

NATIONAL BUREAU OF STANDARDS REPORT

10 581

Progress Report
on
**INTERMEDIARY BASE
AND CEMENTATION**



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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INTERMEDIARY BASE AND CEMENTATION

by

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Intermediary Base

An intermediary base is that portion of a restoration placed: 1) directly between the dentin and the final restorative material, or 2) interposed between a therapeutic material for pulp treatment and the restorative material. Ideally, the intermediary base replaces some of the dentin lost by caries, trauma or cavity preparation.

Selection of a material for use as an intermediary base is dependent on the amount and condition of the remaining tissues as well as the intended purpose of the base. Table 1 lists the materials currently available. Some of the brands* in the various classes are: Zinc phosphate cement (ZP) "Tenacin"[†]; zinc oxide-eugenol cement (ZOE); modified zinc oxide-eugenol, e.g. o-ethoxybenzoic acid (EBA) "EBAC"^{††}, aluminum oxide (Al_2O_3) "Opotow EBA with alumina"^{†††} and poly(methylmethacrylate) (PMMA) "T & B"[‡]; calcium hydroxide ($\text{Ca}(\text{OH})_2$) "Hydrex"^{‡‡} and zinc polycarboxylate or zinc polyacrylate (PC) "Durelon"^{‡‡‡}.

[†] Tenacin: L. D. Caulk Co., Milford, Del.

^{††} EBAC: The Lorvic Corp., St. Louis, Mo.

^{†††} Opotow EBA with alumina: Opotow Dental Mfg. Corp.,
Brooklyn, N.Y.

[‡] T & B: L. D. Caulk Co., Milford, Del.

^{‡‡} Hydrex: Kerr Manufacturing Co., Detroit, Mich.

^{‡‡‡} Durelon: Premier Dental Products Co., Philadelphia, Pa.

* Certain commercial materials and equipment are identified in this paper in order to specify adequately the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards nor does it imply that the material or equipment identified is necessarily the best available for this purpose.

Condition of remaining tooth tissue

Dental caries and attrition gradually expose dentin tubules, allowing the natural defensive mechanisms of the tooth to form reparative and sclerotic dentin.^{1,2} This is contrasted with operative procedures and trauma which immediately expose unaltered dentin tubular contents to destructive forces such as heat, dehydration and chemicals. Generally, 2.0 mm of remaining unaltered dentin between the floor of the cavity and the pulp provides an adequate insulating barrier against irritating components of restorative materials.³

It is impossible to determine remaining dentin thickness during a cavity preparation. Pulp tissue may be irritated through open tubules of viable dentin. Damage may also occur through an undetected exposure. Ischemia produced by the epinephrine in the anesthetic often restricts bleeding so that a small exposure is not noticed.

Functions of an intermediary base

The functions of an intermediary base are: (1) insulation from chemical and thermal shock; (2) strength to resist the forces transmitted toward the pulp by compaction of filling materials or compression of cementing media; and (3) modification of the internal walls of cavity preparations. Some authors⁴ include insulation against electric shock as a function but cements are seldom used to alleviate this problem.

Chemical and physical properties

Table 1 and Figure 1 present the various materials and a comparison of essential properties.

Chemical irritation by the intermediary base or final restorative material should be avoided, or kept to a minimum, since the pulp has recently been weakened by the carious process or operative procedure. The initial contact of the base material with the dentin produces the greatest irritation and injury to the pulp.

All of the materials given in Table 1 provide insulation against temperature change. Voth⁵ observed that a layer 1.4 mm thick of Ca(OH)_2 , ZOE or ZP was an effective barrier against both heat and cold but that a thin film was of no value. He did not determine the optimum thickness; however, 0.5 mm is accepted as a minimum to prevent discomfort caused by thermal changes.

In addition to chemical irritation of the pulp a chemical reaction of the base with the final restorative material must be avoided. Any material which hardens by free radical polymerization should not contact eugenol-containing bases because the eugenol inhibits the polymerization. This is true for acrylic resins, some composite filling materials and rubber base impression materials. Two thin coats of varnish placed over the cement are usually sufficient to control this polymerization inhibition.

The highest compressive stress is usually exerted during compaction of the dental amalgam or gold restoration and is within the first 3 - 8 minutes after mixing.⁶ Early and ultimate compressive strengths are included in Table 1. Thickness of the intermediary base to disseminate compressive forces is also important. It has been shown⁷ that 1 mm thick bases made of materials exceeding 14 kg/cm² (200 psi) will not crumble or be displaced by usual condensing forces. Since there is sufficient space in deep cavities, it is better to err on the side of using an excess of the material.

Modifying internal cavity walls

Another function of a base material, modifying internal walls of cavity preparations, is required for indirect restorations, i.e., those completed outside the mouth to be cemented in place. Properly selecting and using material for this function reduces the amount of tooth structure to be removed and assists in the retention of the restoration. Selection of a material for this base need not be limited to the usual cements but can include dental amalgam and gold. Retention of the final restoration will be improved when parallelism can be achieved without removing excessive amounts of tooth structure.

Radiopacity

Since they are completely covered by the permanent restorations, intermediary bases cannot be identified by visual examination. To facilitate subsequent interpretation of x-rays in diagnosis of recurrent caries the intermediary base should be radiopaque. The relative radiopacity of various materials is shown in Figure 1.

Mixing

Mixing base materials is in reality one of the final steps in the manufacture of the cement. The ingredients should be carefully formulated and packaged by the manufacturer after exhaustive experimentation and testing. Carefully worded and illustrated instructions for each product are generally included in the package to insure obtaining the optimum physical properties. Consequently, detailed mixing instructions have been omitted in this discussion of the various classes of materials. The only way to assure success is to follow the instructions provided with each package. As one paint manufacturer so aptly stated on the label of his product, "If you don't intend to follow our instructions, don't use our paint".

Several brands of intermediary base materials are being packaged in preproportioned capsules for mixing in mechanical devices. No results have been reported of tests made using this technique. However, from experience with similar packaging for silicate cements and dental amalgam, the resultant products should be highly satisfactory.

