received 29 June 1994; reviewed 30 November 1994; accepted 27 March 1995)

INTRODUCTION

For over a century, zinc phosphate cements have been widely used to retain fixed prostheses due to easy handling characteristics and adequate retentive properties. However, zinc phosphate cements have limited bonding qualities[1], the long-term sealing is jeopardized when the cement space exceeds 20 μm, and the cement is relatively soluble in the oral environment[2]. These factors may explain the relative high rates of secondary caries associated with cast restorations[3–4].

A continuous search for alternative luting materials has resulted in the development of other cements, such as reinforced zinc oxide eugenol cements[5], and fluoride-containing silicophosphate, polycarboxylate, and glass polyalkenoate (ionomer) luting cements[6–7]. The reinforced zinc oxide eugenol and the silicophosphate cements were never considered as serious alternatives to zinc phosphate cements[8]. Polycarboxylate cements, with the potentially advantageous effect of fluoride release, have gained some popularity[9–11]. However, the current use of polycarboxylate cements seems limited[8].

Many general practitioners use glass ionomer luting cements as the only alternative to zinc phosphate cements to retain fixed prostheses[12,13]. The assumption that glass ionomer cements and zinc phosphate cements are clinically comparable has primarily been based on data from laboratory experiments. Numerous laboratory experiments during the last 10–15 years have focussed on different physical and mechanical properties: microleakage, dissolution, etc.[8] However, the general opinion is that there are no well-established correlations between laboratory measurements of apparently relevant properties and the clinical performance of luting materials[1,8,14].

Clinical data on the clinical performance of glass ionomer cements used as luting materials have been sparse. Although products were commercially introduced in the beginning of the 1980s, the first clinical study appeared in 1986[9], and only four short-term studies have since been reported in the literature[11,15–17].

The aim of the present clinical longitudinal study was to observe the long-term clinical prognosis of abutment teeth restored with fixed prostheses retained by two glass ionomer luting cements and one conventional zinc phosphate cement.

Correspondence should be addressed to: Dr odont. Asbjørn Jokstad, Department of Prosthetic Dentistry, Dental Faculty, University of Oslo, P.O. Box 1109 Blindern, N-0317 Oslo, Norway.
*Present address: College of Dentistry, University of Florida, PO Box 100415, Gainesville, FL 32610-0415, USA.

MATERIAL AND METHODS

The aim, clinical study design and procedures to be used were described in a protocol issued to three Scandinavian general practitioners in 1983. The study was designed according to the guidelines for clinical evaluation of dental materials endorsed by the American Dental Association[18], and had been used in a previous clinical study[10]. The protocol gave instructions on the choice of patients, abutment teeth, clinical procedures, clinical evaluation criteria and other technical details.

The patients were regular patients attending general practices in Scandinavia. They were considered to represent 'average' rather than selected patients. Both vital and root-filled teeth could be used as abutments and the latter were restored with a separate cast dowel and core before the final preparation and impression. All abutment teeth had occluding antagonists. The dentists were to maintain their daily clinical routines, including the use of impression materials. However, it was stressed that the powder–liquid ratios, mixing time and handling of the luting materials were to follow the manufacturers' instructions. The three dentists did not carry out any further calibrations for the clinical procedures and clinical evaluations.

All abutment teeth were temporized during the period between preparation and cementation of the prostheses. The temporary restorations were cemented with Nobetec, a zinc-oxide eugenol-based cement (Astra, Södertälje, Sweden).

