Some Properties Of Dental Cements Of Specific Importance In The Cementation Of Orthodontic Bands*

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The use of dental cement for the attachment of orthodontic bands to the teeth was first described in the latter part of the 19th century. The cementation of bands is today a routine procedure in orthodontics. Much of the preventive, interceptive, and corrective orthodontic treatment relies upon the use of appliances retained by bands.

Probably no dental practitioner is more dependent upon the performance of dental cement than is the orthodontist, for no matter how skillfully an orthodontic band may be constructed, it will not remain on the tooth throughout its functional use without the aid of cement. In addition to the role that cement plays in attaching bands to the teeth, it has the equally important function of protecting the tooth under the band from caries. For these reasons the physical characteristics of dental cements and their manipulations are of particular interest to the practitioner of orthodontics.

Although the dental cements are relied upon by the orthodontist to such an extent, their application to orthodontics per se has received little attention in the literature. While investigations into the decalcification of enamel under orthodontic bands[3,6,7,9,10,11] and the "adhesive" forces of the cement with the band[2,13] have been made, the physical properties of the cement mixes used for band cementation have not been reported.

The preparation of a cement mix to be used for the cementation of orthodontic bands appears to be achieved rather arbitrarily. In some suggested techniques the generally accepted principles for the manipulation of cement are lacking. If the orthodontist is to obtain the optimum service from the carefully fabricated bands placed in the mouth, he must consistently produce cement mixes which possess the best possible physical properties commensurate with his requirements of clinical working time.

This study was undertaken to provide some basic data regarding the physical properties of some dental cements as they may be used for the cementation of orthodontic bands. The specific objectives of this investigation were: (1) to determine the consistency of a typical dental cement in use by practicing orthodontists which is applicable for the cementation of orthodontic bands, (2) to standardize this consistency and to establish the same consistency for some other dental cements currently used for band-cementation, (3) to determine by laboratory testing some of the physical properties resulting

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from these dental cements when mixed to this standardized consistency, (4) to evaluate the effectiveness of several methods proposed for increasing the setting time, and (5) to suggest the manner in which these data may be applied by the practicing orthodontist to his clinical practice.

Survey of Techniques

Orthodontists are generally agreed that the consistency of cement used for the cementation of orthodontic bands lies somewhere between that used for the cementation of inlays and consistency used for a cement base, and that the "best" mix for the orthodontist to use is that mix which combines the maximum amount of powder consistent with the time requirements of clinical practice. The requirements of working time for the individual orthodontist bear a direct relationship to the number of orthodontic bands that he may set with a single mix of cement. Since a wide variation exists among orthodontists with respect to the number of bands cemented with one mix, a standard consistency for cements used in orthodontics has never been defined. For the purposes of this investigation it was necessary to establish such a starting point, that is, a cementing consistency which was applicable for the cementation of orthodontic bands. In order to achieve this first objective a modification of the survey technique used in establishing the zinc phosphate and silicate cement specifications was employed.

This modified technique consisted of a survey of thirteen practitioners of orthodontics to ascertain their manner of manipulation of cement and the consistency used by them for the cementation of orthodontic bands. This survey was accomplished through the use of a questionnaire directed to each of the practitioners in order to gather some general information regarding the cementation of bands in their practices. A quantitative observation was also made of the actual mixing procedure employed by each of these practitioners.

A single dental cement [Stratford-Cookson] which was currently being used by all the practitioners was selected for the survey. The cement powder was weighed and stored in gelatin capsules with each capsule containing 1.5 grams. The practitioner dispensed the liquid in a normal fashion from the dropper supplied by the manufacturer. This dropper had been previously calibrated so that each drop dispensed with the lumen parallel to the slab surface contained 0.036 ml of liquid. The cement mixes were made on a standard 6x3x¾ inch smooth glass slab using a number 324 S.S. White Tarno spatula. Each of the practitioners was asked to make five trial mixes of the cement to the consistency used for cementing an average number of orthodontic bands, which according to this survey was four. The practitioner was free to manipulate the powder and liquid in any manner desired. Observations were recorded with respect to the number of drops of liquid used, the room temperature and relative humidity at the time of the mix, and whether a cooled mixing slab was used. The total time of mixing, the rate of incorporation of powder, the approximate amounts of powder incorporated, and the manner of spatulation were noted. The unused powder from each mix then was weighed, and the amount of powder used in the mix, relative to the number of drops of liquid used, allowed the calculation of the powder-liquid ratio of each trial mix.

