

Guide For Selection Of Cements In Fixed Prothodontics

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There are a number of properties which are clinically important in the final cementation of cast restorations. Such properties include : setting time, film thickness, bonding to dental substrates, solubility and disintegration, mechanical properties and biological responses. (...) Most of these properties are measured in vitro, so that their meaning clinically is not always obvious.

With the development of the modified zinc oxide-eugenol, zinc polyacrylate and composite resin cements, final cementation materials with improved properties are available to the clinician. The purpose of this paper is to discuss the properties of final cementation materials in terms of clinical behavior and to present criteria for the selection of these cements.

Properties

Setting Time :

A sufficient period of time must be available after mixing a cement in order to seat and finally adopt the margins of a casting.

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The cementation of an inlay, however, generally requires less working time than the placement of a multi-unit bridge. It is desirable to have an extended period of working time available outside of the mouth, but once a restoration has been seated the cement should set relatively fast.

ADA Specifications No. 8 for zinc phosphate cement require that a cement of luting consistency should set between five and nine minutes when tested at 37° C. and 100 percent humidity. (3). According to these specifications, a cement is set when a specimen resists indentation by a Gillmore needle. Setting times for various cements are shown in Table 1, as measured according to ADA Specification No. 8 under simulated oral conditions.

It has been customary to define working time as the time available for mixing and manipulating the material. This is often unsatisfactory when the period of mixing is prolonged as with zinc phosphate cement. Plant, Jones and Wilson have defined the practical working time as the time available from the completion of the mix to the time when the material is no longer workable. (4) They have measured the practical working time for several cements with the aid of an oscillating rheometer. These data are shown in Table 1, for cements available in Europe, and represent a more useful guide for estimating the working time of a cement than values obtained by the ADA Specification tests.

Film Thickness :

The film thickness a cement attains will do much to determine the wall and marginal adaptation of a casting to the tooth. The ultimate film thickness that can be achieved by a well mixed cement is dependent upon the particle size of the powder and the consistency to which the cement is mixed. For example, a zinc polyacrylate cement mixed to a consistency represented by a powder to liquid ratio of 1.5 to 1 had a laboratory value for film thickness of 22.5 μm (microns); whereas, one mixed using a powder to liquid ratio of 2.5 to 1 had a film thickness of 53.5 μm . (5)

The film thickness will vary with the amount of force and the manner in which this force is applied to a casting during cementation. Jorgensen (6) concluded that forces above 11 pounds had no significant effect on reducing film thickness, nor did the maintenance of seating forces for longer than one minute. The ease with which cement escapes from around the margins of a restora-

tion is determined by the type of restoration and the area of the tooth surface covered. Typical values for film thickness determined under simulated (7-9) and actual (10) clinical conditions of cementation (unvented) also are shown in Table 2. The dramatic increase in values for film thickness when tested under these conditions provides evidence that factors such as preparation design, venting, the amount of excess cement to be extruded, and individual techniques play an important role in the complete seating of a cast restoration. Jorgensen and Esbensen (11) have demonstrated, however, that variations in cement film thickness have only a moderate effect upon retention.

Bonding to dental substrates :

The retaining action of most hardened cements is one of mechanical bonding between surface irregularities of the tooth or casting and the cement. This mechanical interlocking depends on the ability of the cement to wet substrate and to penetrate into its irregularities. The acid-etch technique used in conjunction with a composite resin cement, is meant to clean the tooth surface and increase the number of irregularities in order to improve mechanical bonding.

If a chemical interaction occurs between a cement and a substrate that results in bonding, the process of bonding can be referred to as adhesion. An adhesive luting cement is a material that will bond to tooth structure and to the restoration to be cemented, and will, if sufficiently strong, withstand the functional stresses of mastication and hold a restoration in position without retention form. (12)

There is evidence to suggest that adhesion occurs between zinc polyacrylate cement and substrates of enamel (13, 14) and gold casting alloy. (15) Smith (16) has emphasized the importance of providing clean tooth surfaces to promote adhesion. The adhesion to gold casting alloy was found to be highly dependent on surface preparation. (15) Pickling, or any other procedure resulting in a surface film or coating on the gold alloy, will reduce adhesion. Sandblasting or electrolytic etching of the gold surface is necessary to achieve optimum adhesion.