For the final cementation, three luting materials were used; a zinc phosphate cement, De Trey Zinc Zement Improved (De Trey, Zürich, Switzerland) batches BJ31 83/01 (liquid) and CC35 83/05 (powder) and two glass ionomer cements. One glass ionomer cement consisted of a 10% tartaric acid solution in water and freeze-dried powder consisting of a blend of a copolymer of acrylic and maleic acids with an aluminosilicate glass; Ketac Cem (Espe GmbH & Co., Seefeld, Germany) batches I 082 (liquid) and I 153 (powder). The other glass ionomer cement consisted of a liquid copolymer of polyacrylic and itaconic acids and powder consisting of aluminosilicate glass; Fuji Ionomer (GC Dental Industrial Corp., Tokyo, Japan) batches 016012 (liquid) and 120321 (powder). The decision as to which cement to use was made at random. The cement mixing procedures were carried out manually. Zinc phosphate cement was mixed on a cold slab by adding small increments to the liquid. The glass ionomer cements were mixed by dividing the powder into two halves. Once the first half had been fully incorporated in the liquid, the second half was added and mixing completed. Before cementation, the retainers were controlled for passive fitness on the abutment teeth. The abutment teeth were cleaned with a slurry of pumice, isolated with cotton rolls and air dried, and the retainers seated with finger pressure. The dentine was not preconditioned with polyacrylic acid when a glass ionomer cement was used. Excess luting material was removed after setting.

The abutment teeth were examined clinically by the dentists for possible defects 1 week after cementation, after 6 months and then subsequently each year up to 10 years. The recall examinations included recordings of the patients' dental status, and, when necessary, calculus removal, routine restorative therapy and oral hygiene remotivation. The examination was carried out with the patient in the operatory chair with the teeth being examined in the routine clinical manner with the help of a mirror, sharp probe (Maillefer explorer no. 6), good lighting, and blasts of air. Criteria for failures were retention-loss or fracture of the retainer, secondary caries, tooth fracture, poor aesthetics and pain to percussion. The vitality of the abutment teeth were assessed by testing with heat/cold or with a pulp tester, and by periapical radiographic evaluation. Finally, a questionnaire was completed by the dentist recording the subjective opinion of the patient concerning postoperative abutment tooth sensitivity and general satisfaction with the prosthesis.

The service period of the abutment teeth was defined as the number of years between cementation and the time of a defect to occur. In case of patient dropout, the date of the last observation at which the fixed prosthesis was assessed as satisfactory was recorded. The data for the crowns and bridges were pooled since it was considered that the potential effects of differences in clinical stresses would not be significant during the first 10 years after cementation. The estimated survival of the abutment teeth, i.e. abutment tooth remaining intact, was computed using Kaplan-Meyer's non-parametric estimations[19].

RESULTS

The three dentists prepared, between July 1983 and February 1985, 135 abutment teeth in 61 patients to retain 81 fixed prostheses. Dentist no. 1 placed 14 prostheses in 13 patients, dentist no. 2, 18 prostheses in 13 patients, and dentist no. 3, 103 prostheses in 35 patients. A few prostheses provided in the later part of the study were lost due to patient drop out or abutment tooth failure. Thus, all the abutment teeth in the present study were observed for 10 years.

The prostheses were either single crowns or bridges with up to 11 units, and were made from gold–resin ($n = 62$) or metal–ceramic ($n = 73$) combinations of materials. At the time of cementation, 86 abutment teeth (64%) were vital, while 49 were root-filled. The proportions of vital abutment teeth varied with the size of the prostheses. Thus, only 11/43 (26%) abutment teeth for single crowns were vital, while the proportions of vital abutment teeth included in the bridges were 38/48 (79%) in the three-unit-, 19/22 (86%) in the

four-unit- and 18/22 (82%) in the larger-than-four-unit-bridges. The time span between preparation and cementation varied between 2 and 4 weeks.

At the 10-year observation, 57 abutment teeth (42%) retaining 33 prostheses remained intact. During the observation period, 31 abutment teeth (23%) retaining 16 prostheses exhibited some defect. Patient drop out accounted for the loss of 47 abutment teeth (35%) retaining 22 prostheses. Non-parametric survival estimations indicate 80% (s.e. = 4%) survival of the abutment teeth, i.e. remaining intact, after 5 years, and 71% (s.e. = 6%) survival after 10 years (*Table I*).

