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Dental materials, 1975: a review of the literature

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There has been, in 1975, a continuation of the considerable volume of literature related to dental materials science which has characterized other recent years. In particular, several notable books appeared, as well as many interesting research abstracts and a number of patent specifications. However, considerations of space make it necessary to confine this review to periodical literature and to exercise considerable selectivity. The selection is to some extent arbitrary, yet it is hoped that the result will serve as a useful reference to current trends in the field.

AMALGAM

Espevik (1975a) examined the one-hour compressive strengths and the creep rates of 22 brands of amalgam (Espevik and Sörensen, 1975) and the effect of heat treatment on creep (Espevik, 1975b). Large variations were found in compressive strengths and creep rates. It is suggested that a medium one-hour compressive strength is clinically desirable, since a low one-hour strength will predispose to early fracture and a high one-hour strength is associated with a high mercury content. Creep was lowest in spherical amalgam and seemed to be unrelated to $\gamma 2$. Heat treatment can lower creep rates. Espevik (1975c) questions the need for a flow test for amalgam in a standard specification, if a one-hour compressive test is incorporated. There is no correlation between flow and creep, but a creep test is needed in a specification since it is related to marginal breakdown.

In a series of papers on the reactions of amalgams Sarkar and Greener (1975a, b and c) found that *in vitro* corrosion is related to $\gamma 2$ and Cu_6Sn_5; that the corrosion resistance of dispersed phase amalgam improves with ageing; that addition of copper improves corrosion resistance; and that gold is not effective in improving corrosion resistance.

An electron microprobe analysis of various amalgams was the subject of a comprehensive report which, in general, confirms previously reported studies employing other techniques (Mahler, Adey and van Eysden, 1975).

Vrijhoef, Spanauf and Driessens (1975) made specimens of amalgam with varying mercury contents. Specimens were stored at 37°C and the dimensional changes recorded after 24 h and after 3 500 h. Specimens containing more than 50 per cent mass of mercury were found to expand excessively.

Four methods of determining the setting rate of amalgam were compared by Ohashi, Ware and Docking (1975). The methods were a mercury absorption method, a guillotine method, a Gillmore needle method and an early compressive strength method. The correlation of the first method with the other three was poor, although the correlation between the last three methods was acceptable. The authors consider the early compressive strength test to be the most satisfactory for standardization purposes.

Okabe, Hochmann and Sims (1975) have studied the reaction of mercury applied to silver-tin alloy electroplated with mercury. The method was found to be particularly useful as a means of studying the formation of phases in amalgam and the rate and manner of crystal growth therein.

Public health authorities in New Zealand have set up a commendable scheme to combat the mercury intoxication hazard in 1 350 school dental clinics (Anonymous 1975). The report describes briefly the regular testing of atmospheric mercury levels, excretion testing and a decontamination method.

CASTING ALLOYS AND SOLDERS

Civjan *et al* (1975) examined 2 gold casting alloys for porcelain veneering and found that they are hard, strong and rigid, but not very responsive to heat hardening. Furthermore, neither alloy can be cast satisfactorily at the temperature recommended by the manufacturer.

Morris and Asgar (1975) examined 4 new base metal casting alloys. Two of the alloys contained large amounts of iron (46,0 per cent in one case and 63,3 per cent in the other), while the other 2 were fairly typical cobalt-chromium alloys, although 0,1 per cent of platinum was incorporated in one of them. The yield strength, tensile strength, elongation, Young's modulus and hardness were measured for each alloy and compared with figures for a well-known cobalt-chromium alloy. The distribution of additives in castings was analysed by electron microprobe. It was found that the

addition of platinum to one alloy achieved no improvement. The iron-based alloys had much higher elongation than the others, but their poor resistance to permanent deformation made their suitability for clasps questionable. In the light of their findings the authors make observations which suggest that the American specification for cobalt-chromium alloys needs some revision.

In a series of 6 papers Lewis (1975a, b, c, d, e and f) reports the results of a comprehensive examination of the properties of a nichrome denture base alloy, with particular attention to the effects of multiple meltings and the nature of internal flaws. Space does not permit detailed discussion of this work, which is commended to all with an interest in such alloys.