From the powder/liquid ratios and mixing times recorded for each practitioner, a mean powder/liquid ratio and a mean mixing time were established for the entire sample. The cementing consistency for the zinc phosphate cement used in this survey was developed with 1.3 grams of powder and 0.5 ml of liquid. While this standard cementing consistency to be used with bands is not to be construed as necessarily representing the optimum consistency, it does represent a clinically usable mix which yields a cement possessing good clinical characteristics.

The survey revealed a considerable variation in the technique of manipulation of cement used by the different practitioners. This variability may reflect the latitude that is possible in manipulating the zinc phosphate cement as long as one adheres to the generally accepted principles of manipulation.

Materials and Method

The eight brands of dental cements used in this investigation were (A) Stratford-Cookson Zinc Cement, (B) Tenacin Cement, L. D. Caulk Company, (C) Cem Cement, L. D. Caulk Company, (D) S. S. White Zinc Improved Cement, (E) Fleck's Extraordinary Cement, Mizzy, Inc., (F) Ormco Orthodontic Cement, Atwood Laboratories, (G) Ames Crown, Bridge, and Inlay Cement, W. V-B Ames Company, and (H) S. S. White New Germicidal Kryptex Cement. The first seven of these cements were of the zinc phosphate type, and the last cement was of the silicophosphate type. Only five of the eight dental cements are certified by the Council on Dental Research of the American Dental Association. These eight products were selected for testing since they are representative of dental cements in use for cementing orthodontic bands. These cements were purchased on the open market.

Manipulation Procedure

In order to standardize the method of preparation of test specimens one technique for manipulating the zinc phosphate type cement was established,

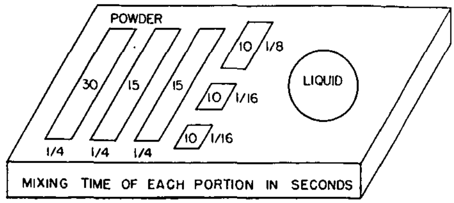

Figure 1 Mixing technique employed for zinc phosphate cement. Adapted from Paffenbarger, G. C., Sweeney, W. T., and Isaacs, Aaron. Am. Dent. A. J., 20: 1960-82, Nov. 1933.

and another for the silicophosphate cement. Each of these techniques is based on a sound, well-documented understanding of the nature of the setting reaction which occurs in each type of cement, and both techniques can be simply and conveniently applied to the clinical situation.

The one method of manipulation selected, in general, followed that recommended in the American Dental Association Specification No. 8 for Dental Zinc Phosphate Cement.[1] The preparation of the test specimens was conducted in a humidity chamber at a constant temperature of 70°F and at a relative humidity of 55%. The mixing technique employed with the zinc phosphate cements was that used by Paffenbarger, Sweeney, and Isaacs,[12] and is illustrated in Figure 1. At least one half of the total area of the slab was used in making the mix. A rotary motion of the spatula with light pressure in combination with a scraping motion which would pick up the cement and deposit it in a heap was used intermittently. The total mixing time was 90 seconds which was equal to the mean mixing time obtained from the survey of orthodontists. This standard procedure was used because considerable variation existed in the directions supplied by the manufacturers of the eight dental cements used in the study.