Zinc phosphate cement

Zinc phosphate (ZP) cement continues to be the standard used for the evaluation of all new dental cements. The powder for this cement contains approximately 9 parts calcined zinc oxide to 1 part magnesium oxide.⁸ When this powder is mixed with the liquid containing phosphoric acid buffered with salts of aluminum or zinc, the compounds formed are phosphates of zinc, magnesium and aluminum. The outer layers of the particles react to form a phosphate matrix that surrounds the unreacted cores of the larger particles. The proportion of powder particles and matrix varies with the amount of powder incorporated into a given amount of liquid. As the powder particle content increases in proportion to the matrix, better physical property values are obtained.

The liquid is a precisely balanced phosphoric acid and water solution. The water content is sensitive to the room atmosphere. In conditions of high humidity the phosphoric acid takes on additional water and in dry conditions gives off

water. Either condition disturbs the setting reaction, consequently the liquid bottle should be open just long enough to remove the needed amount. This should be done immediately prior to mixing to protect the liquid on the mixing slab.

In the past few years a ZP cement has been introduced using water as the liquid which replaces the unstable phosphoric acid. The resultant cements when compared to acid liquid ZP have greater film thickness, less strength, higher solubility and are equally irritating to the pulp tissue.⁹

Both of these cements, acid and water settable, are irritating to the pulp tissue. However, placing an underlay of two thin coats of varnish or a base of either $\text{Ca}(\text{OH})_2$ or ZOE will prevent this irritation. ZP cement has a high crushing strength, both early and late,^{4,10} Table 1, it is radiopaque, Figure 1, and its thermal insulation is effective even in thin layers.

Zinc phosphate cement is mixed on a cool, clean and dry glass slab. The powder is separated in small units so that a little powder is incorporated at a time. The mixture is spread with heavy pressure on a flexible steel spatula so the heat of the reaction will dissipate into the glass. Most manufacturers recommend $1\frac{1}{2}$ minutes to complete the mix. As stated earlier the amount of powder controls the physical properties, more powder gives higher strength and lower solubility than when less powder is used.

Zinc oxide-eugenol cements

In the 1960's considerable research and development attention was focused on ZOE cements. The favorable response by the pulp to this material stimulated interest in improving physical properties such as crushing strength, solubility and film thickness for cementation procedures.^{11,12} Table 2 presents representative products as they evolved from the addition of zinc acetate to hasten the set to the most recent additive, polycarbonate, which contributes strength and abrasive resistance. The products, with Al_2O_3 , Figure 2, and PMMA develop early crushing strengths much in excess of the minimum 200 psi required to resist the forces used in compacting amalgam and direct gold, Table 1.^{4,10} Virmani reports that two modified ZOE cements, B & T and Temrex*, along with the ZP material Tenacin, have sufficient early strength to resist forces necessary to place gold foil, mat gold or powdered gold.

Pulpal tissue response to ZOE with additives (EBA, hydrogenated rosin, Al_2O_3 or PMMA) is similar to the original ZOE.^{13,14}

Zinc oxide-eugenol cements are mixed as prescribed by each manufacturer by spatulating to wet the powder particles and to develop the consistency desired by the operator. The mixing procedure does not have as critical an effect on the

* Temrex: Interstate Dental Co., New York

physical properties as does the mixing of ZP, but again strength and solubility are improved as the powder concentration increases. Moisture accelerates the setting reaction consequently working and setting times can be modified by carefully controlling the moisture content. A few drops of glacial acetic acid in the bottle of eugenol also accelerates the set.

These cements are radiopaque, Figure 1, and can be used safely in deep cavities without danger to the pulp. The development of secondary dentin, when actual exposures are covered with ZOE with or without additives, has not been as consistent as with Ca(OH)_2 . Therefore, when close to the pulp tissue and there may be an undetected pulp exposure, use of these cements is not the treatment of choice. In such circumstances use of Ca(OH)_2 is indicated.¹⁵⁻²⁰

Calcium hydroxide cements

Calcium hydroxide, Ca(OH)_2 , when mixed with distilled water is an effective agent for the treatment of exposed pulp tissue. Unfortunately the resulting product has no strength. There are several commercial mixtures containing Ca(OH)_2 , e.g., Dycal* and Hydrex, which, when hardened, have sufficient early crushing strength to withstand compaction forces required for amalgam but not direct gold, Table 1.^{4,10} These also permit

* Dycal: L. D. Caulk Co., Milford, Del.

resolution of mild inflammation of the pulp and the formation of reparative dentin. These materials are used mainly in deep cavities for their therapeutic effect on the pulp and remaining dentin. When they are placed on dry dentin they flow freely filling the deepest portions, thus ensuring complete adaptation. Moisture accelerates the set and interferes with coverage of the dentin wall. $\text{Ca}(\text{OH})_2$ is not radiopaque therefore the commercial products add varying amounts of a radiopaque material, Figure 1.

Thanik²¹ reported that with less than 0.1 mm of dentin $\text{Ca}(\text{OH})_2$ is the least irritating base material, with ZOE next and ZP the most irritating. To avoid pulp displacement in deep cavities, $\text{Ca}(\text{OH})_2$ should be carefully placed over the dentin in the pulpal or axial walls for there may be an undetected pulp exposure. Sufficient bulk must be provided so the combined dentin and intermediary base will withstand compaction forces.

These $\text{Ca}(\text{OH})_2$ bases are the material of choice under some composite and resin restorations for there is no eugenol to interfere with polymerization hardening. Berk¹⁹ demonstrated that these materials protect the pulp against irritation by silicate and ZP cements. They are equally effective in protecting the pulp under composite restoratives.

