NATIONAL BUREAU OF STANDARDS REPORT

9611

Progress Report

on

A LABORATORY AND CLINICAL COMPARISON OF SILICATE CEMENTS AND OF A DIRECT FILLING RESIN, WITH AND WITHOUT FUSED SILICA

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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A LABORATORY AND CLINICAL COMPARISON OF SILICATE CEMENTS AND A DIRECT FILLING RESIN, WITH AND WITHOUT FUSED SILICA

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A LABORATORY AND CLINICAL COMPARISON OF SILICATE CEMENTS AND OF A DIRECT FILLING RESIN, WITH AND WITHOUT FUSED SILICA

R. L. Bowen, G. C. Paffenbarger and A. L. Mullineaux

Two silicate cements showing a difference of about 0.7 percent solubility and disintegration in distilled water for 24 hours, showed approximately the same durability in clinical service during a four-to-six year period. There was more disintegration in the interproximal areas of the silicate restorations than there was in the self-cleansing areas.

An experimental reinforced resin gave sufficiently good results to warrant further clinical investigations of more recent and perhaps better composite formulations. Both unreinforced and reinforced resin materials appear to benefit from the use of a primer or "cavity seal."

1. INTRODUCTION

A comparison is being made of the clinical durability of two brands of silicate cements. These cements had different solubilities when tested as described in the American Dental Association Specification No. 9 for Dental Silicate Cement.[1] One of these cements, which is referred to as silicate cement "C," had a solubility and disintegration at 24 hours in distilled water of 1.1 percent, over twice that of another cement, which is referred to as silicate cement "D." The primary purpose of the clinical testing was to determine whether this difference in 24-hour solubility in distilled water would be reflected in clinical durability of the silicate cements.

Somewhat later, the project was broadened to include restorations made with a commercially available direct filling resin and a composite material made by mixing the monomer of the direct filling resin with powdered fused silica, which had been treated with a silane coupling agent.

2. MATERIALS

Both silicate cements (C and D) complied with the requirements of American Dental Association Specification No. 9, which at that time, had the maximum permissible solubility and disintegration at 24 hours in distilled water set at 1.4 percent by weight. This value was reduced to 1.0 percent in second revision of the specification adopted in 1962. Some of the properties of silicate cements C and D are given in Table 1.

The proprietary direct filling resin (Sevriton®)* consisted of a monomer which was assumed to be predominately methylmethacrylate, an accelerator (para-toluene sulfinic acid or one of its derivatives), and a polymer powder, presumably containing benzoyl peroxide as the initiator for polymerization of the monomer. A "cavity seal" was supplied and recommended by the manufacturer for use in the cavity prior to the insertion of the resin.

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*Some commercial materials and equipment are identified to specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that material or equipment identified is the best available for the purpose.

The reinforced direct filling resin contained the same proprietary monomer and catalyst. However, in place of the proprietary polymer powder, powdered fused silica was used. This silica powder had been treated with 0.9 percent of vinyltrichlorosilane as a coupling agent in bonding the inert fused silica powder to the resin binder. Benzoyl peroxide (1.2 percent), an initiator for polymerization of the proprietary monomer, was added to the treated silica powder.

Further description of the resin and reinforced resin is given in a previous publication.[2] Data on a few of the properties of the resin and reinforced resin are given in Table 2.

3. METHODS

Seventy-four silicate cement and twenty-four direct filling resin and reinforced resin restorations were placed, with few exceptions, in proximal surfaces of adjacent teeth as illustrated in Figures 1.A and 2.A.

One-half of the amount of powder and liquid (0.75 Gm of powder and 0.2 ml of liquid) required to produce a mix of standard consistency of each silicate cement was used in making the mixes. A calcium hydroxide-containing cavity liner was placed on the pulpal walls of most of the cavities prepared for the silicate cement restorations. The cavity seal was used on some but not all of the cavity preparations that were to receive the resin or reinforced resin materials. It was used on both (or neither) of the cavities that were side by side for direct comparison of restorations.

In every case, the matrix was not removed until ten minutes from the time the mix was started. After 24 hours, the fillings were finished down approximately to the margins and polished. The clinical evaluations were made by two dentists soon after the restorations had been dressed down. In some instances, the patients could not return until several weeks after the placements for the finishing and the original inspection.

The evaluations included clinical observations of the surface contour,

appearance, and color and the conditions of the margins with respect to flushness, apposition, and staining. The rough qualitative degrees of assessment are given in columns 3, 6, 9, 12, 15 and 18, respectively, in Table 3. No common criteria were developed. Instead each observer used his clinical judgment just as if he were an indepent, private practitioner.