Although tensile bond tests made in the laboratory showed an order of magnitude difference in the values for zinc polyacrylate cement, 1,380 psi (lbs./in. 2), and zinc phosphate cement, 125 psi,

on enamel, (13) laboratory tests measuring the force necessary to remove a cemented casting showed little difference between the retentive abilities of these cements. (9,17) Thus, the effect of adhesion of the polyacrylate cements in improving retention is still unclear.

Solubility and disintegration :

The terms, solubility and disintegration, describe the dissolution and leaching of a cement in contact with water or oral fluids. The processes of solubility and disintegration are accelerated by the premature contact of incompletely set cement with the oral fluids. The prolonged contact of a wellhardened cement with these fluids, the attack of decomposition products from food, and wear also contribute to the breakdown of cements. In the cemented cast restoration, breakdown occurs at the margins where a thin line of cement is exposed to the oral fluids. As the cement gradually dissolves, leakage occurs with subsequent loosening of the restoration and the development of secondary caries.

Failure to incorporate a maximum amount of cement powder into the liquid when mixing to a desired consistency will lead to increased solubility and dissolution. A common example of this failure is the mixing of zinc phosphate cement on a warm glass slab. A warm slab accelerates the setting reaction, and the mix will contain less powder than could have been incorporated on a cooler slab. A cement that is richer in liquid and, therefore richer in matrix will be less resistant to solubility and disintegration, and will have reduced mechanical properties.

ADA Specifications No. 8 allows a maximum of 0.2 percent weight for disk of zinc phosphate respectively, when the disk is suspended for 24 hours in distilled water at 37° C. The solubility and disintegration of other cements have been tested according to this procedure and these data are shown in Table 3. The solubility and disintegration of cement under oral condition, however, should not be inferred from tests in distilled water. Clinical observations have shown that zinc silico-phosphate cement is less soluble in the mouth than zinc phosphate cement; 18 the opposite result is observed for solubility tests in distilled water. The in vivo disintegration of cements appears to be an effect of the interactions of solubility and abrasion.

Jrgensen (6) has observed that a phenomenon similar to filtra-

tion can occur when very accurate castings are seated. According to his study, large powder particles become trapped between the restoration and prepared tooth and act as a filtering media by allowing the unset cement liquid to pass through them. This process results in a liquid-rich cement at the margins of the restoration; a condition conducive to accelerated disintegration.

Mechanical Properties :

Mechanical properties of cements include compressive and tensile strengths and the modulus of elasticity. These properties are shown in Table 4 for dental cements used for the permanent retention of cast restorations.

No determination of the minimum compressive strength that is required for final cementation has been made. The minimum compressive strength required for zinc phosphate cement by the Specification is 9,956 psi, but this value is only for material screening purposes. Clinical studies by Horn (19) and by Gilson and Byers (20) have demonstrated that modified zinc oxide-eugenol cements with compressive strengths from 8,000 to 10,000 psi were successful over a two year period for the cementation of bridges and single restorations of good retentive quality. No differences could be detected clinically among the retentive abilities of EBA-alumina-modified ZOE, zinc polyacrylate or zinc phosphate cements when used to retain crowns and bridges over an 18-month period (21).

McLeen (22) has stated that the compressive strength and adhesive properties of the zinc polyacrylate cements are inadequate for cementing less-retentive restorations. However, when the polyacrylate cements were used to cement gold inlays, crowns or metal-ceramic fixed bridge restorations in which the preparations possessed good retention form, the results were extremely satisfactory (22).

Most dental cements are weak in tension. Their strength in shear is even less. A study of the stress distribution in an idealized mathematical model of a first molar with a chamfer preparation demonstrated that maximum values of stress would occur at the dentin-gold interface (23). These tensile stresses could be of sufficient magnitude to cause failure in weaker cements. Stress gradients resulting from a shoulder preparation were somewhat higher than those of the chamfer preparation. These results suggest

that the use of cements with tensile strengths above 1,000 psi may be desirable.

The modulus of elasticity of dental cements characterizes their rigidity or ability to resist deflection. In restorations where deflections are likely to occur, cements with higher values of modulus will resist these deflections with less likelihood of failure (24). The values of modulus reported in Table 4 were obtained from stress-strain curves (25).