Polycarboxylate cements

The relatively recently developed polycarboxylate cement (PC) is a mixture of a modified zinc oxide powder and polyacrylate acid liquid.²² Durelon, Poly-C,* Zopac,** and PCA*** are representative products currently on the market. The results of several studies²²⁻²⁴ show adhesion by Durelon to enamel and to a lesser extent to dentin. This adhesive action to tooth structure is of interest in its potential use as an intermediary base to modify the contour of tooth preparations. It can be painted on undercut areas then, upon hardening, the crown or inlay preparation can be completed. Its early strength is not known; however, the 24 hour strength,²⁴ Table 1, should be adequate to help protect a thin dentin wall against hydrostatic forces present during cementation of precision castings. It is radiopaque, Figure 1, and is less irritating to pulp tissue than zinc phosphate cement,²²⁻²⁴ indicating a potentially promising material. The extremely critical method for handling to obtain maximum adhesion is discussed later in the cementation section.

* Poly-C: Claudius Ash Inc., Niagara Falls, N.Y.

** Zopac: The Lorvic Corp., St. Louis, Mo.

*** PCA: S. S. White Mfg. Co., Philadelphia, Pa.

Summary

As Manley¹ stated, "The respect the operator shows for the dentin is directly reflected in the health of the pulp." To aid dentists in showing this respect for the dentin there is a wide range of materials available to use as an intermediary base. Choice should be determined by the role the operator wants the material to fill, e.g., strength (ZP), non-irritating (ZOE, modified ZOE, or $\text{Ca}(\text{OH})_2$), adhesive (PC) and radiopaque (all the zinc cements and others with radiopaquing added). Frequently a combination of materials is desirable, such as $\text{Ca}(\text{OH})_2$ to permit formation of a dentin bridge followed by either ZOE with EBA and Al_2O_3 or ZP. Some commercial preparations of $\text{Ca}(\text{OH})_2$, such as Dycal and Hydrex, have sufficient strength to be used alone under dental amalgam compaction.

EBA, alumina and hydrogenated rosin in ZOE have improved the early strength and solubility so these cements can be placed on freshly-cut dentin with confidence that there will be no pulp irritation and that the cement will withstand compaction forces. They can be used as a temporary restoration and the deeper portion retained as an intermediary base when the final preparation is completed at a subsequent appointment. Studies concerning the response of the pulp

tissue to all the modified ZOE cements indicate that they retain the "kind-to-the-pulp" characteristic of ZOE.

As newer materials and modifications of old ones are brought on the market, they should first be evaluated for pulp tissue response. This is true of any product even though it may be only slightly varied in formulation from an already cleared product.²⁵

Table 1

Intermediary Base

	Material	Compressive Strength				Pulp Response **
		Early 7 min		Ultimate 24 hr		
Zinc phosphate	Acid	kg/cm ²	psi	kg/cm ²	psi	(21)
		77	1100 (4)*	1190	16900 (4)	++++
	Water settable	n o t available		(9)	673 9550	(9)
						++++
Zinc oxide-eugenol	Zinc acetate	40	600 (4)	88	1250 (4)	++ (15,20,21)
	EBA & Al ₂ O ₃	400	6000 (11) (ten min)	900	13000 (11) (one week)	++ (13,14)
	PMMA	60	900 (4)	140	2000 (4)	++ (13)
	Cavetec	30	400 (4)	53	750 (4)	++ (4)
Calcium hydroxide	H ₂ O	0	0	0	0	- (15,20,21)
	Dycal	77	1100 (4)	77	1100 (4)	- (4)
	Hydrex	35	500 (4)	100	1400 (4)	- (16)
Poly-carboxylate		n o t available		(24)	350 5000	+++ (24)

