Retention Of Orthodontic Bands As Influenced By The Cementing Media*

John D. Williams, D.D.S., M.S.D.
Marjorie L. Swartz, M.S.
Ralph W. Phillips, M.S., D.Sc.
Indianapolis, Indiana

Introduction

Considerable research has been devoted to the determination of the relative "adhesiveness" or, more correctly, the retentive properties of cementing materials.

With a few exceptions these tests have been somewhat empirical in nature consisting of the cementation of flat components with subsequent measurement of the force required for separation.[1-15] However, it does seem logical that the strength requirement of the luting agent might vary with the structural form of the appliance and with its function, that is, the amount and distribution of the applied stress.

This investigation consisted essentially of measuring the amount of tensile force required to remove orthodontic bands when cemented with various agents.

Method and Materials

Freshly extracted, sound, upper central incisor teeth, as free of discrepancies as possible, were selected. The teeth were thoroughly cleaned and then buffed lightly with levigated alumina in order to provide enamel surfaces of uniform texture for the subsequent experiments. The apical third of the root was notched by means of a separating disc and this portion was embedded in a block of self-curing acrylic to serve as a base. The teeth were stored in tap water and never permitted to become dehydrated during the ensuing tests.

After considerable preliminary experimentation, the following test method was evolved. The acrylic base was held in a bench vise while seamless anterior wide bands, 0.03 inch thick, were carefully adapted to the incisal third of the crown. The bands were removed and 360° loops formed from 0.028 inch round stainless steel wire were hand soldered to each proximal surface. The band was then reseated on the tooth and the adaptation checked. If distortion had occurred, the band was either reburnished to the tooth or discarded. Again, the band was carefully teased off the tooth and by means of a flame soldering technique a layer of solder 0.5 to 1.0 millimeter thick was applied over the entire external surface. The bands were again reseated and if there was the slightest evidence of distortion they were discarded. A tooth with a band in place is shown in Figure 1.

The rigidity of these solder-reinforced bands allowed them to be repeatedly removed without tearing or perceptible distortion; hence, the same band and tooth could be used for testing all cementing agents. The variables which would be introduced through differences in the size and shape of the teeth as well as the adaptation of individual bands were thus minimized. Due to the rigidity of the bands, the selection of the particular teeth to be used was

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Figure 1 Tooth, mounted in acrylic block, with band in place.

limited to those with crowns which were parallel or converging.

Five different cements involving three classes of materials were utilized for cementation of the bands (Table I). Representative brands of a zinc phosphate, a silico-phosphate, and a zinc oxide-eugenol cement were included. Two experimental zinc oxide-eugenol materials were also tested. Both were prepared from 0.3 micron zinc oxide powder. One cement was composed only of the zinc oxide powder and eugenol, while in the second, hydrogenated rosin was added to the powder and o-ethoxy benzoic acid to the eugenol. The setting time of both cements was controlled by incorporation of 0.03 grams of zinc acetate crystals during mixing. The physical properties of all of these materials had been determined in previous studies from this laboratory.[16,17,18]

The liquid-powder ratios, shown in Table I, were established for each material by mixing trial quantities of the powders with standard volumes of the liquids until consistencies ideal for the clinical cementation of orthodontic bands were secured. All mixing was accomplished in accordance with accepted manipulative procedures.

Immediately prior to cementation the teeth were buffed lightly with levigated alumina, washed, and then carefully dried with compressed air.