Biological compatibility :

In evaluating materials for placement in direct contact with freshly cut dentin, one of the important properties to be considered is the biological compatibility of a material with vital oral tissues. The response evoked within subjacent pulpal, periapical, or periodontal tissues may be the prime factor in determining success or failure of a cast restoration. In most cases, caries ultra-speed instrumentation and prior medication have induced varying degrees of inflammatory response, and the reparative processes already may be active at the time of cementation. Consideration of these cause and effect relationships, and correlation with clinical symptomatology is essential to the success of the restorative procedure.

Zinc phosphate cement possesses many of the physical properties desirable in a luting media, but its biological compatibility is poor. The pH of a fresh mix of zinc phosphate cement at a primary consistency has been measured to be about 3.5, but it rises rapidly to values of 4.2 at three minutes and 6.0 at one hour (26).

Ions appear to penetrate dentin tubules and evoke pulpal, and even periapical, responses. A mix of thinner consistency (lower powder/liquid ratio) not only possesses poorer mechanical properties, but also has a lower initial pH and causes a greater inflammatory response. Zinc phosphate cements should be manipulated and applied carefully, and in conjunction with protective liners to minimize the penetration of ions.

Zinc oxide-eugenol cements are neutral at the time of insertion and have been shown to exert an obtundant effect upon previously irritated pulpal tissue (27). This medicating effect has resulted in cements containing eugenol being used as interim dressings, temporary luting agents, endodontic sealers, and as a standard for minimal irritation in current biological testing programs for new

materials (28). Even with very thin amounts of remaining dentin, zinc oxide-eugenol cements produce only a minimal amount of disruption in the odontoblastic layer of cells and result in the formation of only minor increments of reparative dentin. Since cements containing zinc oxide and eugenol have their greatest advantage in biological compatibility, they should be considered for use when more severe irritating factors or pulpal symptomatology are present.

Zinc polyacrylate cements are less acidic than zinc phosphate cement when first mixed (pH 4.8), and the acid is only weakly dissociated. Penetration of the high molecular weight polymer molecules toward pulpal tissue is minimal. Histologic reactions to polyacrylate cements appears to be similar to those of zinc oxide-eugenol cements, although the production of reparative dentin under the polyacrylate cements is more rapid (29). In most cases, zinc polyacrylate and zinc oxide-eugenol cements can be used interchangeably with respect to tissue reaction, whereas zinc phosphate is more toxic material.

Composite resin cements are equally as toxic as composite restorative materials (30) and pulpal protection is recommended. The inflammatory response to these materials is of a moderate to severe nature, but is usually reversible with the formation of large amounts of irregular reparative dentin. Extreme caution should be used in the treatment of selected cases with composite resin cements.

Criteria for Selection

Zinc phosphate cement :

Over the years zinc phosphate cement has become the most «tried and proven» material for permanent cementation. The setting time is within desirable limits to provide for the cementation of multiple units from one mix; yet the excess material can be easily removed and adaptation of the margin can be accomplished before hardening of the cement occurs. Final polishing can begin after 10 minutes when the material has hardened and pressure can be removed from the restorations. Values of film thicknesses are the lowest among available material; however, it is important that castings be seated with zinc phosphate cement before the setting reaction progresses to the point where the viscosity rises significantly (usually after the first five minutes).

The compressive strength of zinc phosphate cement is high. Clinically, however, the retention of a casting is related to the design of the preparation and the fit of the casting, as well as to the compressive strength of the cement. At present, zinc phosphate cement is still the material of choice when there is minimal retention between the finished casting and the prepared tooth, and in cases involving devital teeth or where pulpal irritation is anticipated to be minimal. The only major drawback to the universal use of zinc phosphate cement is its irritating effect upon pulpal tissue. When teeth have been traumatized by caries and ultra-speed instrumentation or when clinical symptoms of inflammation are present, every effort should be made to use a less irritating cementing material.

Modified zinc oxide-eugenol cements :

The improvement of zinc oxide-eugenol cements to gain suitable properties for permanent cementation marks a significant development for clinical restorative dentistry. The setting and working times of the modified ZOE cements are ideal; a usable working consistency can be prolonged for 20 minutes on a glass slab and yet the setting reaction will progress rapidly in the mouth upon exposure to humidity and heat. Final polishing can be instituted safely after 10 minutes from the time the restoration is inserted in the mouth. The values for film thickness are low enough to allow easy and complete seating of all castings, including those with pin retention; but once set, the cement is extremely difficult to remove from the surfaces of the casting and surrounding structures.