An aluminium bronze alloy was used to cast partial denture bases, which were subsequently electroplated with a tin-nickel alloy, (Murray, 1975). It is claimed, on the basis of a 6-month clinical trial, that the plating is effective in preventing corrosion, which has previously been reported to occur with the aluminium bronze alloy.

The atmospheric concentrations of beryllium resulting from the finishing of castings made of a base metal alloy containing 0,470 per cent beryllium were determined under various conditions (Hinman *et al*, 1975). The finding that there is a health hazard to the technician in the absence of suitable ventilating equipment or effective filtration by a mask confirms the work of Moffa *et al* (1973).

The loss of cadmium from 6 dental gold solders was measured by Bergman and Ginstrup (1975). The experiments were conducted *in vitro*, but it would seem unlikely that cadmium intake from soldered restorations alone would be harmful in clinical conditions.

Preston and Reisbick (1975) examined the tensile strength of laser-welded non-precious and gold alloys and compared the results with other methods of joining alloys. The laser weld proved superior in the case of non-precious alloys, but was not advantageous when applied to precious alloys.

The tensile strengths and electron micrographic appearances of oven and torch soldered joints between ceramic-metal alloy pieces were examined by Stade, Reisbick and Preston(1975). Oven-soldered joints were found to be markedly stronger than torch-soldered, with less porosity evident. A gap of 0,76mm between the pieces gave stronger joints than smaller gaps.

CEMENTS

Barton *et al* (1975) experimented with zinc polycarboxylate cements which were modified by 16 additives, the liquids also being modified in several ways. It was found that the mechanical properties of the cements could be substantially improved without detracting from other desirable properties.

The electrical conductivity of 5 commercial zinc polycarboxylate cements was employed in examining their setting characteristics, which were variable, although all the cements had setting reactions which continued for at least 1 h (Braden and Clarke, 1975).

Kafalias, Swartz and Phillips (1975) found that increasing the powder-liquid ratio of a zinc polycarboxylate cement increased the compressive and tensile strengths and the film thickness, while reducing the adhesion of the cement.

Farah, Hood and Craig (1975) studied the relationship between failures of loaded amalgam restorations and the linings subjacent to those restorations. They concluded that the modulus of elasticity of the supporting cement is of greater importance than its compressive strength.

Bryant and Wing (1975) have directed attention to the fact that a luting cement and a therapeutic cement may not always be compatible in terms of mutual adhesion. They investigated the relationships, in terms of mutual adhesion, of several typical materials and advise that note should be taken of these relationships in clinical practice. They further demonstrated that the use of cavity varnish will substantially reduce the retention of inlays and crowns.

The *in vivo* dissolution of 4 cements used as luting agents was studied by Richter and Ueno (1975). The cements were a zinc silicophosphate, a zinc phosphate, a ZOE-EBA and a zinc polycarboxylate. The cements were placed in cavities cut in gold pontics prior to placement of bridges in 9 patients. The bridges were removed after a year and the state of the cements compared with records made at the start of the investigation. It was found that the zinc silicophosphate cement showed least dissolution, the zinc phosphate more, followed by the ZOE-EBA and zinc polycarboxylate. The position was reversed when the cements were tested by the A.D.A. distilled water method, the zinc polycarboxylate cement showing the least dissolution, followed by zinc phosphate, ZOE and zinc silicophosphate being the most soluble.

The solubility and disintegration of 5 luting cements were tested by the standard distilled water test method and all were found to meet standards requirements (Valcke, 1975). However, the results do not correlate well with clinical trials and the test method is of limited usefulness.

The impact strength of a polycarboxylate cement and 3 other cements when used to attach gold alloy discs to a dentine surface was investigated (Stevens, 1975a). It was found that the polycarboxylate cement provided superior strength compared to the other 3 cements tested. The same 4 cements were the subject of a further investigation (Stevens, 1975b). Inlays were cemented into prepared teeth and a tensile force was applied. The polycarboxylate cement and a zinc phosphate cement yielded results superior to the other 2 cements tested. The polycarboxylate specimens showed failure wholly or partially within the cement.

The retentive properties of zinc phosphate, zinc polycarboxylate and ethyl cyanoacrylate cements when used for luting pins in extracted teeth were compared by Trabert, Caputo and Hanson (1975). The cyanoacrylate cement was less retentive than the other cements, which provided the best retention when the size of the pin was closely matched to the size of the pinhole.