The cements were applied directly to the tooth in the area which was to be banded and the band itself was filled with the cement. Firm hand pressure was used to seat the bands. The banded

TABLE I

MATERIAL	BRAND	COMPONENTS		LIQUID/POWDER RATIO
Zinc Phosphate	Tenacin L. D. Caulk Co.			1.0 ml/2.5 g
Silico Phosphate	Kryptex S. S. White Dental Mfg. Co.			1.0 ml/3.3 g
Zinc Oxide-Eugenol	Temrex Interstate Dental Co.			1.0 ml/3.0 g
Zinc Oxide-Eugenol	Experimental	Powder Liquid	Zinc Oxide Eugenol	1.0 ml/3.0 g
Zinc Oxide-Eugenol + o-Ethoxybenzoic Acid	Experimental	Powder Liquid	Zinc Oxide 90%, Hydrogenated Rosin 10% EBA 62.5%, Eugenol 37.5%	1.0 ml/3.0 g

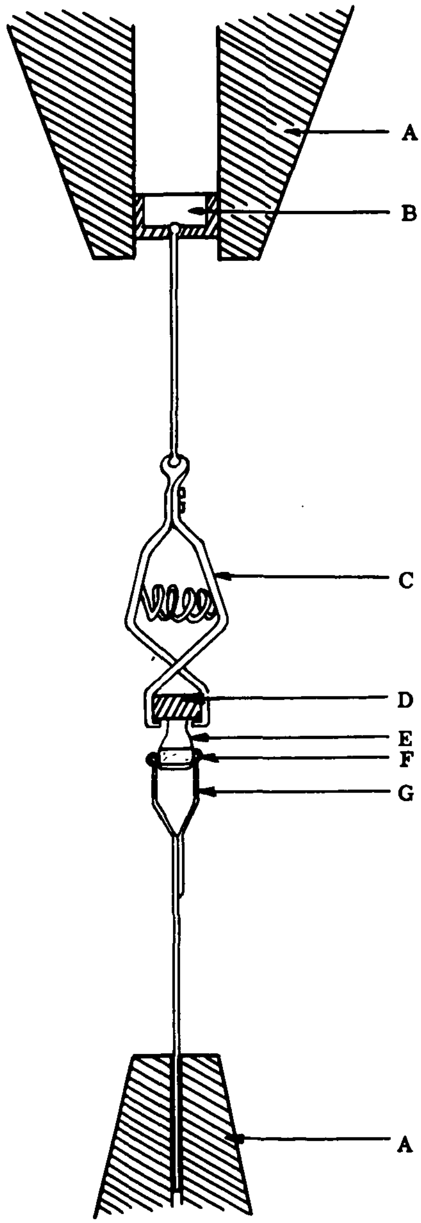

Figure 2 Schematic diagram of apparatus employed to support specimen in the testing machine. A Grips of tensile machine. B Steel cap supporting wire with ball and socket arrangement. C Battery clip. D Acrylic block holding teeth. E tooth. F Orthodontic band with loops. G Wire yoke.

teeth were stored in air at room temperature under normal atmospheric conditions until the initial set of the cement when the excess was carefully removed. They were then immersed in tap water until tested.

The apparatus fabricated for support of the specimens in the tensile test machine appears in Figure 2. All specimens were loaded at a cross head speed of 0.02 inch per minute. Prior to cementation of any of the bands, tests were conducted to determine how much retention was provided simply by the "fit" of the band itself. It was found that less than one pound force was required to remove all bands.

The amount of force required to remove bands cemented with each of the five materials was determined twenty-four hours after cementation. Additional tests were carried out after one week on bands cemented with zinc phosphate cement and with the zinc oxide-eugenol mixture containing rosin and o-ethoxy benzoic acid. Eight teeth were utilized in the study and each band was cemented on the respective tooth four times with each of the cements. A total of thirty-two individual tests were thus conducted for each material.

Prior to recementation, both the tooth and the inside of the band were carefully cleaned and the tooth surface was repolished by buffing lightly with the levigated alumina slurry. Adaptation of each band was carefully checked each time before it was recemented.