Post-operative hypersensitivity was recorded in five abutment teeth at the 1-week examination. All five teeth had been restored using a glass ionomer luting cement, either Fuji Ionomer ($n = 4$) or Ketac Cem ($n = 1$). In one tooth, the hypersensitivity persisted for 1 year. In the four other teeth, the late sequelae were necrosis after 1 year in one tooth, caries after 4 years in two teeth, while one tooth remained hypersensitive throughout the study.

The defects on the abutment teeth were either secondary caries ($n = 21$) or necrosis ($n = 5$). No prostheses were remade due to esthetic reasons, and no fractures of either the abutment teeth or the prostheses were observed. Secondary caries on more than one abutment tooth was observed in four patients. These four patients accounted for 12 of 21 (60%) abutment teeth with secondary caries (*Table II*, patient nos 1–4). In patient no. 1, a bridge with three pontics and eight retainers, became loose after 6 years. Before the loss of the bridge, secondary caries had been diagnosed on one abutment tooth after 1 year and on two other abutment teeth after 4 years. It was assumed that this particular bridge had never been properly cemented and/or had inadequate initial marginal fit. Patient no. 2 became seriously ill after 4 years and abandoned all oral hygiene habits. One consequence was the development of secondary caries on five abutment teeth in two four-unit bridges retained with Ketac Cem.

The failed abutment teeth in the first two patients were ignored in the further analyses of a possible relationship between defects and other clinical factors identified in the present study (*Table II*), due to the special situations that led to these abutment tooth failures.

After excluding the first two patients, the estimates of intact abutment tooth survival increased to 85% (s.e. = 4%) and 81% (s.e. = 5%) survival after 5 years and 10 years, respectively.

The vitality and intraoral distribution of the abutment teeth are shown in *Table III*. The defective abutment teeth do not seem to be associated with any specific intraoral location or tooth vitality. Also, the association with the operator or size of the prosthesis seemed negligible (*Table IV*). Furthermore, the material used in the retainer did not seem to influence the risk of defects on the abutment teeth. Finally, the distribution of intact, defect and lost abutment teeth was comparable among the three luting materials (*Table V*). Thus, the estimated survival of the abutment teeth did not differ significantly among the three luting materials (*Fig. 1*).

DISCUSSION

The present study design is not experimental, which limits the possibility to determine any cause–effect relationships between the observed defects on the abutment teeth and the different clinical variables. Furthermore, extrapolating the observations in the present patient sample to other populations should be made with caution. The value of the present study is that the results give an indication of the clinical performance of dental materials when the dental service is provided by dentists in general practice. There is consensus that such data are lacking in the dental literature[20], in contrast to clinical data derived from trials carried out in dental school environments. In these

Table I. Actuarial life table for 135 abutment teeth in the present study

Period (months)	Abutments entering period (no.)	Defective abutment teeth (no.)	Lost abutment teeth (no.)	Cumulative proportion (survival)	Std. error cumulative proportion (survival)
0–12	135	2	13	0.98	0.01
13–24	120	0	4	0.98	0.01
25–36	116	1	3	0.98	0.01
37–48	112	12	5	0.87	0.03
49–60	95	7	4	0.80	0.04
61–72	84	5	5	0.75	0.05
73–84	74	0	0	0.75	0.05
85–96	74	0	4	0.75	0.05
97–108	70	0	1	0.75	0.05
109–120	69	4	8	0.71	0.06

Table II. Characteristics of the defective abutment teeth ($n=31$) after 10 years observation