Three acrylic, two bis-GMA and 3 zinc polycarboxylate cements, which are used in orthodontic practice, were the subjects of determinations of water absorption and water solubility (Moser *et al*, 1975). The solubilities of the polycarboxylate cements were about three times those of the synthetic resin cements and the ratio of absorption to solubility of the resinous cements was about 10 to 1, and about 5 to 1 in the polycarboxylates.

A fluoride-containing silicophosphate cement, intended for luting and stated by its makers to cause less pulp damage than other cements was subjected to cell culture and usage tests (in monkeys) by Dahl, Tronstad and Spanberg (1975). The results led to the conclusion that the material is so injurious to the pulp that its use in vital teeth is contraindicated.

Three calcium hydroxide preparations were compared with zinc oxide/eugenol and zinc phosphate cements in their effects on rat pulps and their permeability (Karjalainen and Forsten, 1975). Rather surprisingly, there were no definite differences in pulpal responses to the materials, but one phosphate and one calcium hydroxide preparation were found to be permeable.

Several variations in the formulation of glass-ionomer cement are discussed by Crisp *et al* (1975) who find it possible to alter the working and setting times and other properties of ASPA.

Fell and Combe (1975) have attempted to compress cement powders into tablets and found that some powders lend themselves to this process. It would presumably aid in proportioning cements and be more economical than capsulating.

COMPOSITE RESINS, FISSURE SEALANTS AND BONDING SYSTEMS

A clinical trial of 4 brands of composite resin, using an unfilled PMMA and a conventional silver amalgam as controls, was reported on by Leinfelder *et al* (1975). One hundred and forty-three amalgam, 88 PMMA and 668 composite restorations were observed for periods ranging up to two years. It was found that the colour match with PMMA was superior to that with composites; composites resisted wear better than PMMA; wear of posterior composite restorations was so much greater than that of amalgams that composites cannot be recommended for restorations subject to occlusal stress; composites showed good marginal adaptation and resistance to interfacial staining; and none of the composite restorations exhibited clinical evidence of secondary caries.

A number of restorations fabricated from 4 different brands of composite resin were kept under observation for 3 years by Smales (1975). Regardless of brand many restorations developed defects and, rather disturbingly, there was a high incidence of inflammatory changes in related gingival tissues. The suitability of these resins for subgingival restorations becomes increasingly questionable. The author considers, for the usual reasons, that the radiolucency of the materials is a disadvantage, disregarding the fact that it is sometimes clinically helpful to be able to demonstrate the presence of a radiopaque lining.

A clinical and laboratory study of the surface characteristics of one brand of composite resin filling was undertaken by Weitman and Eames (1975). In the laboratory study specimens finished by 5 different techniques were compared, using a surface roughness measuring machine. Appreciable roughness was demonstrated, although the roughness of specimens which had simply set against a strip was relatively low. Specimens were also examined by scanning electron microscopy, which showed numerous air inclusions and filler particle projections. The clinical study demonstrated an affinity for plaque. This work again raises the question of the suitability of composites for gingival-related restorations.

Lee *et al* (1975) placed restorations of a composite resin in 12 human teeth which were to be extracted in the course of orthodontic treatment. Nine teeth were extracted after 14 days and 3 after 98 days. Histological examination showed no inflammatory pulpal response in one 14-day specimen and in all three 98-day specimens. The specimens showing no inflammatory pulpal responses were all Class I cavities. The remaining eight 14-day specimens were all Class V cavities and all showed inflammatory pulpal responses. The resin is intended specifically for the restoration of cervical erosions.

The same material is the subject of another report (Lee, Orlowski and Enabe, 1975). About a score of properties were investigated and comparisons made with several other materials. The authors conclude that the material is suitable for use as a coating material in camouflaging stained or malformed enamel.

Stanley, Going and Chauncey (1975) reported on the pulpal effects of 2 composite resins in 150 human teeth. Their detailed histological report leads them to recommend that pulp protection should be employed in all cases where these 2 resins are employed.