The mechanical properties of the modified ZOE cements are not as high as the zinc phosphate cements, but appear to be sufficient to retain castings on teeth which have highly retentive preparations. Preparations with minimal degrees of taper and flare, sharp line angles, and flat floors and walls will provide good frictional resistance to the seating of a casting, and will place less demands upon the retaining properties of the cement.

The biological acceptability of zinc oxide-eugenol cements is excellent and is the prime criterion for their selection. They act as pulpal obtundants to decrease the inflammation induced during restorative procedures and are indicated for use under all castings which approach vital pulpal tissues.

Zinc polyacrylate cements :

The zinc polyacrylate cements have been proposed as acceptable substitutes for zinc phosphate cements. The biological acceptability of polyacrylate cements makes them more desirable than zinc phosphate, but they are not quite as obtundant in action as the zinc oxide-eugenol cements. The setting and working times for polyacrylate cements are very short, and the cementation of more than two castings from a single mix would be difficult and is contraindicated. The physical properties of these cements are quite similar to those obtained for the modified zinc oxide-eugenol cements and are clinically acceptable for the cementation of castings for retentive preparations. There is little or no evidence to support the use of any cement other than zinc phosphate cement to permanently retain the loose-fitting or less retentive type of casting. The qualities of the polyacrylate cements have led to their use in the cementation of orthodontic appliances because of the adhesion of this cement to properly prepared enamel.

Composite resin cements :

The composite resin cements have shown very few advantages to indicate their use in clinical dentistry. Values of film thickness are too high to be clinically acceptable for accurate seating of a casting and these cements are irritating to the pulpal tissue. The setting and working times of the cement are short, and would restrict its use to the cementation of one casting from a single mix. Removal of the excess cement after seating is difficult. If excess is removed while the cement is in a plastic stage, material may be removed from under the margins; if the flash is removed after setting, it must be fractured away and rough edges may remain to irritate the gingiva. Composite resin cements may be indicated for the long-term temporary cementation of a loose-fitting casting during a period in which restorative care must be delayed.

Ö Z E T

Bu sayfada belirtilen özellikler, diş simanlarının klinik kullanımına uygulanabilirliklerinden dolayı seçilmiştir. Laboratuvar testleri ile elde edilen kesin değerler gerçek klinik değerlerden uzak olabilir; ne vaki bu ölçümler standardizasyon ve benzer materyaller arasında karşılaştırma amaçlarıyla kolaylıkla yapılabılır. Çok ayrıntılı bir klinik yoruma girmeksizin, fiziksel nitelikler, spesifik klinik durumların gereklerini yerine getirmek amacı ile yapılan, diş simanı seçimine temel oluşturan en güvenilir kaynağı oluşturmaktadır.

Herhangibir klinik olguda biyolojik gereksinmelerle ilgili, sürekli bir sement seçiminde birinci ölçüt, örneğin döküm restorasyonların simante edilmesinde, yapım işlemi sırasında bir pupa travması ya da iltihap varlığını belirten kanıtlar varsa modifiye edilmiş çinko oksit-öjenol simanı optimal biyolojik özellikleri içerir ve seçecek en iyi materyaldir. Gözönüne alınması gereken ikinci önemli ölçüt, dış kesimi biçimine uygunluk ve döküm restorasyonunun retansiyonudur. Diş uyumsuz ve retansiyondan yoksun restorasyonların retansiyonunun sağlanması için çinko fosfat simanının yüksek bir direnci, gücü olması gerekir. Bu iki ölçütün de büyük bir sorunu belirlemediği olgularda çinko pliakrilat kullanılabilir. Her klinisyen spesifik olguların gereksinmelerini önemle incelemeli, bu gereksinmeleri en uygun biçimde karşılayacak bir siman seçmelidir.