* Figures in parentheses represent reference

** Pulp response

a. Exposure

Dentin bridge -

b. Dentin unbroken

Mild inflammation ++

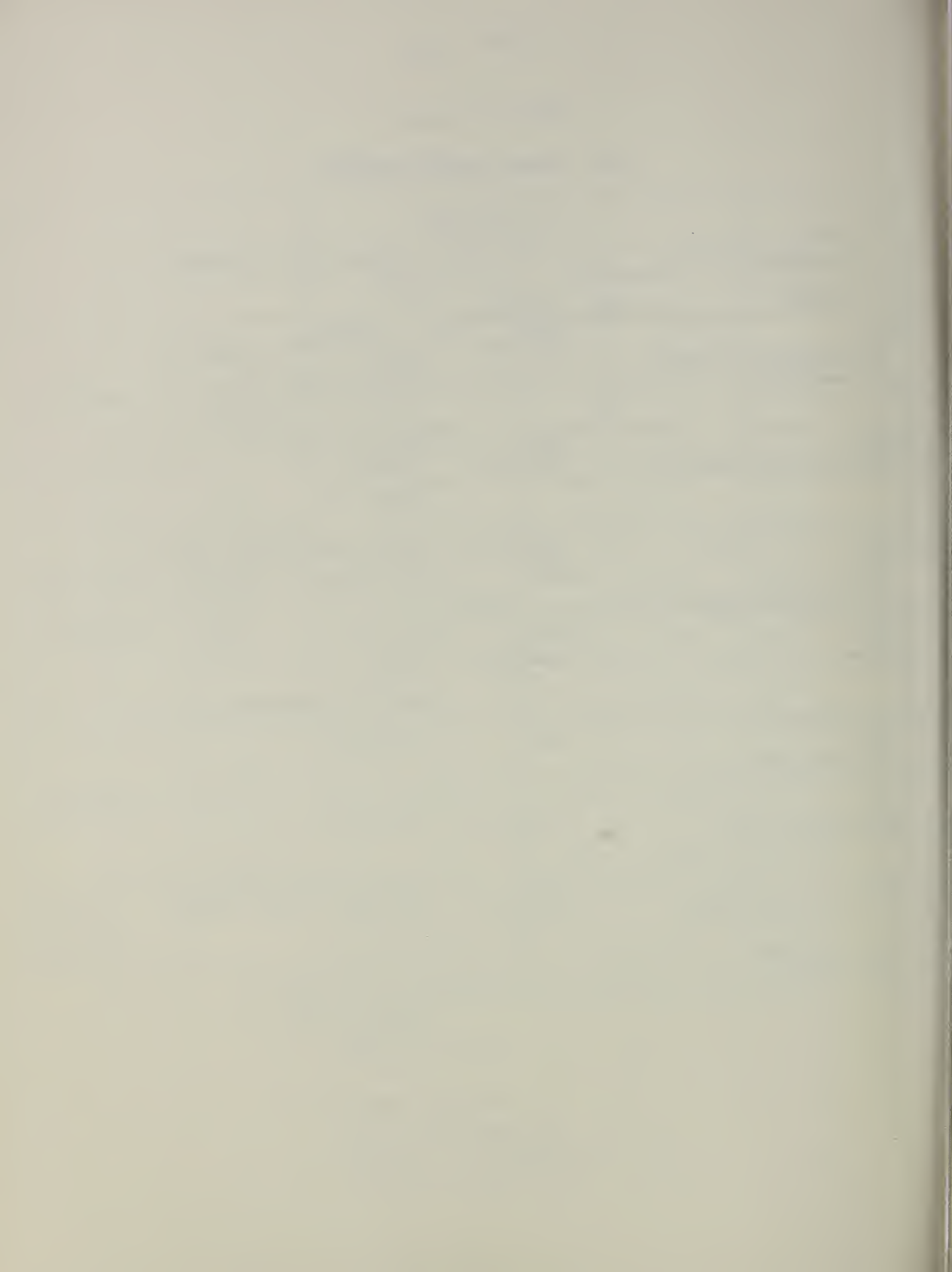
Moderate inflammation +++

Severe inflammation ++++

Table 2

ZINC OXIDE-EUGENOL CEMENTS

Composition		Commercial Products
Powder	Liquid	
ZnO Hydrogenated rosin Zn acetate	Eug.	Intermediary bases Temporary restorations Periodontal packs Root canal sealers
ZnO Hydrogenated rosin	EBA Eug.	Opotow EBA ProCem Ultim EBA EBAC
ZnO Al ₂ O ₃ Hydrogenated rosin	Eug. EBA	Opotow EBA with alumina ProCem with alumina
ZnO PMMA	Eug. Acetic acid	Fynal IRM T & B Opotow temporary
ZnO Polystyrene	Eug. + ?	Kalzinol
ZnO Polycarbonate	Eug. + ?	Decigenol
ZnO Polymerized resin Carnaba wax Zn acetate	Eug. Mineral oil	Cavitec (ingredients blended in two tubes)



Cementation

The term cementation is used to describe the process of using a soft substance which, when hardened, holds a dental restorative appliance to oral structures or to another dental appliance. Currently, retention of the dental restorative appliance is dependent on mechanical, not adhesive or bonding, factors. Some laboratory studies appear promising in the quest for such a bonding agent as active research studies continue.

Included in the physical properties responsible for mechanical retention are: 1) crushing strength; 2) ability to wet the surfaces of the tooth and restoration; 3) resistance to solubility and disintegration in the oral environment; and 4) film thickness. Among many additional factors affecting retention are: 1) total area of the axial walls; 2) degree of parallelism of two opposing axial walls of the preparation, e.g., mesial vs. distal or buccal vs. lingual; 3) accuracy of fit of the restoration; and 4) direction of forces of occlusion in relation to the path of insertion of the restoration or appliance.

The criteria for selecting a cementing medium are based on these physical properties and the biological response of the pulp tissue to the cement. The manner of handling also has a bearing on selection since ease of manipulation is extremely important in a clinical environment.

The operator has some control over each of the above factors by his design of the various tooth preparations and by selecting the correct cement and manipulating it properly. This discussion is limited to the selection and handling of the materials. Crushing strengths of cement, as Worner²⁶ described so well, are a measure of their cementing properties. He said, "The ability of these materials to hold restorations in position appears to be due to the fact that the finely divided particles of cement fill small irregularities in the surfaces and lock the metal in place. To remove requires a fracture of these irregular extensions (exceeding the crushing or shear strength of the material)."

Jorgensen²⁷ presented a comprehensive analysis of various operator controlled factors which affect film thickness. He states that the more viscous the cement, the more difficult it is to seat the restoration completely. Viscosity is dependent on the type of cement, the powder-liquid ratio, duration of mixing time and the temperature. Once the cement is mixed and placed on the materials to be cemented the viscosity has been established. The amount and method of applying the positioning force then becomes the principal factor controlling the residual film thickness at the tooth-restoration interface. The operator should

apply a steady 10 pound force²⁷ until the cement has hardened. A small dab of wet cement on an adjacent tooth provides a good test sample. An additional element contributing to film thickness, which the operator controls, is venting. In this way the hydrostatic pressure is released as the fluid cement escapes. An accurately fitting casting placed in or on a tooth preparation with a minimum of film thickness takes full advantage of both the frictional resistance and the cement's compressive strength.

The American Dental Association Specification No. 8 for dental zinc phosphate cement⁸ defines the limits of certain physical properties, Table 3. Two types of cement, based on powder particle size, are specified. The manufacturer should print on the package which Type, I or II, of Specification No. 8 that the cement is guaranteed to meet. Maximum film thickness permitted for Type I is 25 micrometers μm (0.001 in.). Type II may have a film thickness up to 40 μm (0.0016 in.). Type I is designed to permit seating of precision castings. Type II is suitable for all other uses. These specified physical properties are also used as a standard for comparison of the other classes of cementing materials as listed on Table 3. Manufacturers that claim comparable cementation film thickness for their

materials should state in their directions the powder to liquid ratio that will meet the Type I specification.

Zinc Phosphate Cement

Zinc phosphate cement, ZP, Type I, Tenacin, Fleck's* etc., for cementation continues to be the standard for comparison of other materials being developed for luting precision castings. Although ZP is irritating to the pulp tissue a liner of varnish (two thin layers) or a base of either $\text{Ca}(\text{OH})_2$ or ZOE, covering unaltered dentin effectively protects the pulp. A thin but complete layer of varnish does not reduce the retentive strength of ZP.²⁸ Additives to the phosphoric acid liquid, such as eugenol, are not effective in reducing pulpal irritation. If in the event of a weakened pulp the sedative effect of zinc oxide-eugenol is desired, temporary cementation with one of the ZOE cements is recommended. Permanent cementation with ZP can be delayed until resolution of the hyperemia is complete.