Rafei and Moore (1975) compared the marginal leakage of 2 composite resins, placed in cervical cavities and tested by dye penetration. A two-paste material was inserted without any addition, whereas an ultraviolet polymerized material was inserted after acid etching and priming with an unfilled resin and coated with the unfilled resin after insertion. Seventy-two percent of the two-paste restorations leaked but none of the ultraviolet activated restorations leaked.

Cavities cut in extracted teeth were filled with 3 different brands of composite resins, the adaptation of the resins to the margins and walls of the cavities being subsequently examined by dye penetration and by scanning electron microscopy (Al-Hamadani and Crabl 1975). The 3 brands of resins all showed varying degree of defective adaptation.

A novel method for the estimation of the microleakage of restorative materials has been described by Jacobsen and von Fraunhofer (1975). It depends on the measurement of conduction by an electrolyte in the space between the test material and a glass tube. Filled and unfilled resins were tested and the method proved highly sensitive, but the relationship between adaptation of a resin to a glass surface and to a calcified tooth tissue surface would seem to need elucidation.

Working with extracted human teeth Jörgensen,

Asmussen and Shimokobe (1975) demonstrated that resins attached to the acid etched enamel margins of cavities could induce defects in the enamel by polymerization contraction, thermal contraction and elastic hysteresis. It would seem that *in vivo* studies might be valuable.

Asmussen (1975) studied the polymerization contraction of a dozen composite resins and found that the contraction and consequent marginal defects are related to the low-viscosity monomers in the resins.

A new use for composite resin was proposed by Stahl and O'Neal (1975), who described a technique for fabricating a composite resin post and core *in situ* for the reception of a jacket crown. The method offers economic advantages, since a patient visit can be eliminated, laboratory work can be eliminated and a saving in precious metal can be effected. The method has been used for 36 cases. Three failures were due to trauma and were successfully retreated. If the method proves to be a long-term success it could be of great value.

Another use for composite resin is found in a method of fabricating a temporary fixed partial prosthesis, described by Stolpa (1975). Acrylic resin denture teeth are attached to abutment teeth by composite resin.

The relationship of wear of restorative materials to other properties and the relationship of laboratory tests of wear to clinical observations are both poorly understood and sometimes contradictory or poorly correlated (Phillips, 1975; Craig and Powers, 1976). A method of wear testing which is claimed to correspond with clinical observations is described by Powell, Phillips and Norman (1975). Human enamel was employed to abrade amalgam and composite resin.

The shelf life of an ultraviolet activated resin after the addition of benzoin methyl ether was found by Low and von Fraunhofer (1975) to be 6 days and they reported that refrigeration was unnecessary.

The strength of the bond between mature and new composite material of 4 different brands was tested by Causton (1975) and found to be sufficient to justify the repair of worn restorations. Bond strength was found to be related to low viscosity. It is, however, intriguing to note that the material considered by Causton (1975) to be the least viscous was found to be more viscous than other brands by McLundie and Messer (1975).

Williams, von Fraunhofer and Winter (1975) report a study of fissure sealants. The materials studied were 3 resinous materials, 2 of which are activated by ultraviolet radiation, and 2 cements, one a zinc polycarboxylate, the other a glass-ionomer. Microhardness, water absorption and water solubility were examined. Microhardness was found to vary with time, as did the other characteristics. Similar time-related changes in hardness in 3 sealants were found by Watkins (1975).

A method of examining the condition of fissure sealants by taking an impression in a synthetic elastomer, pouring an Araldite model and examining the model by scanning electron microscopy is described by Davies, Tranter and Whitten (1975).

The penetration coefficient of a fissure sealing resin was measured by Fan, Seluk and O'Brien (1975) and was found to be 2,5 times greater at 37°C than at 25°C. It was also shown that the rate of penetration of the resin is dependent on the penetration coefficient.

Meurman *et al* (1975) report a clinical trial of a fissure sealant activated by ultraviolet radiation. The subjects were 146 children and the period of observation was 18 months. In 241 permanent teeth the sealant was retained in 97,5 per cent of the teeth, while in 95 primary teeth the retention rate was 92,5 per cent. The caries incidence in sealed permanent teeth was 3,3 per cent (controls 26,3 per cent). The caries incidence in sealed primary teeth was 9,4 per cent (no controls). The loss of sealant from permanent molars was associated with salivary contamination.