Color photographs were taken in duplicate. One or more impressions were made with a poly-sulfide rubber impression material. Permanent casts were prepared using a white "dental stone." The patients were recalled at intervals of about one year, and the restorations were re-evaluated. At the last evaluation (just before this report was prepared), the restorations were four to six years old. At this last examination, each restoration was evaluated in terms of the question, "should this restoration be replaced at this time?." Furthermore, each pair of restorations was evaluated as to which of the two was better in general appearance and condition.

The summed scores of the two evaluators were, for the most part, converted into percentages. Where this was not feasible, the summed scores were divided by two to correspond to restorations. Fractional numbers are due to different evaluations by the two observers.

4. RESULTS AND DISCUSSION

The qualitative clinical evaluations are given in Tables 3 and 4. The change in the conditions of some of the restorations is shown in Figures 1 and 2.

Surface contour. There was no apparent difference in the loss of substance from the two silicate cements having different solubilities in water. The resins and reinforced resins were definitely better than the silicate cements. There was little, if any, difference between the two types of plastic restorations (columns 3, 4, 5 - Tables 3 and 4).

The amount of solubility and disintegration of each silicate cement restoration varies with the location of different parts of the restoration. As has been pointed out[3] the self-cleansing areas have little attack while the areas of the restorations which are not self-cleansing are severely attacked. Some of the loss in the self-cleansing areas may have been caused by abrasion. Fluid exchange with the saliva

would be at a minimum on those areas of the restorations where severe erosion occurred; these areas were associated with food debris and materia alba. Abrasion and wear would also be minimal in such sheltered areas of the restorations.

Thus the disintegration of the silicate cements resembled dental decay more than a straightforward solubility in the main stream of oral fluids. In other words, the solubility required a very specific and localized biological milieu. Therefore to determine the cause or mechanism of the decomposition of silicate cements in their oral setting, might be as difficult as to determine the mechanism of dental caries.

Surface appearance. After four years, nearly half of the silicates presented roughened surfaces. The resins retained their smooth surfaces, while the surfaces of about 15 percent of the reinforced resins became rough in four years.

Surface color. Only one shade (21) of silicate cement was used which accounts for the degree of matching as shown by original inspections as given in columns 9 and 10 of Tables 3 and 4. The data show that the cement D with the least solubility in water is not necessarily more resistant to discoloration than cement C with more than twice the water solubility of D (columns 9, 10 and 11 of Tables 3 and 4).

Flushness of the margins. There is virtually no difference between the "high" or "low" solubility silicate cement restorations as far as maintenance of the evenness or flushness of the margins. The silicate cements did not seem to hold up as well as the reinforced resin restorations (columns 12, 13 and 14 of Tables 3 and 4).

Apposition of the margins. If a dental explorer would catch at the margin when drawn in both directions, this was recorded as a gap or notch at the margin.

As reflected in columns 15 and 16 in Tables 3 and 4, there was poor apposition in many instances when the restorations were evaluated the first time. The situation went from bad to worse in time with the silicate cements. The reinforced resin restorations had the best ranking with respect to apposition over the time period observed.

Staining at the margins. All of the silicate cements and the resins showed a tendency to become somewhat stained at the margins during four years of service in the mouth (columns 18, 19, 20 in Tables 3 and 4).

When the proprietary cavity seal was used as directed by the manufacturer, there appeared to be relatively better adaptation and less staining of the margins. The clinical impression was that this was the case with both the resin and reinforced resin materials.

Length of serviceability. The question "Should this restoration be replaced at this time?" was asked at the final inspection. The tabulated replies to this question are given in Table 5. Sixty-four restorations of silicate cement and twenty-four resin restorations were available for the final inspection. About 42 per cent of the silicate cement restorations needed replacement in from 3-1/2 to 6-1/2

years. Cement C ("high solubility") had as good a length of service as cement D ("low solubility"). The resin and reinforced resin restorations had about 4 per cent that needed replacement after 4 to 5 years. No recurrent decay was detected at the margins of any of the restorations when the teeth were observed with transillumination. However, restorations were not removed to see if there was underlying decay.

Comparison of restorations. A comparison of the general appearance of paired restorations was made at the last examination, where the restorations were in close proximity and of similar size and type. More of the silicate cement C ("high solubility") restorations were judged in better condition compared with cement D ("low solubility") restorations (Table 6). This seeming inconsistency between the "high" and "low" solubility silicate cement restorations is also reflected slightly in some of the data given in Tables 3 and 4.

In the small number of the resin and reinforced resin restorations that were compared after 4 to 5 years, there was little difference in appearance (Table 6).

5. SUMMARY AND CONCLUSIONS

Two silicate cements showing 1.1 and 0.4 percent solubility and disintegration in distilled water for 24 hours, when tested as described in American Dental Association Specification No. 9 for Dental Silicate Cement, did not show corresponding durability in clinical service. Restorations of neither of the silicate cements showed much loss of material in self-cleansing areas during 4 to 6 years of service, rather, they disintegrated in an interproximal, decay-like manner.