Type I powder is used for cementing precision dental castings. The liquid is handled and mixing is completed as described in the section on intermediary bases. To obtain the cementation consistency the amount of powder incorporated into the liquid is reduced.

* Fleck's: Mizzy, Inc., Clifton Forge, Va.

Should additional working time be required the mixing slab is cooled to just above the dew point. If too cold, water will condense on the slab and be incorporated in the mix and interfere with the hardening reaction.

Another recommended method of prolonging the set is to spatulate a "pinhead" of powder into the liquid and let stand two to three minutes before mixing. This is not as consistent or precise as controlling the mixing slab temperature, but in some situations may be the method of choice. This technique cannot be employed in areas of high humidity because the liquid is hygroscopic and must be dispensed immediately before mixing to prevent upsetting the acid-water balance of the liquid component.

As stated earlier the greater the amount of powder in a given quantity of liquid within the limits of the system the better are the physical properties.²⁹ Therefore, careful mixing is important to: 1) increase the strength; 2) reduce solubility; and 3) provide a consistency which permits seating a precision casting,²⁷ Table 3. Careful mixing means using a cooled slab, incorporation of small increments, thoroughly wetting each particle of powder before adding more, using heavy pressure on a flexible spatula, spreading the mix over a large area of the slab and using the full time prescribed by the manufacturer to complete the mix. This is one and a half minutes for most brands.

Water settable zinc phosphate cements are inferior to the conventional ZP cements and should not be used, Table 3.^{30,9}

Polycarboxylate cement

The polycarboxylate cements, (PC), Durelon, Poly-C, Zopac and PCA have been introduced for the express purpose of cementing stainless steel to enamel.²² This cement is formed by mixing zinc oxide powder with polyacrylic acid liquid. Smith²² claims that while the carboxyl bonds are still available immediately after mixing, they form a bond with the calcium ions in the tooth, thus effecting true adhesion to the enamel and to a lesser extent to dentin.²² Etching or other pretreatment of the enamel surface does not change the bond strength.³¹ Thermal cycling apparently has no effect on strengths evaluated by static fatigue, dynamic fatigue and peal bond tests.²² Water uptake and solubility are quite high in laboratory testing, indicating that considerable long term clinical testing is required before routine use can be recommended.

Strict observance of the mixing instructions is necessary to obtain the maximum properties of the polycarboxylate cements. The powder to liquid proportion for cementation should be between $1\frac{1}{2}$ to $2\frac{1}{2}$ parts of powder to one part liquid by weight.

The desired consistency should be developed through trial and error. Once the proportions are determined mixing can be completed by bringing all the powder into the liquid and spatulating quickly. The cement should be completed in less than 30 seconds and in contact with the restoration and tooth immediately thereafter. Correct powder to liquid ratio and prompt usage, well before the gloss disappears, develops the strongest adhesive and physical properties. Operators who have used this cement are enthusiastic over the lack of discomfort experienced by the patient during the seating of the restorations.

Although polycarboxylate cements were specifically formulated for cementation of stainless steel orthodontic appliances to enamel, tests have been made on retention of gold cast crowns on teeth prepared with a 10° taper.³² Results have also been reported of laboratory testing of retention of gold castings in Class I cavities prepared in recently extracted teeth.²⁴ A comparable force was required in both experiments to remove crowns cemented with zinc phosphate and polycarboxylate. ZOE with polymer had about one half the retentive strength of PC. These laboratory tests do not indicate a superiority over ZP for cementing gold crowns. Instability of this cement in water, high uptake and solubility,²³

indicates potential risks in its routine use. Preliminary reports, however, are very favorable from dentists who are meticulous in following the recommended handling technique.

Modified zinc oxide-eugenol and EBA cements

The modified zinc oxide-eugenol and EBA cements, discussed in the Intermediary Base section, are mixed to cementing consistency and used as luting agents for precision castings. Some have physical properties, as indicated on Table 3,^{12,33} comparable to ZP and viscosity and wetting properties which are easier than ZP to use in seating precision castings. These new EBA, Al_2O_3 filled cements continue to have the original ZOE pulp protective and sedative characteristics.^{13,14}

In light of these favorable qualities these cements are growing in popularity as luting agents. The EBA cements with Al_2O_3 have compressive strengths and retention values similar to ZP, Table 3, but are somewhat higher in their solubility values.¹²

Solubility and disintegration data are based on the specification test³ that measures the residue after 24 hours. Another aspect of disintegration related to solubility but not determined by the 24 hour residue is the loss of eugenol as shown by Wilson and Batchelor.³⁴ These investigators claim that aqueous leaching of eugenol from ZOE cement

(unmodified) is continuous as the cement matrix hydrolyzes to eugenol and zinc hydroxide. Thus, the cement in 20 weeks time loses mechanical strength and disintegrates. This long-term process is not evident in the 24 hour specification test.

As with ZP, mixing for intermediary base and cementation differ only in the proportion of powder added to a given amount of liquid.

Well controlled long-term clinical studies of cementation with modified ZOE or EBA have not been reported. Two progress reports^{35,36} have indicated favorable results over a short period of time. However, other operators are observing failures after one year, especially in those cases involving bridge abutments or short crown teeth. Consequently, until long-term (3 years or more) well controlled studies are reported these modified ZOE cements are not recommended for general use in cementation of fixed prostheses.

Silicophosphate cement

Silicophosphate cements such as Kryptex*, Lucent** and the recently introduced Fluorothin* might be termed hybrid cements for the powder is a mechanical mixture of about 9 parts silicate and 1 part zinc phosphate cement.²⁹ Since the

* Kryptex, Fluorothin: S. S. White Mfg. Co., Philadelphia, Pa.

** Lucent: L. D. Caulk Co., Milford, Del.

liquid is similar to that for ZP the same handling precautions are necessary.