Tooth	Dentist no.	Material	Luting material	Retainer Type	Units	Age (years)	Defect	Patient no.**
24	3	Gold–resin	Fuji I	Full crown	5	1	Necrosis*	
47	3	Gold–resin	Zn-phos	Core/post	11	1	Caries	1
26	2	Metal–ceramic	Ketac Cem	Full crown	1	2.5	Necrosis	
37	3	Metal–ceramic	Zn-phos	Full crown	3	3.5	Caries	
44	3	Metal–ceramic	Zn-phos	Full crown	3	4	Caries	
21	3	Metal–ceramic	Fuji I	Core/post	3	4	Caries	3
12	3	Metal–ceramic	Fuji I	Full crown	3	4	Caries*	3
45	3	Metal–ceramic	Ketac Cem	Core/post	1	4	Caries	
23	3	Metal–ceramic	Ketac Cem	Full crown	3	4	Caries*	
23	3	Gold–resin	Ketac Cem	Full crown	4	4	Caries	
45	2	Metal–ceramic	Zn-phos	Core/post	1	4	Caries	
23	3	Gold–resin	Fuji I	Full crown	8	4	Necrosis	
46	3	Gold–resin	Zn-phos	Full crown	11	4	Caries	1
44	3	Gold–resin	Zn-phos	Full crown	11	4	Caries	1
34	3	Gold–resin	Zn-phos	Full crown	4	4	Necrosis	
45	3	Gold–resin	Zn-phos	Full crown	3	4.5	Necrosis	
36	3	Metal–ceramic	Ketac Cem	Full crown	4	4.5	Caries	2
44	3	Metal–ceramic	Ketac Cem	Full crown	4	4.5	Caries	2
33	3	Metal–ceramic	Ketac Cem	Full crown	4	5	Caries	2
46	3	Metal–ceramic	Ketac Cem	Core/post	4	5	Caries	2
22	3	Gold–resin	Fuji I	Core/post	1	5	Caries	
11	3	Metal–ceramic	Zn-phos	Core/post	3	5	Caries	4
45	3	Gold–resin	Zn-phos	Core/post	11	6	Loss	1
42	3	Gold–resin	Zn-phos	Full crown	11	6	Loss	1
41	3	Gold–resin	Zn-phos	Full crown	11	6	Loss	1
32	3	Gold–resin	Zn-phos	Full crown	11	6	Loss	1
33	3	Gold–resin	Zn-phos	Full crown	11	6	Loss	1
47	3	Metal–ceramic	Ketac Cem	Full crown	4	9	Caries	2
21	3	Metal–ceramic	Zn-phos	Full crown	3	9.5	Caries	4
45	1	Metal–ceramic	Zn-phos	Full crown	3	10	Caries	
21	1	Metal–ceramic	Zn-phos	Full crown	1	10	Caries	

*Post-operative hypersensitivity.
**Note secondary caries developed on abutment teeth of the same bridge at different time intervals.

studies, the operators, the working environment, the patients and the size and intraoral location of the restorations are controlled, which reduces confusion when comparing different materials or products. However, the data from such studies do not reflect the situation in the 'real-world' dental practice[21,22], and are especially apparent when technique-sensitive materials are involved[23].

Variables that may account for clinical failures that were not assessed in the present study include geometrical configuration of the abutment tooth[3,4], the cement film thickness[24], and prosthesis design[25]. Finally, the precision of the clinical evaluation at the recall examinations can be questioned, since this was done by the same dentist who had cemented the prostheses. On the other hand, this is offset by the long observation period, which allows a long-term assessment of possible undetected clinical failures that may have developed during the earlier stages of the study.

Several investigators have attempted to estimate the success of crown and bridge therapy in terms of survival rates or median ages of failed prostheses[3,4,11]. The estimates vary markedly, which may reflect study designs, patient, operator and evaluator differences,

Table III. The location of defective abutment teeth ($n=18$), and initial pulp vitality and intraoral distribution of the abutment teeth at the time of cementation ($n=135$)

Maxilla						
	Incisor	*Cuspids*	*Bicuspids*	*Molars*	*Sum*	
Vital	21 (3)	14 (3)	14 (1)	6 (1)	55 (8)	
Avital	20 (3)	4	6	4	34 (3)	89 (11)
Mandible						
	Incisor	*Cuspids*	*Bicuspids*	*Molars*	*Sum*	
Vital	6	4	10 (4)	12 (1)	32 (5)	
Avital	1	1	9 (2)	3	14 (2)	46 (7)
Sum	48	23	39	25		