The mixing technique employed with the silicophosphate cement was that

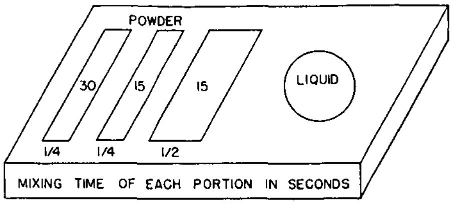

Figure 2 Mixing technique employed for the silicophosphate cement. Adapted from Paffenbarger, G. C., Schoonover, I. C., and Souder, Wilmer. Am. Dent. A. J. 25: 32-87, Jan. 1938.

specified in the American Dental Association Specification No. 9 for Dental Silicate Cement.[1] This technique is illustrated in Figure 2 and was selected because it had been previously used by other investigators working with a silicophosphate cement.

Consistency

Using the techniques of manipulation described, the orthodontic band cementing consistency established from the survey was then standardized in order that the same consistency could be used for each of the other seven dental cements to be studied. In general, this consistency was standardized in accordance with the procedure described in the American Dental Association Specification No. 8 for Dental Zinc Phosphate Cement. It was necessary, however, to modify these procedures since the original specification had been designed for a cementing consistency for cementing inlays. The equipment used to determine the consistency was comprised of a glass tube which delivered a 0.5 ml volume of mixed cement, two flat glass plates, and a 1 kg weight. A trial mix of cement was made using the mean powder/liquid ratio established from the survey (1.3 gram of Stratford-Cookson Cement/0.5 ml). Following spatulation, 0.5 ml of mixed, but unset cement, was measured into the glass tube and deposited onto a flat glass plate. Three minutes after the mix was started another glass plate and the 1 kg load was carefully placed on the soft cement. The major and minor diameters of the disk of cement thus formed were measured 10 minutes after starting the mix, and the two diameters were averaged. Ten such determinations were made and a mean disk diameter of 26.5 mm ± 1 mm was established as the standardized cementing consistency.

Results

Powder-Liquid Ratio

Using trial amounts of powder mixed with 0.5 ml of liquid, similar determinations were made on each of the other seven dental cements. Trial mixes were made on each product until the average of the major and minor diameters of the disks was within the standardized disk diameter of 26.5 mm ± 1 mm. The average of the amounts of powder used in three such determinations was the amount of powder necessary to produce a mix of standard consistency.

There was a wide variation in the powder-liquid ratios observed when the eight dental cements were mixed to the standardized consistency of 26.5 mm ± 1 mm disk diameter. From Table I it is seen that this amount of powder varied from 1.0 to 2.0 grams per 0.5 ml of liquid. This finding is in general agreement with earlier investigations and has been demonstrated[18] to be the result of differences in the specific gravity and composition of the liquid, and the particle size and composition of the powder used by the various manufacturers. While it is true for any given dental cement the more powder used up to a maximum point, the better the physical properties of the cement, this does not necessarily hold true when comparing the powder/liquid ratios of different cements. From a comparison of the eight cements mixed to the same consistency shown in Table I, it is apparent that those cements with the higher powder/liquid ratios do not necessarily reflect better physical properties.

With the powder/liquid ratio thus established for each of the eight dental cements, the next objective of the study was a comparative testing of the resulting physical properties of each product when mixed to the standardized consistency for cementing orthodontic bands. The physical properties selected for testing were those of particular clinical importance to the practicing orthodontist: setting time, compressive strength, toughness, and solubility and disintegration. The testing procedures were those used in the A.D.A. Specification No. 8 unless otherwise stated.

Setting Time

The practicing orthodontist is probably more clinically aware of the setting time than of any other physical properties of cement. The setting time is directly related to the working time and the working time of a cement is of critical importance in the cementation of orthodontic bands. Sufficient time must elapse between the mixing and the setting of the cement to allow the precise placement of the bands on the teeth. The working time requirements of each orthodontist will vary somewhat depending upon the number of bands seated with one mix of cement, and the comparative difficulty of cementing certain bands resulting from such factors as limited access and tight interproximal contacts. In the labora-