Jedrychowski and Reisbick (1975) examined the bond strengths of several resin systems to bovine enamel. They concluded that primers may not confer any great advantage, the acid etching technique appearing to be more important. These conclusions seem to be supported by a scanning electron microscopic study of the adaptation of resins to etched human enamel (Jörgensen and Shimokobe, 1975). The study used contralateral pairs of teeth, which Jörgensen (1975) had shown to etch in a symmetrical manner. In another S.E.M. study of 5 resins one of the materials was found to be too viscous to adapt to an etched surface (McLundie and Messer, 1975).

In a study of the adhesion of a resinous restorative to human enamel and dentine Retief (1975a) was unable to confirm the manufacturer's claims for adhesiveness of the material and the value of a surface-active comonomer supplied with the material as an adhesion promoter appeared to be dubious.

The improvement of the attachment of polymers to calcified tooth tissues by a "mordanting" process, involving the use of metal ions to provide bonds to the hydroxypatite of the tooth, has been studied with the aid of a synthetic hydroxyapatite by Misra, Bowen and Wallace (1975) and is of interest as another approach in the search for satisfactory adhesive restorative materials.

Low, von Fraunhofer and Winter (1975) made a study of the tensile bond strength of an ultraviolet activated fissure sealant applied to extracted human teeth which had been treated with fluoride solutions after etching the enamel. They found that the use of an acid phosphate fluoride reduced the bond strength, while stannous fluoride had the opposite effect.

The effects of 3 enamel etching acid solutions were compared by Retief (1975b) and it was found by surface roughness measuring that a 50 per cent solution of orthophosphoric acid with 7 per cent zinc oxide produced the maximum effect. Scanning electron microscopy was used in observing the etched surfaces and their relationship to an adhesive.

Duff and El Motayam (1975) analysed a variety of phosphoric acid enamel etching solutions, which were found to vary considerably from their stated compositions.

The pulpal reaction to a citric acid preparation was investigated in human teeth by Tidmarsh and Huxley

(1975), who came to the conclusion that the preparation did not cause significant pulpal damage in young healthy teeth.

Khowassah *et al* (1975) investigated the bond strengths of 2 direct bonding orthodontic bracket systems. The specimens were stored for various periods before testing. In tension the polycarbonate brackets failed before the adhesive bond to the enamel of the specimen teeth, although they withstood shear tests. In the light of these *in vitro* tests it was concluded that the direct bonding systems should be clinically useful and that the brackets could withstand the forces used in clinical tooth movement. In another study the effect of environmental variation on orthodontic bonding systems was examined and marked changes in temperature and moistness were shown to be harmful (Bishara, Khowassah and Oesterle, 1975).

Faulkner and Harcourt (1975), in investigating the effects of silane coating of stainless steel inserts embedded in PMMA found that in all cases, although subjected to varying treatments, silane coating invariably improved the bond between the steel and the resin.

The possibility of bonding porcelain denture teeth to acrylic resin denture bases by using silanised teeth has been re-examined by Moffa, Jenkins and Weaver (1975). They undertook both clinical and laboratory observations and concluded that silane bonding offers no improvement over the usual methods of retention, principally because the silanised teeth sometimes fractured during processing with heat-cured resins and were sometimes lost from self-cured denture bases in clinical service.

DENTIFRICES

With the development of standards for toothpastes it will be interesting to see how well the specified requirements relate to clinical usage. Since the cleansing effectiveness of a dentifrice is one of its most important properties a quantitative method of measuring this is of obvious value in clinical trails. Such a method is described by Davis and Rees (1975).

DENTURE BASE RESINS

The surface hardness of denture base resins was increased by removal of the superficial layer (as in denture finishing) and decreased by storage in water (von Fraunhofer and Suchatlampong, 1975).

Jager and Huggett (1975) added a cross-linking agent, ethylene glycol dimethacrylate, to a commercial denture base resin and examined its effects on hardness, creep and recovery. They concluded that the hardness was not improved and that the improvements in the other properties were too small to have clinical significance.

The molecular weight distribution in denture base resin cured in 3 different ways and in the original polymer powder was examined by gel permeation chromatography (Beech, 1975). It was found that ordinary techniques for curing denture base resins result in molecular weight distributions which are satisfactory.