The compressive strength of these products is superior to ZP while the solubility is inferior,^{37,38} Table 3. The fluoride which is a basic ingredient of the silicate portion, is gradually leached out and may increase the resistance of the adjacent enamel to solubility in mouth fluids.³⁹ Along with these qualities the ability to retain or hold crowns and castings is almost as strong as ZP.²⁸ The manipulative characteristics, viscosity and film thickness, however, make it difficult to seat accurately fitting castings. One brand, Fluorothin, meets the film thickness specification of 25 μ m for Type I cement. A favorable feature is the silicate-like translucency which blends well esthetically with porcelain and acrylic restorations. Consequently, this class of cement is used principally for their esthetic value in cementing crowns and porcelain inlays.

Acrylic resin cements

The physical properties, esthetic qualities and manipulative characteristics of acrylic cements such as Justi Resin Cement* are similar to the direct filling acrylic resins. Solubility,

* Justi Resin Cement: H. D. Justi, Philadelphia, Pa.

which is near zero, and surface wettability are two properties which are superior to ZP. This surface wettability, or adaptation, makes it seem as though a bonding reaction has occurred. The apparent bonding is lost, however, as the cement absorbs water and the cement-tooth interface becomes wet.

The acrylic resins are mixed by blending carefully measured quantities of powder and liquid. Unless otherwise specified, the desired portion of powder is placed in a mound on a paper mixing pad. A flexible stainless steel spatula is used to make a crater in the powder and the corresponding proportion of the viscous liquid is dropped into the crater. After letting the liquid soak into the powder for a few seconds it is rapidly mixed, using approximately 1 square inch of the mixing area, to a homogenous mass. The total elapsed time from adding the liquid to the completion of mix should be less than 30 seconds. Immediately after cementation the excess material must be removed from the tooth, restoration and spatula, for any that is permitted to set is most difficult to remove. The resin cements contribute to the desirable esthetic qualities of porcelain inlays, thus they, like silicophosphate cements, are used principally for their favorable appearance.

Polyurethane

In recent years polyurethanes have attracted much attention as potential adhesive liners and tissue sealants. These materials are still in the experimental stage but appear promising.

The isocyanates used in urethane formulations act as water scavengers, reacting with residual water on the tooth surface to form carbamate intermediates. The carbamate intermediate immediately decomposes to amines that in turn react with excess isocyanate groups to yield a substituted urea, polyurethane. Eventually, as the tooth surface is dried the polyurethane is crosslinked. Urethanes can be formulated to yield elastic films that appear suitable for use as adhesive liners between dentin or enamel and conventional and composite resins and amalgam restorations.

A modified polyurethane has been used to cement restorations to teeth without undercutting or removing an excessive amount of tooth tissue.⁴¹ The bonding of acrylic restorations was improved by adding a coupling agent to the urethane. Etching the enamel with citric or formic acids before applying the urethane further increased the retention of the acrylic restorations.

Temporary cementation of completed restorations

Two of the factors controlling the choice of a material for temporary cementation are: 1) the need for a sedative material and 2) the compressive strength required for retention of the temporary coverage. Temporary cements vary from a sedative ZOE that can be prepared with varying compressive strengths to the high compressive strength of ZP that is irritating to the pulp tissue.

Zinc oxide-eugenol cements can make a hypersensitive tooth less sensitive and more receptive to subsequent permanent cementation. Recently cut, non-sensitive dentin remains comfortable when sealed against oral fluids. Either ZOE or ZP will maintain a marginal seal if formulated with the appropriate compressive strength to maintain the retention of the restoration. Both Horn³⁴ and Gilson⁴² discuss selecting temporary cements according to compressive strengths. An accurately fitting restoration is almost self retaining; however, a suitable material is needed to develop the marginal seal.

Horn³⁴ gives the following directions for preparing a non-setting ZOE. Trial mixes should be made of a commercial ZOE with varying amounts of silicone grease (Dow Corning 3 compound* or R. M. Silicone grease**) and about 1% methyl or

* Dow Corning, Midland, Michigan

** Rocky Mountain Products, Denver, Colorado

propyl paraben to establish the appropriate consistency to permit seating a single or multiple casting. The paraben additive contributes to the plasticity of the mix and is said to increase the bacteriostatic or fungistatic capability of the cement. This non-setting material maintains the marginal seal and will not require undue force to remove the restoration when ready for further treatment.

As the accuracy of fit or the self-retaining capacity of the temporary coverage is reduced, a more adhesive, stronger temporary cementation material is needed. This can be made by mixing varying amounts of petrolatum with ZOE. An ill-fitting temporary crown may need the strength of a strong cement, preferably ZP. In these cases varnish is used to protect the pulp and the temporary crown can be cut off so that chance of damage to the preparation during removal is reduced.

Table 3

Physical Properties of Various Materials Mixed to Cementing Consistency

Material	Time of Setting	Compressive strength 24 hr		Film thickness	Solubility and Disintegration (by weight)	Diametral tensile strength 24 hr	Relative retention ZP = 100
(8) ADA Spec. #8 Type I (cementing)	min	kg/cm ²	psi	μm	%	kg/cm ² psi	No speci- fication
	5 min. 9 max.	700	9956	25 maximum	0.2 maximum	No specification	
acid ZnPO ₄ water settable	5.5	(12) 1050	15000	18	(12) 0.2	820 (4) 12300	(28) 100
	8.5	(30) 630	9000	75	(9) 0.4	Not available	Not available
ZOE + EBA and alumina	(12) 9.5	(12) 955	14000	26	(12) 0.05	49 (33) 700	(28) 100
ZOE + polymer	(33) 6-10	(33) 490	7000	32 (4)	(33) 0.08	(33) 70 1000	(28) 55
Silicophosphate	(37) 3½-4	2800* (37)	29500*	42 (38)	(37) 0.4	Not available	(28) 80
Resin cement	(40) 4-10	(40) 670**	** 9500	(40) 10-60	(40) 0.0-0.4	Not available	Not available
Polycarboxylate	(24) 7.5	(24) 320	4600	21 (24)	(23) 0.6	(23) 55 800	(24) 100