TABLE I

SELECTED PHYSICAL PROPERTIES OF EIGHT DENTAL CEMENTS MIXED TO A STANDARD CONSISTENCY

Cement	Powder in 0.5 ml. of liquid to produce std. consistency (26.5±1 mm.) (Gms.)	Average Setting Time at mouth temperature 99°F (Minutes)	Average Compressive strength at 24 hours (lbs./in.^{2})	Average Solubility and disintegration during first 7 days (Per Cent)
Stratford-Cookson Zinc	1.3	7	18,300 ± 1400	0.07
Tenacin (L. D. Caulk Co.)	1.8	6	23,400 ± 1100	0.06
Cem (L. D. Caulk Co.)	1.3	7	17,800 ± 900	0.13
S. S. White Zinc Improved	1.9	6	20,300 ± 700	0.04
Fleck's Extraordinary (Mizzy, Inc.)	1.7	6	21,400 ± 800	0.06
*Ormco Orthodontic (Atwood Laboratories)	2.0	6	21,100 ± 1100	0.13
*Ames Crown, Bridge & Inlay**	1.0	10	13,600 ± 600	2.80##
*S. S. White New Germicidal Kryptex	1.8	5	27,300 ± 2000	1.07#

* These three products are not certified according to A.D.A. specifications.

** Used with type C liquid.

Experience indicates that silicate type cements are less "soluble" in clinical service than zinc phosphate cements.

Specimens of this product evidenced crystal growth during the tests for solubility and disintegration.

tory testing procedures the total mixing time for the cement was one and one half minutes except for silicophosphate cement where the mixing time was one minute. Another one and one half minutes was allowed for preparing the test specimen prior to placing it in an environment which simulated mouth conditions. In a clinical situation this interval should allow sufficient time to fill the orthodontic bands with cement prior to placing them on the teeth.

The setting time of the eight cements mixed to the standard consistency ranged from 5 to 10 minutes as seen in Table I. It is important to understand, however, that these setting time determinations included: (1) a mixing time of 1½ minutes, except with Kryptex which was one minute, (2) the time for preparation of specimens or filling bands (1½ minutes), (3) the working time, and (4) a time period extending from the end of the "good working time" until the cement achieves an initial set, which is approximately 1½ to 2 minutes prior to the measured setting time. Therefore, the actual working time of the cement represents only a portion of the setting time. For example, the actual working time of the Stratford-Cookson cement that sets in 7 minutes may be only 2½ to 3 minutes. From a consideration of setting time values, it is seen that only the Ames Cement allowed a comparatively long working time of 10 minutes. The working times of the other cements are relatively short (5-7 minutes) and at this consistency will probably not allow for the placement of a large number of bands.

One way in which the operator can assure the maximum working time with a mix of any given consistency is to allow the filled bands to remain on the mixing slab until each band is ready to be positioned on the tooth. Since the mixing slab temperature is considerably lower than mouth temperature, the setting reaction of the cement will proceed at a slower rate than would be the case if all the bands to be set are initially placed on the teeth.

The protection of the unset cement from premature contact by saliva is of sufficient importance to deserve mention in a discussion of setting time. Control of saliva, particularly in the mandibular arch, is often a problem in the cementation of orthodontic bands. It is well established[5,14] that premature contact of the cement with saliva before it has reached the initial set results in a significantly weakened cement. It is important, therefore, that adequate precautions be taken by the orthodontist to ensure that the cement is kept dry until the initial set has taken place. In addition to the routine use of cotton rolls two suggested methods for accomplishing this goal are: (1) the use of Burlew Dryfoil and (2) the premedication of the patient with a salivary suppressant such as Pro-Banthine prior to band cementation procedures.

Compressive Strength

The testing of compressive strength for each of the eight dental cements was carried out in the manner prescribed in the A.D.A. Specification No. 8 with two exceptions. The specimens were stored at 99°F rather than room temperature, and the testing was done at the end of 24 hours rather than 7 days.

Peyton[17] has stated that the compressive strength is useful for comparing materials which are brittle and generally weak in tension. The dental cements are brittle materials and are well suited to testing in compression. However, it is questionable whether a dental cement ever fails as a result of pure compression, and it is more likely that the failure of the cement arises as the result of a complexity of forces. Peyton, however, states that when the cylindrical test specimen is subjected to stress in compression, there is a complex stress pattern consisting of compression, shear, and tension forces developed in the specimen, and that the failure of the material may occur as a result of this complex stress formation. Therefore, it can be assumed that testing in compression provides a reasonable measure of the strength properties of the cements under function.