Table IV. The location of defective abutment teeth ($n=18$) in relation to the dentists and size of the prostheses at the time of cementation ($n=135$)

	Single crowns	*Bridges**			
		3 units	*4 units*	*5–6 units*	*> 6 units*
Dentist 1:	14 (2)				
Dentist 2:	14 (1)	4 (1)			
Dentist 3:	15 (2)	44 (8)	22 (2)	6 (1)	16 (1)

*24 three-unit, nine 4-unit, two 5- and 6-unit, three 7–11-unit bridges.

and criteria for success and failures. Most of these clinical studies have focussed mainly on the performance of the prostheses, and less on the prognosis of the abutment teeth. Data on the performance of prostheses are of particular interest for cost–benefit analyses, but the fate of the abutment teeth is also of prime interest. The survival rate, defined in the present study as no further treatment of the abutment teeth, was 80–85% after 5 years and 71–81% after 10 years, figures varying depending on whether two patients were included in the study. These estimates are in accordance with other studies[3]. However, from the above discussion, it can be inferred that comparing the survival rate of the abutment teeth in the present study to survival data on prosthetic constructions may be unjustified.

There are diverging opinions about the potential of different luting materials to cause post-cementation hypersensitivity. Previous data suggested that glass ionomer luting cements frequently caused post-operative hypersensitivity[26]. However, later reports have shown that the frequencies are similar for zinc phosphate- and glass ionomer luting cements[12,27]. The 6% post-operative hypersensitivity in the present study was somewhat low compared to that of other reports[3,27]. It is possible that the different incidences reflect the time requirement for fabrication of the prosthesis[17].

It has been reported that the hypersensitivity usually resolves after a few weeks[16,27]. In the present study, however, further damage developed in at least three teeth, which suggests that the post-operative hypersensitivity in these cases could have been due to initial poor seating or lack of cement obturation. It is well established that erratic film thickness and inferior physical properties may sometimes occur when using glass ionomer cements, due to the cements' difficult handling characteristics[1,9,15,24,28].

The defects on the abutment teeth were primarily secondary caries (21 of 88 teeth or 25%) and necrosis (five of 88 teeth or 6%). The observation that secondary caries is the most common reason for failure of fixed prostheses is in general agreement with other clinical studies[3,4]. The frequency of necrosis is in accordance with some clinical studies[29], but in contrast with others[16,28]. There were no recordings of replacement due to technical failures of the prostheses or fracturing of the abutment teeth, which contrasts other clinical studies[3,4]. However, part of the explanation may be that previous clinical studies have focussed on the reasons for removal of bridges or complications with prosthetic appliances[3,4], instead of focussing on the abutment teeth.

Reasons for abutment tooth failures vary undoubtedly with time, e.g. retention losses occur primarily after 10 years. Therefore, even the present 10-year observation period is really too short to truly detect real differences in cement retention properties. However, longitudinal clinical studies extending for more than 10 years are rare, due to cost, logistic and practical reasons[3]. Unfortunately, the data in the present study cannot predict the failure reasons during the next decade.

Except for the one 11-unit bridge that failed, no retention losses were recorded during the observation period. This is a significantly better result than that in other long-term clinical studies[3,4]. It is uncertain if the retention loss of this particular bridge occurred because of incorrect seating initially, inadequate handling of the luting material, poor geometrical configuration of the abutment teeth or a weakening effect due to

Table V. The clinical status of the abutment teeth at the 10 years' observation in relation to the luting material employed

Luting material	*Original number*	*Lost patient drop out*	*Abutment teeth*	
			Defective	*Intact*
Zn-phosphate cement	52	17 (33%)	17 (33%)	18 (34%)
Ketac Cem	41	17 (41%)	9 (22%)	15 (37%)
Fuji ionomer	42	13 (31%)	5 (12%)	24 (57%)
Sum	135	47 (35%)	31 (23%)	57 (42%)