* 7 days

** 1 hour

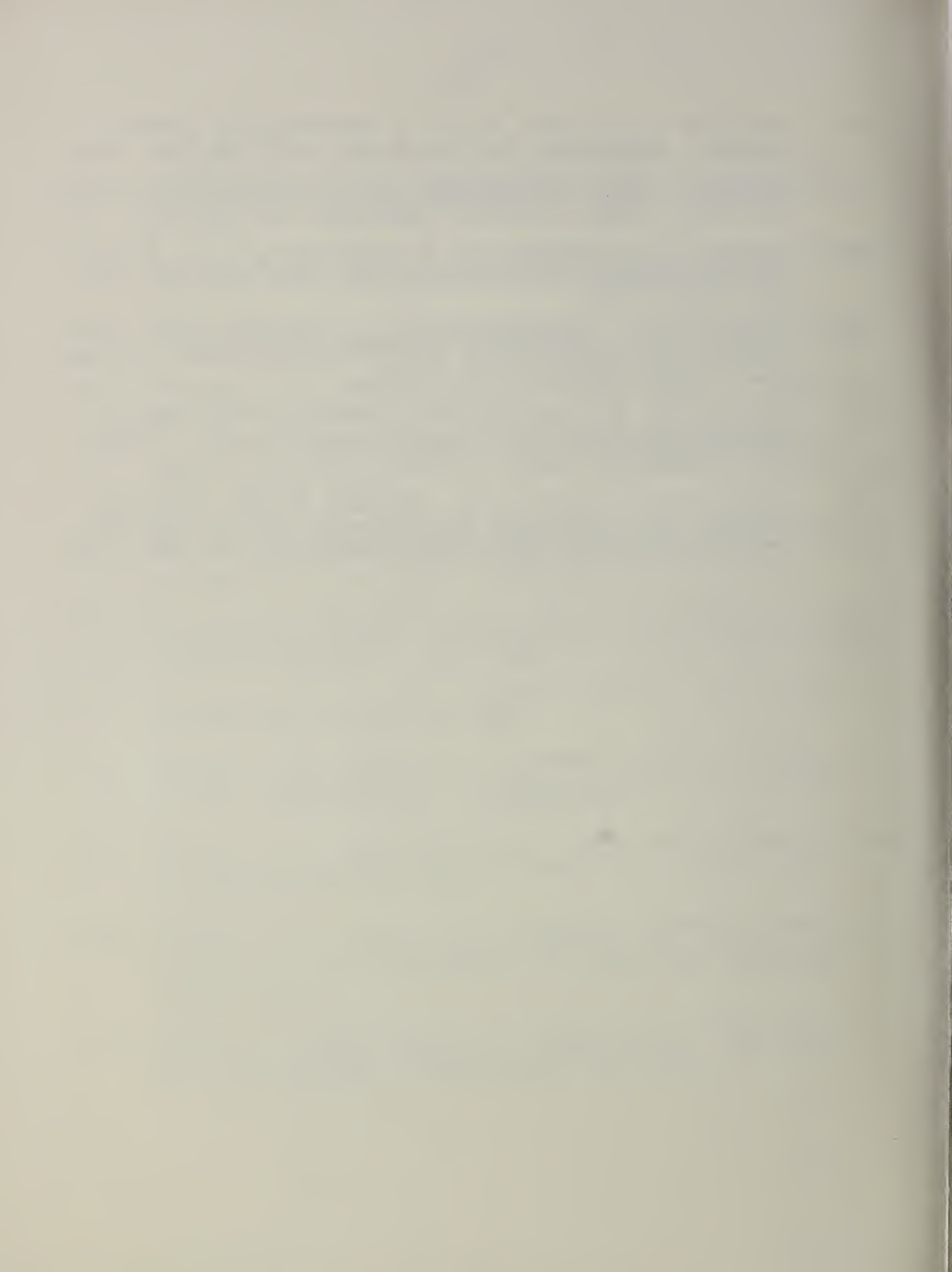
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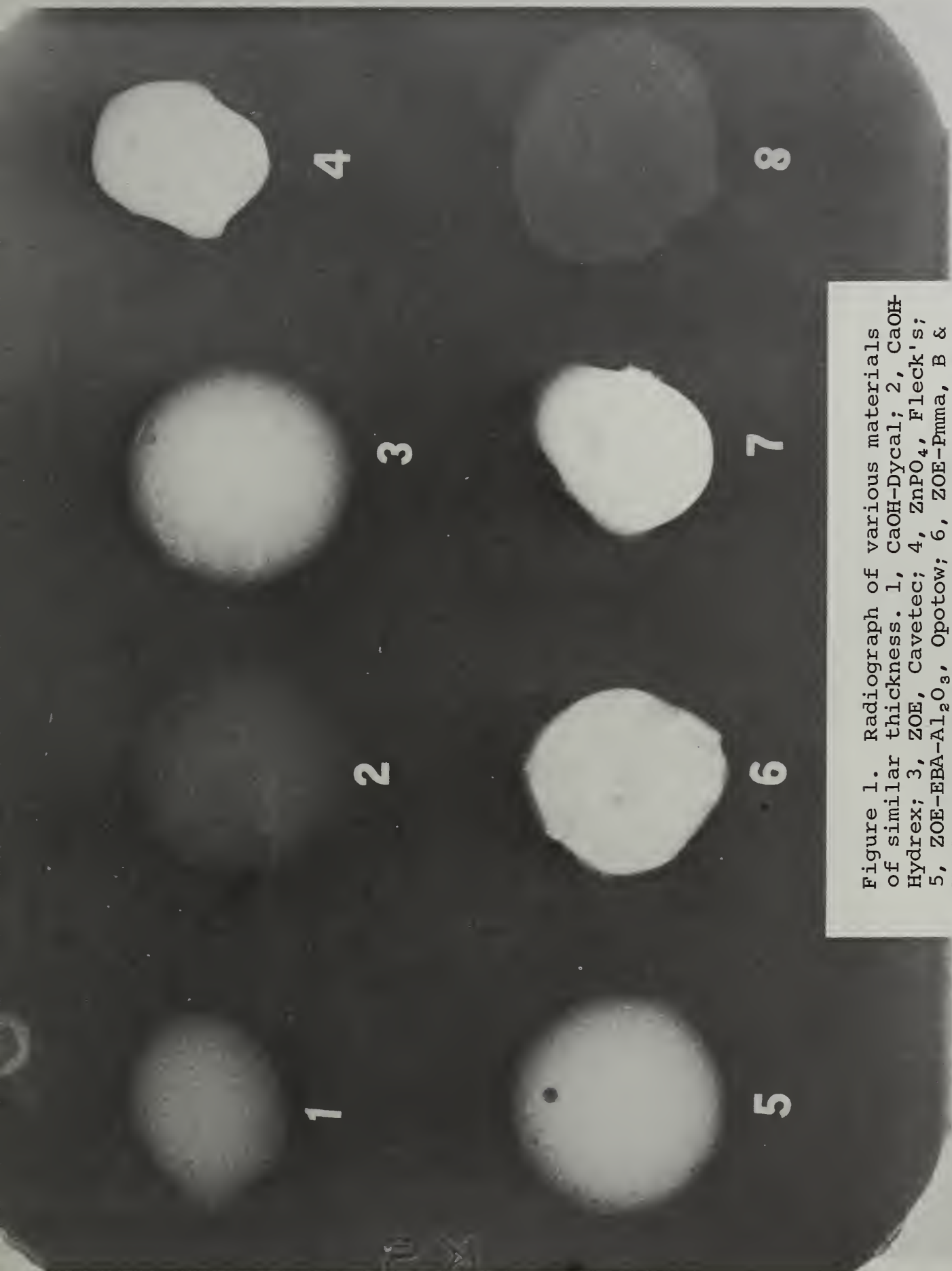