A reinforced resin gave sufficiently good results to warrant further clinical investigations of more recent and perhaps better composite formulations. Both unreinforced and reinforced resin materials appeared to benefit from the use of a primer of "cavity seal."

No recurrent marginal decay was detected on any of the restorations with the aid of transillumination. No restorations were removed to inspect for underlying decay.

About 42 percent of the silicate cement restorations were judged to need replacing after 5 ± 1-1/2 years. On the other hand only about 4 percent of the resin and reinforced resin restorations needed replacement after 4 ± 1 years.

REFERENCES

1. American Dental Association Specification No. 9 for Dental Silicate Cements. Guide to Dental Materials (1962-1963), American Dental Association, Chicago, Illinois, page 54.

2. Bowen, R. L. Effect of particle shape and size distribution in a reinforced polymer. JADA 69:481 Oct., 1964.

3. Henschel, C. J. Observations concerning in vivo disintegration of silicate cement restorations. J Dent Res 28:528 Oct., 1949.

TABLE 1

Properties of two silicate cements used in clinical tests

Cement		Powder	Setting time		Compressive strength	Solubility and disintegration	Opacity		Arsenic content
		Gm*	minutes		kg/cm^2	%	$C_{0.70}$		%
C†		1.55	6		1,710	1.1	45-50		<0.0002
D†		1.50	4		2,100	0.4	45-50		<0.0002
			min	max			min	max	max
ADA Specification No. 9 for Dental Silicate Cement	‡	*	3	8	1,620	1.4	35	55	0.0002
	+	*	3	8	1,700	1.0	35	55	0.0002

* Grams of powder necessary to mix with 0.4 ml of liquid to produce a mix of standard consistency (disk 25 ± 1 mm in diameter)

† Tests were conducted as described in ADA Specification No. 9 for Dental Silicate Cement First Revision (1950-1961)

‡ First revision of specification (1950-1961)

\+ Second revision of specification (1962). Same as FDI Specification No. 5 for Dental Silicate Cement

TABLE 2

Properties of a direct filling resin
with and without mineral reinforcement

Material	Resin content*	Time of hardening†	Compressive strength	Modulus of elasticity	Opacity‡	Coefficient of thermal expansion
	%	minutes	kg/cm^2	kg/cm^2	$C_{0.70}$	ppm/°C
Direct filling resin A+	99.7	6	850	21,000	45	100
Direct filling resin A reinforced with fused silica particles+	26-30	4	1,950	98,500	50	26

* Percentage by weight of material volatile at 700°C

† Interval between the beginning of the mixing and the time when a standard Gillmore needle failed to make a perceptible circle on the surface of the specimen. Test was conducted as described in FDI Specification No. 5 for Dental Silicate Cement

‡ Test conducted as described in ADA Specification No. 9 for Dental Silicate Cement

\+ Complied with color stability test in FDI Specification No. 3 for Denture Base Polymer

TABLE 2

Properties of a direct filling resin
with and without mineral reinforcement

Material	Resin content*	Time of hardening†	Compressive strength	Modulus of elasticity	Opacity‡	Coefficient of thermal expansion
	%	minutes	kg/cm^2	kg/cm^2	$C_{0.70}$	ppm/°C
Direct filling resin A+	99.7	6	850	21,000	45	100
Direct filling resin A reinforced with fused silica particles+	26-30	4	1,950	98,500	50	26

* Percentage by weight of material volatile at 700°C

† Interval between the beginning of the mixing and the time when a standard Gillmore needle failed to make a perceptible circle on the surface of the specimen. Test was conducted as described in FDI Specification No. 5 for Dental Silicate Cement

‡ Test conducted as described in ADA Specification No. 9 for Dental Silicate Cement

\+ Complied with color stability test in FDI Specification No. 3 for Denture Base Polymer

Table 3

Clinical characteristics of silicate cement and plastic restorations after four years of service

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Material	Number of restorations at 4 years	Surface contour			Surface appearance			Color			Flushness of margins			Apposition of margins			Marginal staining		
		condition	original	4 years later	condition	original	4 years later	condition	original	4 years later	condition	original	4 years later	condition	original	4 years later	condition	original	4 years later
			%	%		%	%		%	%		%	%		%	%		%	%
Silicate cement C solubility 1.1%	35	over	10	3	smooth	94	54	lighter	30	11	over	4	0	touching	90	41	none	90	49
		normal	77	34				good	61	66	even	86	24				trace	7	27
		slightly under	12	43	rough	6	46	darker	9	23	under	10	76	gap	10	59	slight	3	21
		severely under	1	20													heavy	0	3
Silicate cement D solubility 0.4%	39	over	13	7	smooth	97	54	lighter	17	1	over	4	4	touching	81	45	none	90	37
		normal	77	37				good	73	59	even	87	29	gap	19	55	trace	6	28
		slightly under	10	32	rough	3	46	darker	10	40	under	9	67				slight	1	19
		severely under	0	24													heavy	3	16
Direct filling resin A	11	over	9	0	smooth	95	100	lighter	9	0	over	23	0	touching	91	77	none	86	36
		normal	73	73				good	82	68	even	77	77	gap	9	23	trace	5	32
		slightly under	18	27	rough	5	0	darker	9	32	under	0	23				slight	9	23
		severely under	0	0													heavy	0	9
Direct filling resin A reinforced with fused silica particles	13	over	8	8	smooth	100	85	lighter	38	27	over	16	8	touching	81	85	none	77	31
		normal	77	65				good	62	61	even	69	69	gap	19	15	trace	15	42
		slightly under	15	27	rough	0	15	darker	0	12	under	15	23				slight	8	27
		severely under	0	0													heavy	0	0