Orthodontists are inclined to think of a shearing type force as being the most destructive with regard to the loosening of bands. Any time a structure is subjected to shearing action, however, there is a concentration of both tension and compressive forces in the material.[17] Here again is demonstrated the complexity and close interrelationship of these forces. It has been further suggested[16] that the compressive strength test provides a reasonable indication of the behavior of the material in shear, and that probably the difficulty and expense involved in designing a shear test would not result in values with any greater significance.

An objection aimed against testing samples in compression by applying a load over a relatively long period of time is that the rates of force application occurring in the mouth more closely resemble impact forces. In spite of this condition the objection is probably not a valid one since the compressive strength values obtained from the impact testing of these cements would probably be of the same order as those evaluated by the present testing procedure except that all the values would be raised.[16]

Of the eight dental cements tested, one product, S. S. White Kryptex Cement, showed a high compressive strength of 27,300 ± 2,000 psi, while one other product, Ames Cement showed a low compressive strength of 13,600 ± 600 psi. The other six dental cements were intermediate in compressive strength values, ranging from 17,800 ± 900 to 23,400 ± 1,100 psi. The compressive strength values of the cements certified under the A.D.A. Specification No. 8 are considerably higher than the values reported by the manufacturers for their cements when mixed to the consistency for cementing inlays. This difference can be attributed principally to the increased powder/liquid ratio.

A comparison of the characteristics of strength and setting time of the seven dental cements of the zinc phosphate type reveals that these two properties appear inversely related. The compressive strength is related to, among other things, the reactivity of the mixed cement mass. A slower setting cement which exhibits low reactivity also exhibits low strength.

Before any valid appraisal can be made of what constitutes significant clinical differences in compressive strengths of the products tested, it would be necessary to subject these materials to a controlled program of clinical testing. It would seem reasonable, however, that there may be significant differences under function demonstrated between cements which possess high or low compressive strength values. It is possible that the significance of these differences in compressive strength may be somewhat obscured because of the relatively short period of time the cement is in service under orthodontic bands compared to the cement under crowns, bridges, or inlays.

Toughness

The toughness of a material may be defined as a measure of the energy required for breakage and is in contrast to the strength which is the stress necessary to cause rupture. The area

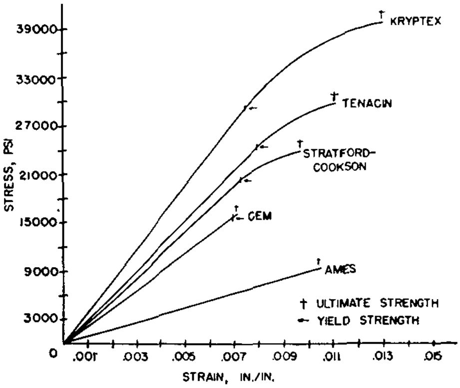

Figure 3 Stress-strain curves in compression for some typical cements used in orthodontic band cementation.

under the plots of the stress versus strain for the various cements in compression shown in Figure 3 is therefore an indication of the toughness of the material. The larger the area outlined by the three boundary lines, (1) the stress-strain curve, (2) a vertical line projected from the maximum stress to the horizontal strain axis, and (3) the intersection of the projected line and the strain axis to the zero position on the graph, the greater the toughness of the material. This area described is determined by the magnitudes of (1) the elastic modulus, the slope of the initial straight portion of the curve, (2) the yield strength, the stress at which permanent deformation occurs, (3) the compressive strength, and (4) the total deformation before rupture.