Results

Early in the experiment it was noted that considerably higher results were consistently obtained with certain individual teeth and bands than with others, even with use of the same cementing agent. Some representative data appear in Table II. This was not unexpected in view of the differences in size, shape and contour of natural teeth. It was

TABLE II
TENSILE FORCE IN POUNDS

Tooth Number	1	5	8
Zinc Phosphate	53.5	93.0	50.0
	56.5	89.0	47.0
	59.0	80.0	48.0
	57.0	103.5	42.0
Average	56.5	91.4	46.8
ZnO-Eugenol + EBA	23.5	37.5	20.1
	21.4	25.1	24.0
	27.2	33.1	21.4
	34.8	59.0	26.4
Average	26.7	38.7	23.0
Silico-Phosphate	51.0	74.0	38.0
	46.5	76.0	39.0
	50.5	75.5	45.4
	47.0	76.5	44.0
Average	48.7	75.5	41.6
Temrex	7.3	11.3	6.7
	9.4	12.0	6.2
	8.0	12.2	6.6
	7.7	13.3	5.7
	8.1	12.2	6.3

deemed advisable to determine the influence of this variation on the data and for this reason "t" tests were conducted. These calculations indicated that any given tooth would be expected to perform at a certain "level" but that the "level" of one tooth may never correspond to that of another tooth.

The mean data obtained in the tests to determine the relative retentive properties of the different cementing agents are shown graphically in Figure 3. These data are presented both in terms of applied force and of stress for each experimental group. A tensile stress of more than 500 pounds per square inch was required to remove bands cemented either with zinc phosphate cement or the silico-phosphate cement. This was appreciably more force than required to remove the same bands when they were seated with any of the zinc oxide-eugenol materials. Considerable differ-

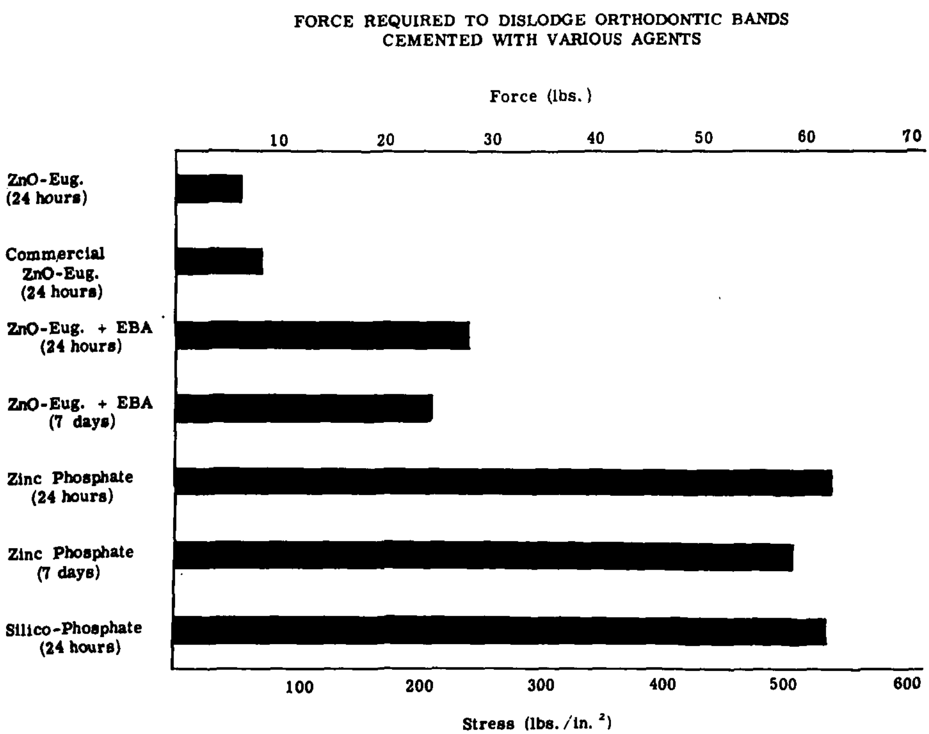

Figure 3 Comparison of tensile forces required to dislodge bands cemented with various agents.