S U M M A R Y

The properties discussed in this paper have been selected because they have applications to the clinical use of dental cements. The exact values obtained in laboratory testing may be far from real clinical values, but such measurements are easily made, can be used for standardization and as a means for comparison among similar materials. Apart from long term clinical evaluation, physical properties provide the most reliable source upon which to base the selection of a dental cement to meet needs of a specific clinical situation.

The prime criteria for selection of a permanent cement relate to the biological requirements of an individual case. In cementing cast restorations when there is evidence of a substantive of pulpal trauma or inflammation during the restorative procedure, a modified zinc oxide-eugenol cement possesses the optimum biological properties and is the material of choice. The second major criteria to be evaluated is the fit and retentiveness of the casting in relation to the preparation. A loose-fitting or less retentive casting requires the high strength of a zinc phosphate cement to optimize retention. The zinc polyacrylate cements can be used as an acceptable substitute when neither of these criteria present severe problems. Each clinician must give serious consideration to the requirements of a specific case and choose a cement which will meet these needs most acceptably.

L İ T E R A T Ü R

- 1 — Peyton, F. A. and Craig, R. G., eds. ; Restorative dental material. 4th ed., St. Louis, Mosby. 1974, pp. 398-430
- 2 — Ollio, G. : Linear dimensional change during setting of zinc phosphate cement-methodological study. J. Oral Rehabil., 2 (2) : 179-85, Apr. 1975.
- 3 — Guide to Dental Materials and Devices, ed. 6 Chicago, American Dental Association, 1972-1973, 291 p.

- 4 — **Plant, C. G., Jones, I. H. and Wilson, H. J.** : Setting characteristics of lining and cementing materials. *Brit. Dent. J.* 133: 21-23, 1972
- 5 — **Dérard, T.** : The influence of the cement layer on the strength of porcelain crown subjected to frequent loading. *Odontol Revy* 26 (3): 239-44, 1975.
- 6 — **Jrgensen, K. D.** : Structure of the film of zinc phosphate cements. *Acta Odont. Scand.* 18: 491-501, 1960.
- 7 — **Tandlakartidningen** : Test of zinc phosphate ceemnt in relation to ISO recommendation 67 (7): 428, Öpr., 1975.
- 8 — **Eames, W. B., O'Neal, S. J. and Miller, C. B.** : Cementation varibales in the seating of castings. Microfilmed Paper No. 545. (Delivered at) the Annual Meeting of the International Association for Dental Research. Dental Materials Group, Atlanta, Georgia, March 21-24, 1974.
- 10 — **McLean, J. W. and von Fraunhofer, J. A.** : The estimation of cement film thickness by an in vivo technique. *Brit. Dent. J.* 131: 107-11, 1971.
- 11 — **Jrgensen, K. D. and Esbensen, A. L.** : The relationship between the film thickness of zinc phosphate cement and the retention of veneer crowns. *Acta Odont. Scand.* 26: 169-75, 1968.
- 12 — Council on Dental Materials and Devices. Council statement claims related to «adhesion» or to «adhesive» restorative materials. *Am. Dent. A. J.* 88: 393, 1974.
- 13 — **Smith, D. C.** : Dental cements. (In *Dental Clinics of North America*, Philadelphia, Saunders, 1971, pp. 3-32).
- 14 — **Smith, D. C.** : Interaction of polyacrylate cements with enamel and dentin. Microfilmed Paper No. 380. (Delivered at) the Annual Meeting of the International Association for Dental Research. Dental Materials Group. Las Vegas, Nevada, March 23-26, 1972.
- 15 — **Kendzior, G. M., et al.** : The effects of cold temperature mixing on the properties of zinc phosphate cement. *Angle Orthod.* 46 (4): 345-50, Oct., 1976.
- 16 — **Smith, D. C.** : A new dental cement. *Brit. Dent. J.* 125: 381, 1968.
- 17 — **Phillips, R. W., Swartz, M. L. and Rhodes, B.** : An evaluation of a carboxylate adhesive cement. *Am. Dent. A. J.* 81: 1353-59, 1970.
- 18 — **Hensten Pettersen, A. et a.** : Evaluation of biologic effects of dental materials using four different cell culture. *Scand. J. Dent. Res.* 85 (4): 291-96, May, 1977.
- 19 — **Horn, H. R.** : Zinc oxide phosphate cement studies on the usefulness of format. *Stomatol. DDR* 26 (1): 7-15, Jan., 1976.
- 20 — **Gilson, T. D. and Myers, G. E.** : Clinical stuides of dental cements: IV. A preliminary studv of zinc oxide-eugenol cement for final cementation. *J. Dent. Res.* 49: 75-78, 1970.