Table 4

Clinical characteristics of silicatecement and plastic restorations after five years of service

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Material	Number of restorations at 5 years	Surface contour			Surface appearance			Color			Flushness of margins			Apposition of margins			Marginal staining		
		condition	original	5 years later	condition	original	5 years later	condition	original	5 years later	condition	original	5 years later	condition	original	5 years later	condition	original	5 years later
			%	%		%	%		%	%		%	%		%	%		%	%
Silicate cement C solubility 1.1%	26	over	6	4	smooth	96	54	lighter	36	23	over	0	6	touching	83	52	none	90	38
		normal	83	35				good	60	44	even	90	21				trace	6	33
		slightly under	9	34	rough	4	46	darker	4	33	under	10	73	gap	17	48	slight	4	21
		severely under	2	27													heavy	0	8
Silicate cement D solubility 0.4%	28	over	9	2	smooth	95	66	lighter	23	4	over	5	5	touching	84	46	none	84	36
		normal	77	45				good	77	46	even	86	27	gap	16	54	trace	9	23
		slightly under	12	25	rough	5	34	darker	0	50	under	9	68				slight	0	25
		severely under	2	28													heavy	7	16
Direct filling resin A	2	over	0	0	smooth	100	100	lighter	50	50	over	0	0	touching	75	100	none	100	25
		normal	25	50				good	25	25	even	100	75	gap	25	0	trace	0	50
		slightly under	50	25	rough	0	0	darker	25	25	under	0	25				slight	0	25
		severely under	25	25													heavy	0	0
Direct filling resin A reinforced with fused silica particles	5	over	0	0	smooth	100	100	lighter	60	0	over	0	20	touching	80	90	none	50	60
		normal	80	60				good	40	80	even	80	40	gap	20	10	trace	30	30
		slightly under	20	40	rough	0	0	darker	0	20	under	20	40				slight	20	10
		severely under	0	0													heavy	0	0

TABLE 5

Length of serviceability

Age of Restoration	Material	Replacement Number of Restorations*	
Years	Silicate Cement	No	Yes
4 ± ½	C	4	2
	D	5	3
5 ± ½	C	12	10
	D	12.5	10.5
6 ± ½	C	1	1
	D	2.5	0.5
TOTAL RESTORATIONS		37	27
4 ± ½	Resin	7.5	0.5
	Reinforced resin	10	0
5 ± ½	Resin	3	0
	Reinforced resin	2.5	0.5
TOTAL RESTORATIONS		23	1

* Summed scores of the two evaluators divided by two

TABLE 6

Comparisons of paired restorations

		Number of restorations*
Silicate cement restorations 5 ± 1 year old	C is better than D	16.5
	C and D are about the same	6.5
	D is better than C	8.5
Resin restorations 4-5 years old	Unreinforced resin is better than reinforced resin	3.5
	Unreinforced resin and reinforced resin are about the same	3.5
	Reinforced resin is better than unreinforced resin	3

* Summed scores of the two evaluators divided by two, resulting in fractional numbers

Fig. 1.A.: Class III restorations soon after they were placed. In the mesial of the upper left cuspid, silicate cement was used with a calcium hydroxide-containing liner; in the distal of the lateral incisor, a direct filling resin was placed following the application of a cavity seal. In the mesial of the lateral incisor is a reinforced resin restoration and in the distal of the central incisor is a direct filling resin, in both of which a cavity seal was used.

Fig. 1.B.: The same restorations after approximately four years. Note the disintegration in the interproximal of the silicate cement and the slight darkening of the other restorations.

Fig. 2.A.: Class III restorations in the mesial surfaces of central incisors soon after they were placed. In the patient's left incisor is silicate cement D. In the patient's right incisor is a reinforced resin. A calcium hydroxide-containing liner was used under each restoration.

Fig. 2.B.: The same teeth after four years and four months. The silicate cement has disintegrated badly and the reinforced resin has discolored.


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