Table III
STANDARD ERROR OF THE DIFFERENCE OF MEANS EXPRESSED IN TERMS OF PROBABILITY

	SILICO-PHOSPHATE (24 hours) $\bar{x}$ = 63.3 S_x = 16.6 $SE_{\bar{x}}$ = 2.9	COMMERCIAL ZnO-EUG. (24 hours) $\bar{x}$ = 8.2 S_x = 2.1 $SE_{\bar{x}}$ = .37	ZnO-EUG. (24 hours) $\bar{x}$ = 6.4 S_x = 2.6 $SE_{\bar{x}}$ = .46	ZnO-EUG. + EBA (7 days) $\bar{x}$ = 25.0 S_x = 7.0 $SE_{\bar{x}}$ = 1.2	ZnO-EUG. + EBA (24 hours) $\bar{x}$ = 28.5 S_x = 8.1 $SE_{\bar{x}}$ = 1.4	ZINC PHOSPHATE (7 days) $\bar{x}$ = 59.9 S_x = 20.3 $SE_{\bar{x}}$ = 3.6
ZINC PHOSPHATE (24 hours) $\bar{x}$ = 63.9 S_x = 17.1 $SE_{\bar{x}}$ = 3.0	P = .9*	P =<.0001	P =<.0001	P =<.0001	P =<.0001	P = .40*
ZnO-EUG. + EBA (24 hours) $\bar{x}$ = 28.5 S_x = 8.1 $SE_{\bar{x}}$ = 1.4	P =<.0001	P =<.0001	P =<.0001	P = .057*		
ZnO-EUG. (24 hours) $\bar{x}$ = 6.45 S_x = 2.58 $SE_{\bar{x}}$ = .46	P =<.0001	P = .0026				
COMMERCIAL ZnO-EUG. (24 hours) $\bar{x}$ = 8.2 S_x = 2.12 $SE_{\bar{x}}$ = .37	P =<.0001					

*THE DIFFERENCE BETWEEN THE MEANS OF THE TWO CEMENTS COMPARED IN THE BLOCKS IS NOT SIGNIFICANT.

ence was demonstrated in the abilities of the individual zinc oxide-eugenol materials to retain the bands. More than 200 pounds per square inch were required to unseat bands cemented with the EBA mixture, as compared with the 70 pounds per square inch utilized to displace bands cemented with Temrex and only 55 pounds per square inch for the 0.3 micron plain zinc oxide-eugenol material.

When a statistical comparison of the agents was performed by means of the standard error of difference, the significance of the differences observed in the preceding tests was revealed. As can be seen in Table III, the difference between the retentive properties of the two phosphoric acid cements and the zinc oxide-eugenol materials was significant. There was also a statistically significant difference between results obtained with the three zinc oxide cements. The analysis also showed that the retentive abilities of the silico-phosphate and zinc phosphate cements were not different. Likewise, when either zinc phosphate cement or the EBA mixture was used, no significant difference was noted between the bands tested at one day and those stored for one week before testing.

The compressive strength of the materials obtained in the previous studies is compared with the retentive ability in the graph shown in Figure 4. In most instances, as with the zinc phosphate cement and the three zinc-oxide-eugenol cements, there appeared to be quite a direct relationship, although not always a completely proportionate one, between retentive ability and compressive strength. However, these data do not lend unequivocal support to the postulation that retention is entirely a function of compressive strength with our present luting agents. The notable exceptions were the zinc phosphate