The loss of cadmium from a denture base resin immersed in acetic acid and in "synthetic saliva" was reported by Rossow and Kappang (1975), who state that the amount of cadmium eluted is small in comparison with the W.H.O. limit of 10$\mu g/l$ in drinking water.

GYPSUM AND RELATED PRODUCTS

It is well recognised that defective castings may result from back pressure which is likely to arise when a less porous investment is insufficiently permeable to gas. Orthodox spruing and venting methods are based on these considerations, among others, and their validity is supported by an investigation of the permeability and porosity of 2 gypsum-bonded and 3 phosphate-bonded materials (Ballard, Leinfelder and Taylor, 1975). The gypsum-bonded investments were more porous than the phosphate-bonded investments and more permeable than two of them. It was also found that the porosity of the materials could be increased by the addition of PMMA.

The effect on thermal expansion of adding glycerol to the water and boric acid and sodium chloride to the powder was investigated in 2 experimental investments, one quartz, the other cristobalite (Earnshaw, 1975). It was found that by adding 0,2 per cent of sodium chloride to the powder and using a 10 per cent aqueous solution of glycerol instead of water the thermal expansion could be substantially increased.

The effects of mixing a popular casting investment with tap water obtained from 5 Southern African sources were compared with the effects when distilled water was used (Sledziewski and Baetz, 1975). Four samples of water caused increased expansion, whilst one caused a contraction. The effects of various salts are discussed.

Young (1975) cast die stone against thiokol rubber impressions. Half the models set with the impressions inverted, the other half were not inverted. After setting, the models were examined under magnification. Models which had set in the inverted impressions were rougher than the others, although the difference was not detectable without magnification.

A comparative study of a die stone and an epoxy resin die material demonstrated that the epoxy has superior compressive strength, abrasion resistance and detail reproduction and yields clinically successful results (Moser, Stone and Willoughby, 1975). However, a centrifuge is recommended for forcing the resin into the impression.

The effects of mixing agents, impression materials and lubricants on die stone were reported by Johansson, Erhardson and Wictorin (1975). It was found that the hardness of the stone was increased by mixing with a gypsum hardener, which also overcame reduction in hardness associated with impression materials. Lubricants tend to decrease the hardness of the stone.

MATERIALS TESTING EQUIPMENT

The construction of a strain gauge tensometer is described by Roberts (1975). It is argued that such a device may be more suitable in some areas of dental materials testing than the conventional commercial tensile testing machines.

An apparatus for use in determining the tensile bond strengths of materials to enamel is described by

Breakspere, Tranter and Weldon (1975). The device permits testing in a conventional testing machine under wet conditions.

SYNTHETIC ELASTOMERS

A comparative study of the dimensional accuracy of flexible impression materials included 5 polysulphides, 5 silicones, 1 polyether, 1 putty and 2 hydrocolloids (Stackhouse, 1975). The polyether material was the most stable.

A study of the relationship between time and permanent deformation in synthetic elastomers was undertaken by Kaloyannides and Christidou (1975). Mercaptans showed more deformation than silicones and polyether shortly after mixing and it is suggested that mercaptans should not be cast until 30 – 40 min after mixing, the other materials being cast after 20 - 30 min.

A test method for determining the dimensional stability of synthetic elastomers was described by Mansfield and Wilson (1975). Early results showed that the combined polymerisation and thermal contraction of polyether was the same as that of polysulphides. At 6 h polyether showed a lesser dimensional change than most of the other material tested.

Millstein, Clark and Myerson (1975) used 3 brands of silicone to make interocclusal records from a pair of models under a standard load. The dimensional changes over 48 h were recorded. Similar samples were used to determine the mass loss over 48 h. The mass losses were broadly proportional to the dimensional changes.

The accuracy of some synthetic elastomers was investigated by Reisbick and Matyas (1975). Nine materials, or combinations of materials, were investigated and 3 of these were highly filled silicones. Impressions of steel dies were made in each material, then cast in die stone, and the resulting replicas were measured when dry. Two of the 3 highly filled materials showed consistent high accuracy. One material proved to be unsatisfactory, due to gas evolution.

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