- 21 — **Silvey, R. G. and Myers, G. E.** : Preliminary report of a three-year study of three luting cements. Microfilmed Paper No. 548. (Delivered at) the Annual Meeting of the International Association for Dental Research. Dental Materials Group, Atlanta, Georgia, March 21-24, 1974.
- 22 — **McLean, J. W.** : Polycarboxylate cements. Five years' experience in general practice. *Brit. Dent. J.* 132: 9-15, 1972.
- 23 — **Farah, J. W. and Craig, R. G.** : Finite element stress analysis of a restored axisymmetric first molar. Microfilmed Paper No. 650. (Delivered at) the Annual Meeting of the International Association for Dental Research, Dental Materials Group, Washington, D. C., April 12-15, 1973.
- 24 — **Farah, J. W., Hood, J. A. A. and Craig, R. G.** : Effect of cement bases on the stresses in amalgam restorations. Microfilmed Paper No. 893. (Delivered at) the Annual Meeting of the International Association for Dental Research, Dental Materials Group, Atlanta, Georgia, March 21-24, 1974
- 25 — **Hall, D. R., Uakayama, W. T., Grenoble, D. E., and Katz, J. L.** : Elastic constants of three representative dental cements. *J. Dent. Res.* 52: 390, 1973.
- 26 — **Brännström, M.** : Pulpal reaction to polycarboxylate and zinc phosphate cement used with inlays in deep cavity preparation. *J. Am. Dent. Assoc.* 94 (2): 302-10, Feb., 1977.
- 27 — **Miani, C., et al** : Dental pulp and dentine reaction any phosphate cement. *J. Minerva Stomatol.* 25 (4): 211, Oct-Dec, 1976.
- 28 — Recommended standard practices for biological evaluation of dental materials. Council on Dental Materials and Devices. *Am Dent. A. J.* 84: 382-97, 1972.
- 29 — **Jendresen, M. D. and Trowbridge, H. O.** : Biological and physical properties of a zinc polycarboxylate cement. *J. Prosth. Dent.* 28: 264-71, 1972.
- 30 — **Eriksen, H. M.** : Pulpal response to monkeys to epoxylike CBA 9080 resin cement. *J. Dent. Res.* (Abstract) 52 (5 Part 1): 992, 1973.

Table 1. Setting time and practical working time of cements

Cement	Setting time at 37°C,	Practical working time
	100 % humidity (minutes)	at 23°C (minutes)
Zinc phosphate	5—9	4.5—11
Polymer modified ZOE	9	6.3
ZOE—EBA—alumina	7—9	22
Zinc polyacrylate	7—9	1.7—2.4
Composite resin	4—5	—

Table 2. Laboratory and clinical values for film thickness of various cements

Cement	Value determined by specification test	Values determined under simulated clinical conditions		
		Ref. 7	Ref. 8	Ref. 9
Zinc phosphate	25 μ m	85 μ m	33 μ m	40 μ m
Polymer modified ZOE	35	170	—	—
ZOE-EBA-alumina	25—35	184	—	97
Zinc polyacrylate	25—48	89	20	63
Composite resin	20—30	—	>500	—

Table 3. The solubility and disintegration of dental cements tested according to ADA Specification No. 8

Cement	Solubility in distilled water at 37°C for 24 hours
Zinc phosphate	0.2% (max.)
Polymer modified ZOE	0.08
ZOE—EBA—alumina	0.02—0.04
Zinc polyacrylate	>0.05
Composite resin	0.13

Table 4. Mechanical properties of dental cements

Cement	Compressive Strength (24 hours)	Diametral Tensile Strength (24 hours)	Modulus of Elasticity
			(24 hours)
		Composite resin	30,000
Zinc phosphate	10,000-17,000 psi	700—900 psi	3,500,000 psi
Polymer modified ZOE	8,800	900	410,000
ZOE-EBA-alumina	11,000-12,000	850	—
Zinc polyacrylate	7,400-8,500	750—1,250	—
Composite resin		6,000	2,000,000