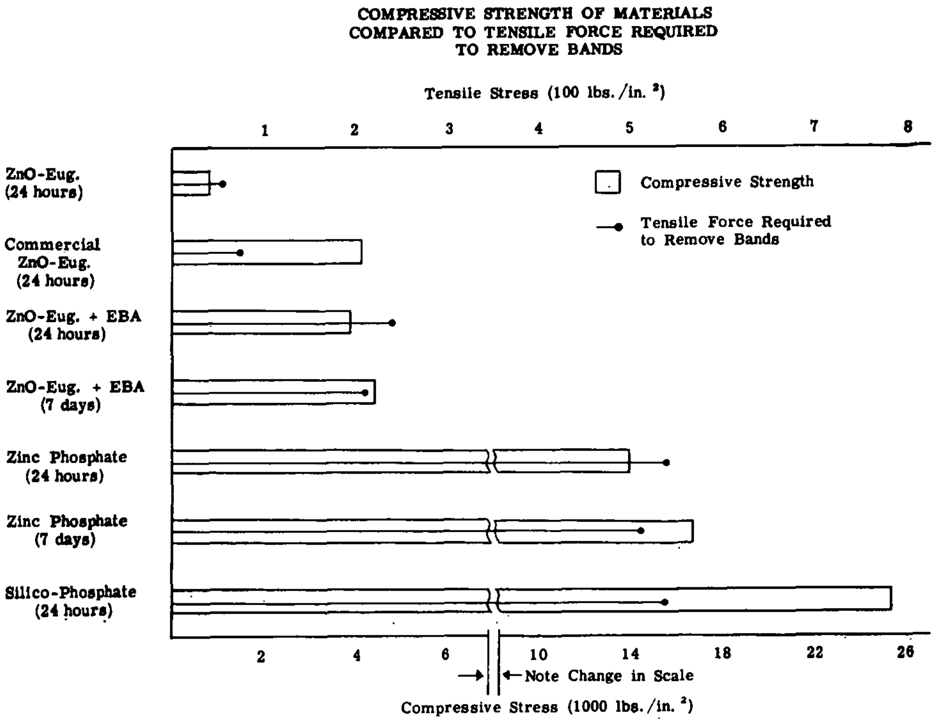

Figure 4 Relationship of the compressive strengths of the various materials to the tensile forces required to dislodge the bands.

cement and silico-phosphate cement. Despite the fact that the compressive strength of silico-phosphate cement is approximately twice that of zinc phosphate cement, comparable amounts of tensile force were required to dislodge bands cemented with either material.

Examination of the remnants of cement on bands and teeth immediately after separation revealed that zinc phosphate cement and silico-phosphate cement had a somewhat greater tendency to adhere to the polished tooth surface than to the metal band while the reverse was true of the zinc oxide-eugenol materials.

No signs of surface change or etching were distinguishable on the enamel beneath the cemented bands. Initially the investigators felt there to be some evidence of surface change when the phosphoric acid cements were employed. However, when the tooth was dusted with graphite to reveal the area, careful microscopic examination disclosed this apparent change to be due to minute particles of cement that were retained on the tooth. When these particles were removed no change was detected on the polished tooth surface. These findings are in agreement with those of Docking[19] who found an increase in the surface height of specimens cemented by zinc phosphate cement.

Discussion

It is readily acknowledged by the authors that this research procedure does have certain shortcomings in that it does not exactly simulate mouth conditions nor the stress patterns to which orthodontic bands are subjected in clinical usage. Nevertheless, it is felt that these experiments do shed some light on the relative ability of the materials to serve effectively for cementation of orthodontic bands. For example, if maximum retentive ability is desired, it is obvious that either silico-phosphate or zinc phosphate cement would be the materials of choice.

It is interesting to note that the strongest materials generally provided superior retention. An exception to this trend was manifested by silico-phosphate cement. Although the silico-phosphate is an appreciably stronger material than zinc phosphate cement, this superior strength was not reflected in the values obtained in retention tests. Hence, one must conclude factors other than strength may exert some influence on retention.

Summary

A testing procedure was developed for the purpose of measuring the relative retention of orthodontic bands when cemented with various types of dental cements. Included in the study were commercial zinc phosphate, silico-phosphate and zinc oxide-eugenol cements. Two experimental zinc oxide-eugenol cements, prepared from 0.30 micron zinc oxide powder, were also tested. One contained no additives other than an accelerator, while the second was modified by additions of hydrogenated rosin and o-ethoxy benzoic acid.