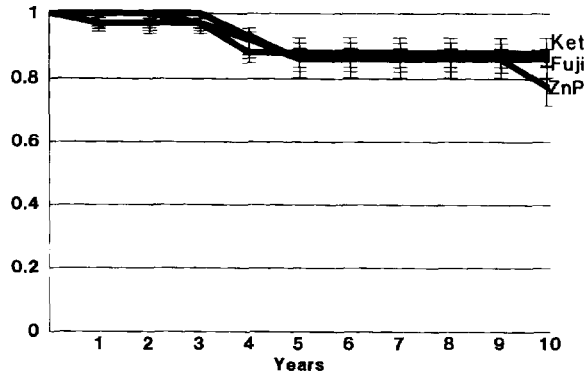

Fig. 1. The proportions of abutment teeth remaining intact, estimated by survival statistics, restored with prostheses cemented with zinc phosphate cement (ZnP), Ketac-Cem (Ket) and Fuji I (Fuji). The vertical axes denote the standard error.

secondary caries on three of the abutment teeth. It seems inappropriate to associate the failure to a specific luting material, which, in this particular case, was the zinc phosphate cement.

No single etiologic factor causing defects on the abutment teeth was identified. An exception was perhaps the patient caries incidence. The patient with the five carious abutment teeth (*Table II*, patient no. 2) was diagnosed with Parkinson's disease after 4 years, and abandoned any oral hygiene habits. The result was a dramatic deterioration of the patient's oral status. The development of secondary caries along the retainers shows that the anticariogenic effects of the fluorides in the glass ionomer luting cements may be insufficient under unfavorable conditions. However, the characteristics of 'unfavorable conditions' for glass ionomer cements are not known in detail. Evidently, excessive accumulation of plaque and frequent low intraoral pH-values will cause both hard tissue demineralization and erosion of luting materials. However, to which degree erosion of luting cement occurs in patients with adequate oral hygiene remains uncertain. It is also probable that the film thickness of the luting material is an important factor in this context[1,2,24].

Previous studies have shown a similar or better clinical performance of glass ionomer cement compared to the performance of zinc phosphate cement[11,15,17]. The present study supports these findings, as the frequencies of defective abutment teeth were comparable when glass ionomer and zinc phosphate cements had been used. Thus, within the limitations of the present clinical study, it may be concluded that during the first 10 years after cementation, the prognosis of abutment teeth restored with fixed prostheses is equally good, whether retained by a glass ionomer or a zinc phosphate luting cement.

Acknowledgements

The authors would like to thank Dr K. Malmestrand, Sweden, Dr T. Rantanen, Finland and Dr A. Wodschow, Denmark for the time and effort devoted to this clinical study.