A tough cement would be desirable for use in orthodontics since it would absorb a great amount of energy from force applications without breaking. For this reason the stress-strain curves in compression were determined for the eight cements according to methods described by Craig, Johnson, and Peyton.[4] Five test cylinders, 1/8 inch in diameter and 5/16 inch in length, were prepared for each of the eight dental cements. All procedures used in their preparation were carried out under water and the specimens were stored in distilled water for 25 days at 99°F prior to testing. This time interval was selected since it was felt that storing the cements for approximately one month would give an indication of the properties after some clinical service. The elastic modulus, yield strength, and total deformation values were determined for the cements as well as the entire stress-strain curves.

The mean values for the elastic moduli of the cements ranged from $0.89 \pm 0.12 \times 10^6$ psi for Ames Cement to $3.97 \pm 0.35 \times 10^6$ psi for S. S. White Kryptex Cement. The other six cements had mean elastic modulus values from 2.15 to 2.92×10^6 psi. The mean yield strength values of the cements varied from 15,100 ± 1,100 psi to 29,500 ± 1,800 psi for S. S. White Kryptex Cement. Five of the cements had yield strength values between 19,400 and 24,800 psi. It should be pointed out that no yield strength value was reported for Ames Crown, Bridge and Inlay Cement because the stress-strain curve remained linear up to the breaking stress. The mean ultimate strengths ranged from 7,400 ± 1,700 psi for Ames Cement to 39,800 ± 5,300 psi for Kryptex Cement. In general, the compressive strengths of these small specimens were higher than those obtained on the larger specification test specimens which is in agreement with previous reports.[4,20] The lower value of 7,400 psi for Ames Cement compared with the value of 13,600 psi obtained from the specification test is probably a reflection of the high solubility of this cement and the longer storage time in water of 25 compared with 7 days. The total deformation before rupture varied from 0.71 ± 0.06 per cent for Cem cement to 1.3 ± 0.1 per cent for Fleck's Extraordinary and S. S. White Kryptex cement. Five of the eight cements had total deformation values of approximately 1.0 per cent.

Typical stress-strain curves for the cements are illustrated in Figure 3. From these curves it can been seen that all of the cements should be classed as brittle materials, particularly on the basis of the low deformation allowed before breakage occurred. There are, however, some interesting differences in the relative toughness between members of this group of materials. Compared with Kryptex cement, the area under the curve for the Ames cement is 19 per cent, for Cem it is 30 per cent, for Stratford-Cookson it is 50 per cent, and for Tenacin it is 70 per cent of the area under the curve for Kryptex cement. The other four cements had a toughness in the range between Stratford-Cookson and Tenacin.

On the basis of these data the toughest zinc phosphate cement was Tenacin. The single silicophosphate cement, however, had considerably greater toughness than any of the zinc phosphate cements tested. Further laboratory and clinical tests should be conducted in order to correlate these data with clinical observations.

Solubility and Disintegration

The solubility and disintegration of the dental cement is used as a relative measure of the resistance of the cement to the effects of oral fluids. This property is of particular importance for the cement is relied upon to fill the void between the tooth and the orthodontic band, thus preventing the formation of bacterial plaques and resultant decalcification under the band. Solubility testing, as determined in the laboratory, is carried out in distilled water rather than natural or artificial saliva. Previous investigations[12,14,15] have established the fact that the values for specimens immersed in saliva and water were very near to each other, and distilled water has been used as a medium for storing cements.

Only two of the eight cements tested had solubility and disintegration values as shown in Table I that could be considered excessive. Ames Cement had a solubility of 2.8% and evidenced crystal growth during the seven day storage in water. The solubility of S. S. White Kryptex Cement was 1.07%. While this value was within the allowable value under the specification for silicate cements, it was excessive when compared with the limit specified for the zinc phosphate cements. The remainder of the cements had solubility and disintegration values between 0.04 and 0.13%. An attempt to draw practical conclusions regarding the solubility of zinc phosphate and silicate cements from the results of laboratory testing may lead to error. While the zinc phosphate cements exhibit a much lower solubility than the silicate cements in a laboratory test using distilled water, this finding is inconsistent with the durability of the two kinds of cements in clinical service. However, the laboratory testing of a series of zinc phosphate cements should give reliable comparisons of their solubility.