Twenty-four hours after cementation, forces of over 500 pounds per square inch were required to separate the bands from the teeth when either silico-phosphate or zinc phosphate cement was used as the luting agent. Although the values were considerably lower than those obtained with employment of the phosphoric acid cements, bands cemented with the experimental zinc oxide-eugenol containing hydrogenated rosin and EBA required application of three times as much force to accomplish removal as did bands cemented with either the zinc oxide-eugenol cement without additives or with the commercial product.

1121 West Michigan St.

References

1. Paffenbarger, G. C., Sweeney, W. T. and Isaacs, A.: Zinc Phosphate Cement: Physical Properties and a Specification. *J.A.D.A.*, 21: 1907-1924, 1934.
2. Berkson, R.: Dental Cements: A Study of its Properties of Adhesion. *Am. J. Ortho.*, 36: 701-710, 1950.
3. Christie, D. T.: Acrylic Fillings — General Comments and Some Experimental Data. *J. Canad. D.A.*, 17: 427-435, 1951.
4. Swartz, M. L. and Phillips, R. W.: A Method of Measuring the Adhesive Characteristics of Dental Cement. *J.A.D.A.*, 50: 172-177, 1955.
5. Rose, E. E., Lal, J., Williams, N.B. and Falcetti, J. P.: Screening of Materials for Adhesion to Human Tooth Structure. *J. D. Res.*, 34: 577-588, 1955.
6. Buonocore, M. G., Wileman, W. R. and Brudevold, F.: Report on a Resin Composition Capable of Bonding to Human Dentin Surfaces. *J. D. Res.*, 35: 846-851, 1956.
7. Sadler, J. F.: A Survey of Some Commercial Adhesives; Their Possible Application to Clinical Orthodontics. *Am. J. Ortho.*, 44: 65, 1958, Abstract.
8. Fusayama, T. and Iwamoto, T.: Relationship between Retaining Force of Inlays and Film Thickness of Zinc Oxyphosphate Cement. *J. D. R.* 39: 756, 1960.
9. Kaufman, E. G., Coelho, D. H. and Colin, L.: Factors in Retention of Cemented Gold Castings. *J. Pros. Den.*, 11: 487-502, 1961.
10. Kaufman, E. G., Colin, L. and Coelho, D. H.: Comparison Studies of the Retentive Ability of Temporary Cements. *J. D. Res.*, 39: 759, 1960, Abstract.
11. Swanson, L. T. and Beck, J. F.: Factors Affecting Bonding to Human Enamel with Special Reference to a

Plastic Adhesive. *J.A.D.A.*, 61: 581-586, 1960.

12. Mahler, D. B. and Armen, G. K., Jr.: Addition of Amalgam Alloy to Zinc Phosphate Cement. *J. Pros. Den.*, 12: 157-164, 1962.
13. Jensen, J. R. and Hagen, P.: Comparative Retention of Plug Castings. *I.A.D.R.*, 40: 93, 1962, Abstract.
14. Myers, C. L., Ryge, G. and Glenn, J.: In Vivo Test for Bonding to Dentin. *J. D. Res.*, 32: 907-911, 1963.
15. Oldham, D. F., Swartz, M. L. and Phillips, R. W.: Retentive Properties of Dental Cements. *J. Pros. Den., in press.*
16. Swartz, M. L., Phillips, R. W., Norman, R. D. and Oldham, D. F.: Strength, Hardness and Abrasion Characteristics of Dental Cements. *J.A.D.A.*, 67: 367-374, 1963.
17. Norman, R. D., Swartz, M. L. and Phillips, R. W.: Studies on Film Thickness, Solubility and Marginal Leakage of Dental Cements. *J. D. Res.*, 42: 950-958, 1963.
18. Norman, R. D., Phillips, R. W., Swartz, M. L. and Frankiewicz, T.: Effect of Particle Size on Physical Properties of Zinc Oxide-eugenol Mixtures. *J. D. Res.*, 43: 252-262, 1964.
19. Docking, A. R., Donnison, J. A., Newbury, C. R. and Storey, E.: Effect of Orthodontic Cement on Tooth Enamel. *D. Record*, 72: 243-256, 1952.