References

1. Øilo G. Luting cements: a review and comparison. *Int Dent J* 1991; **41**: 81–88.
2. Phillips RW, Swartz ML, Lund MS, Moore BK, Vickery J. In vivo disintegration of luting cements. *J Am Dent Assoc* 1987; **114**: 489–492.
3. Leempoel PJ. *Levensduur en nabehandelingen van kronen en conventionelle bruggen in de algemene praktijk*. Dissertation. Universiteit Nijmegen, Holland. 1987.
4. Glantz PO. The clinical longevity of crown-and-bridge prostheses. In: Anusavice KJ, ed. *Quality evaluation of dental restorations*. Chicago: Quintessence Publishing Company, 1989: 343–354.
5. Brauer D, White EE, Mashonas MG. The reaction of metal oxides with o-ethoxy benzoic acid and other chelating agents. *J Dent Res* 1958; **37**: 547–551.
6. Smith DC. A new dental cement. *Br Dent J* 1968; **124**: 381–384.
7. Wilson AD, Crisp S, Lewis BG, McLean JW. Experimental luting agents based on the glass ionomer cements. *Br Dent J* 1977; **142**: 117–122.
8. Smith DC. Dental cements. *Curr Opin Dent* 1991; **1**: 228–234.
9. Knibbs PJ, Plant CG, Shovelton DS. The performance of a zinc polycarboxylate luting cement and a glass-ionomer luting cement in general dental practice. *Br Dent J* 1986; **160**: 13–15.
10. Dahl BL, Gjeitanger R, Ørstavik D, Øilo G. Clinical study of two luting agents used on student-treated patients. Final report. *Dent Mater* 1986; **2**: 269–271.
11. Black SM, Charlton G. Survival of crowns and bridges related to luting cements. *Restorative Dent* 1990; **6**: 26–30.
12. Klausner, PJ, Brandau HE, Charbeneau GT. Glass-ionomer cements in dental practice: a national survey. *Oper Dent* 1989; **14**: 170–175.
13. Reinhardt JW, Swift Jr EJ, Bolden AJ. A national survey on the use of glass-ionomer cements. *Oper Dent* 1993; **18**: 56–60.
14. Mount GJ. In vivo performance of polyalkenoate cements. In: Correlation between in-vitro and in-vivo performance of dental materials. *Transact Acad Dent Mater* 1988; **2**: 126–133.
15. Knibbs PJ, Walls AW. A laboratory and clinical evaluation of three luting cements. *J Oral Rehabil* 1989; **16**: 467–473.
16. Brackett WW, Metz JE. Performance of a glass ionomer luting cement over 5 years in a general practice. *J Prosthet Dent* 1992; **67**: 59–61.
17. Pameijer CH, Nilner K. Long-term clinical evaluation of three luting materials. *Swed Dent J* 1994; **18**: 59–67.
18. ADA, American Dental Association. In: Wychoff HD, Weigl DG, eds. *Clinical evaluation of dental materials*. Bethesda: National Institutes of Health Publication No. 80–117, 1980.
19. Kaplan E, Meier P. Nonparametric estimation from incomplete observations. *J Amer Statist Assoc* 1958; **53**: 457–481.
20. NIDR, National Institute of Dental Research. *Broadening the scope, long range research plan for the nineties*. US Department of Health and Human Services, Bethesda: National Institutes of Health Publication No. 90–1188, 1990.

21. Stanford JW. Future of materials and materials research. *Adv Dent Res* 1988; **8**: 187–192.
22. Tyas MJ. Dental materials science — the maintenance of standards. *J Oral Rehabil* 1992; **18**: 105–110.
23. Anusavice KJ. Criteria for selection of restorative materials: Properties versus technique sensitivity. In: Anusavice, KJ, ed. *Quality evaluation of dental restorations*. Chicago: Quintessence Publishing Company, 1989: 15–56.
24. Kern M, Schaller HG, Strub JR. Marginal fit of restorations before and after cementation in vivo. *Int J Prosthodont* 1993; **6**: 585–591.
25. Selby A. Fixed prosthodontic failure. A review and discussion of important aspects. *Austral Dent J* 1994; **39**: 150–156.
26. ADA, American Dental Association. Council on Dental Materials, Instruments and Equipment. Reported sensitivity to glass ionomer luting materials. *J Am Dent Assoc* 1984; **109**: 476.
27. Johnson GH, Powell LV, Derouen TA. Evaluation and control of post-cementation pulpal sensitivity: Zinc phosphate and glass ionomer luting cements. *J Am Dent Assoc* 1993; **124**: 39–46.
28. Wasson EA, Nicholson JW. Effect of operator skill in determining the physical properties of glass-ionomer cements. *Clin Mater* 1994; **15**: 169–172.
29. Jackson CR, Skidmore AE, Rice RT. Pulpal evaluation of teeth restored with fixed prostheses. *J Prosthet Dent* 1992; **67**: 323–325.