On the basis of the foregoing information it seems reasonable to assume that the Ames Cement may show excessive solubility under clinical testing. It is interesting to note that this is the same product which possessed a significantly lower compressive strength than any of the other dental cements tested.

Methods to Lengthen the Setting Time

It was noted earlier that the setting time determinations on seven of the eight cements when mixed to the standard consistency ranged from 5 to 7 minutes which did not allow for a particularly long working time. It was believed that many orthodontists may prefer a longer working time if it did not result in a significant decrease in the compressive strength or solubility and disintegration properties of the cement. Since the setting time of the cement under a given set of conditions is directly related to the powder/liquid ratio, a decrease in this ratio will lengthen the setting time. The results of such a change in powder/liquid ratio as shown in Table 2 indicate that it is possible to effect a significant increase in setting time with some cements without appreciable loss in properties. Slight changes in compressive strength and solubility only hold true up to a point beyond which further decrease in powder/liquid ratio begins to significantly affect the resulting physical properties of the cement mix. It would seem that, through careful control of powder/liquid ratio, the orthodontic practitioner could appreciably lengthen the working time of the cement without jeopardizing the resulting physical properties.

Two clinical methods have been suggested for increasing the setting time without changing the powder/liquid ratio. The first method was "slaking" or the partial neutralization of liquid by the addition of a minute quantity of powder two minutes before the actual mixing. In order to test this method, approximately 1/32 of the total powder mass was added initially to the 0.5 ml of liquid. This powder/liquid combina-

TABLE II

EFFECT OF VARYING THE POWDER: LIQUID RATIO ON CERTAIN PHYSICAL PROPERTIES OF FIVE SELECTED DENTAL CEMENTS*

Cement	Powder:Liquid Ratio (Gms/0.5 ml)	Setting Time at Mouth Temperature 99°F. (Minutes)	Compressive Strength at 24 Hours (lbs/in.^{2})	Solubility and Disintegration During First 7 Days (Per Cent)
Stratford-Cookson	1.3**	7	18,300	0.07
	1.1	8	17,500	0.16
	0.9	12	8,400	2.17
Tenacin	1.8**	6	23,400	0.06
	1.6	7	21,100	
	1.4	8	20,500	0.09
	1.2	9	17,300	
	1.0	12	12.100	0.13
Ormco	2.0**	6	21,100	0.13
	1.8	6½	20,800	
	1.6	7½	20,400	0.13
	1.4	8	18,100	
	1.2	9	15,000	0.14
Ames Crown, Bridge & Inlay	1.2	7	15,900	0.86
	1.0**	10	13,600	2.80
Germicidal Kryptex	1.8**	5	27,300	1.07***
	1.6	5½	26,600	
	1.4	6½	26,300	1.50
	1.2	9	21,500	1.33

* These values represent mean values. The deviation from the mean of these values is of the same magnitude as expressed in Table I.

** Standard orthodontic band setting consistency.

*** Experience indicates that silicate type cements are less "soluble" in the clinical service than zinc phosphate cements.

TABLE III

EFFECT OF SLAKING ON SETTING TIME OF SEVEN* DENTAL CEMENTS MIXED TO A STANDARD CONSISTENCY**

Cement	Original Setting Time (Minutes)	Setting Time with Slaking (Minutes)	Amount of Change (Minutes)
Stratford-Cookson	7	7½	Gain ½
Tenacin	6	6½	Gain ½
Cem	7	7½	Gain ½
S. S. White Zinc	6	6	No Gain
Fleck's Extraordinary	6	7	Gain 1
Ormco	6	6½	Gain ½
Ames Crown, Bridge & Inlay	10	13½	Gain 3½

** Mean values.
* Did not attempt with S. S. White New Germicidal Kryptex Cement due to necessity of completing mix within 1 minute.

tion was allowed to remain undisturbed on the slab for two minutes, at the end of which time, the mixing procedure was carried to completion using the mixing technique previously standardized. Determinations of the setting time were then carried out as previously described under the testing procedures. Five trials were made for each of the eight cements.