Figure 1. Radiograph of various materials of similar thickness. 1, CaOH-Dycal; 2, CaOH-Hydrex; 3, ZOE, Cavetec; 4, ZnPO₄, Fleck's; 5, ZOE-EBA-Al₂O₃, Opotow; 6, ZOE-Pmma, B & T; 7, ZPA, Durelon; 8, Composite, Adaptic.

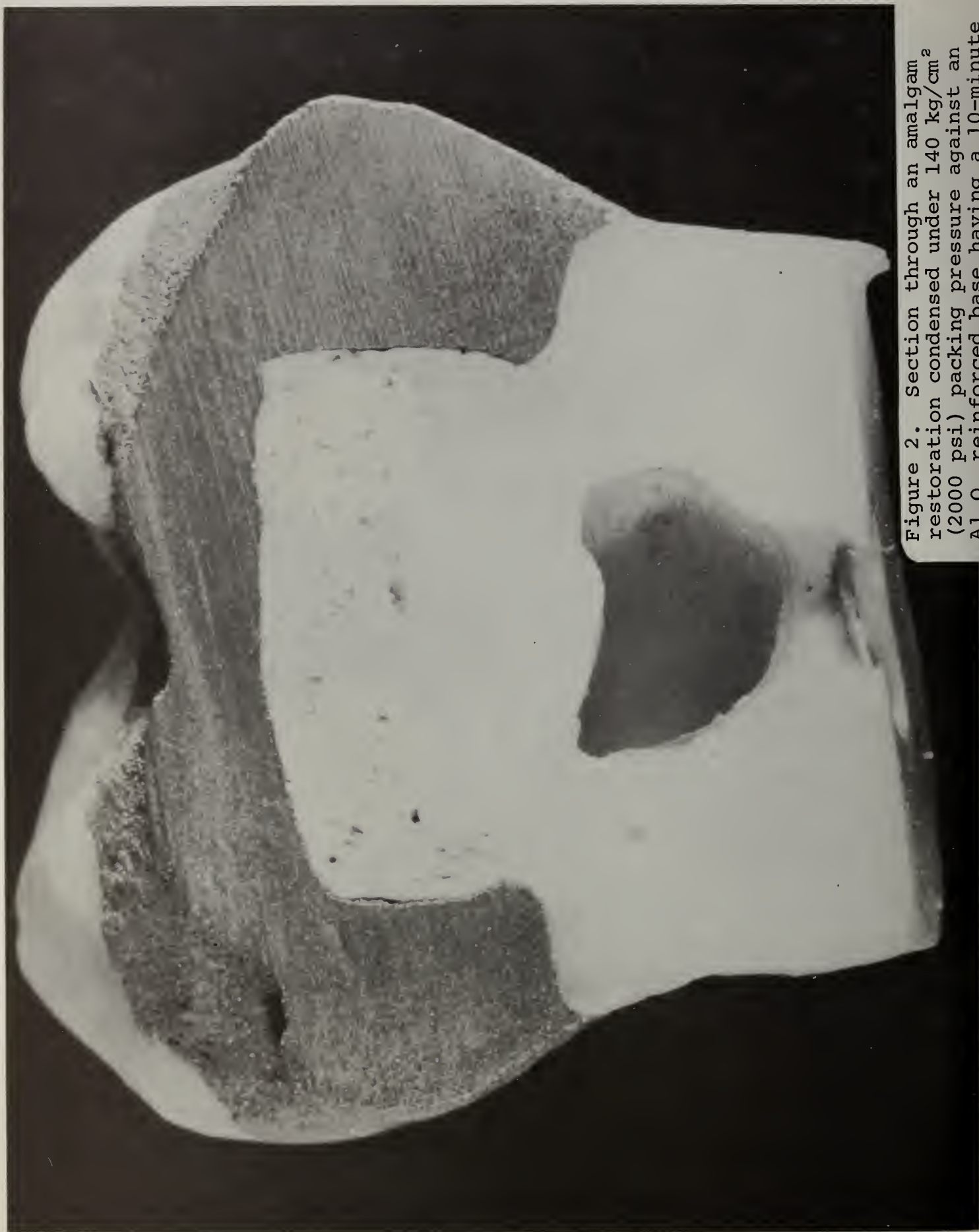


Figure 2. Section through an amalgam restoration condensed under 140 kg/cm^2 (2000 psi) packing pressure against an Al_2O_3 reinforced base having a 10-minute compressive strength of 450 kg/cm^2 (6000 psi).