It does not appear that "slaking" is a generally effective method for lengthening the setting time at mouth temperature of the cement mix according to Table 3. This finding is in good agreement with the observations of Henschel.[8] Only two of the eight dental cements tested showed an appreciable gain of 1 minute and 3½ minutes in setting time. The manufacturer of Fleck's Cement recommends this procedure as an effective way of increasing the setting time of their product. In the case of the Ames cement it was believed that this procedure further delayed the setting reaction of an already slow-setting cement.

The second method proposed for increasing the setting time without changing the powder/liquid ratio was cooling the mixing slab. All of the previously prepared specimens used in the setting time determinations had been made at a constant temperature of 70°F and a relative humidity of 55%. Working under these conditions, the dew point is approximately 17° below this temperature. It was arbitrarily decided to cool the mixing slab to a value of 60°F since this yielded a slab temperature comfortably above the temperature at which moisture would condense on the mixing slab. Only one product was selected for this evaluation, Stratford-Cookson Zinc Cement. The determinations of the setting times were made in the manner previously described under the testing procedures. Ten trial mixes were made, utilizing the cooled mixing slab procedure, and the mean increases in setting time were calculated. Cooling the mixing slab temperature to 60°F did not effect an appreciable increase in setting time at mouth temperature. Even though this determination was made on only one cement it is reasonable to assume that the other dental cements should behave in a somewhat similar manner. This finding is also in agreement with the observations of Henschel. It has been stated that the principal reason for cooling the mixing slab is to dissipate the heat liberated during the mixing of the cement mass and thus to retard the setting reaction of the cement. Cooling the mixing slab becomes of particular importance during the summer months when office temperatures may commonly range above 80°F. If the mixing slabs are not cooled under these conditions, one will note an appreciable decrease in setting time with any given powder/liquid ratio. Peyton[16] has suggested a good rule of thumb with regard to cooling of the mixing slab: with a constant temperature, air-conditioned office where the room remains near 70°F, it is not necessary to cool a slab; however, under conditions where the room temperature is 80°F or above, the slab should be cooled so that moisture does not condense on the surface. Under these conditions it is usually possible to cool the slab 5° to 10°F below the room temperature and still remain well above the dew point.

Recommendations for Manipulation of Cements

From a consideration of the results of the present investigation, it is readily apparent that a number of dental cements currently in use for the cementation of orthodontic bands exhibit good physical properties. These products will provide acceptable service in cementing orthodontic bands when a good standardized technique of manipulation is employed. To assist the orthodontist in establishing a proper standardized technique for the manipulation of cement, the following recommendations are made: (1) select one powder/liquid ratio for a given dental cement which will yield acceptable physical properties consistent with the clinical working time requirements; (2) employ the same powder/liquid ratio in all cement mixes regardless of the number of bands being set; and (3) adopt a standard mixing technique. Close adherence to a standardized procedure will enable the practicing orthodontist to produce consistently cement mixes possessing desirable physical characteristics.

Conclusions

(1) There are a number of dental cements currently in use for the cementation of orthodontic bands which exhibit good physical properties and which are capable of providing good service if the orthodontist disciplines himself to a standardized technique of manipulation of the cement.

(2) The best overall physical properties of the eight dental cements tested was exhibited by a silicophosphate cement, S. S. White Kryptex. One of these cements possessed properties decidedly inferior to the rest of the cements under the conditions of testing. The other six dental cements comprised a group midway between these two extremes and the range in physical properties between the products in this group was relatively wide.

(3) A substantial increase in setting time at mouth temperature without appreciably decreasing the compressive strength or increasing the solubility and disintegration can be effected with some dental cements by decreasing the powder/liquid ratio within *well-defined* limits.

(4) Neither "slaking" nor the cooling of the mixing slab temperature from 70° to 60°F were generally effective in significantly lengthening the setting

time of the cement at mouth temperature.

(5) Although there was considerable variation in the resulting powder/liquid ratio of the eight dental cements when mixed to the standard consistency for cementing orthodontic bands, those cements with the higher powder/liquid ratios did not necessarily have the better physical properties.

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