

United States Patent [19]

[11] E

Patent Number: Re. 32,073

Randklev

[45] **Reissued Date of Patent: Jan. 28, 1986**

[54] **DENTAL FILLING COMPOSITION UTILIZING ZINC-CONTAINING INORGANIC FILLER**

[75] **Inventor: Ronald M. Randklev, White Bear Lake, Minn.**

[73] **Assignee: Minnesota Mining and Manufacturing Company, St. Paul, Minn.**

[21] **Appl. No.: 654,190**

[22] **Filed: Sep. 24, 1984**

Related U.S. Patent Documents

Reissue of:

[64] **Patent No.: 4,358,549**
Issued: Nov. 9, 1982
Appl. No.: 288,289
Filed: Jul. 30, 1981

U.S. Applications:

[63] **Continuation-in-part of Ser. No. 184,916, Sep. 8, 1980, abandoned.**

[51] **Int. Cl.⁴ A61K 5/01; A61K 5/06; A61K 6/08; C08K 3/40**

[52] **U.S. Cl. 523/117; 523/400**

[58] **Field of Search 523/117; 523/400**

[56]

References Cited

U.S. PATENT DOCUMENTS

2,523,266	9/1950	Armistead	106/53
3,413,133	11/1968	Stalego	106/50
3,661,601	5/1972	Dumbaugh et al.	106/54
3,715,331	2/1973	Melner	260/41 B
3,728,139	4/1973	Carrier et al.	106/54
3,801,344	4/1974	Dietz	106/300
3,808,170	4/1974	Rogers	260/42.53
3,814,717	6/1974	Wilson et al.	106/35
3,826,778	7/1974	Dietz	260/42.47
3,873,327	3/1975	Duff	106/35
3,882,080	5/1975	Schmitt et al.	260/42.29
3,911,581	10/1975	Dietz	32/15
3,959,212	5/1976	Rockett et al.	260/42.53
3,971,754	7/1976	Jurecic	260/42.15
3,973,972	8/1976	Muller	106/39.7
3,975,203	8/1976	Dietz	106/29
4,017,454	4/1977	Müller	260/42.52
4,028,325	6/1977	King et al.	260/42.15
4,032,504	6/1977	Lee, Jr. et al.	260/42.18
4,050,947	9/1977	Ahlgren et al.	106/52
4,215,033	7/1980	Bowen	260/42.15
4,217,264	8/1980	Mabie et al.	260/42.15

4,250,277	2/1981	Maries et al.	525/337
4,358,549	11/1982	Randklev	523/117

FOREIGN PATENT DOCUMENTS

36-23728 12/1961 Japan .

OTHER PUBLICATIONS

Milyukov, E. M. et al., "Phase-Separation Phenomena in Glasses of Aluminosilicate Systems Containing Various Modifier Cations," pp. 158-161, *The Structure of Glass*.

Ushakov et al., "Influence of Replacement of Silica by Various Glass-Forming Oxides on the Tendency to Phase Separation in the System R₂O-B₂O₃-SiO₂", pp. 103-106, *The Structure of Glass*, vol. 8, (Ed. by Porai-Koshits), pub. by Consultants Bureau, N.Y. 1973.

Bal'skaya, L. A. et al., "Phase Separation in Low-Alkali Borosilicate Glasses Containing RO and Al₂O₃", pp. 107-113, *The Structure of Glass*.

Grechanik, L. A. et al., "Properties of Glasses Exhibiting Phase Separation in the System, SiO₂-B₂O₃-Al₂O₃ZnO-Na₂O", pp. 114-117, *The Structure of Glass*.

R. L. Bowen and L. E. Reed, "Semiporous Reinforcing Fillers for Composite Resins: I. Preparation of Provisional Glass Formulations", *J. Dent. Res.*, 55, 5, pp. 738-747 (1976).

R. L. Bowen and L. E. Reed, "Semiporous Reinforcing Fillers for Composite Resins: II. Heat Treatments and Etching Characteristics", *J. Dent. Res.*, 55, 5, pp. 748-756 (1976).

Ingerson et al., *Am. Journal of Science*, 246:31-4 (1948).
Chem. Abs. 15425, vol. 75, 1971, "Glass Formation in the SiO₂-Neodymium Oxide System", Margaryan et al.
Chem. Abs. 117908, vol. 89, 1978, "Dental Cement Preparation", Kohmura et al.
Chem. Abs. 145403, vol. 94, 1981, Hoya Corp., *Dental Prosthetics*, Jun. 29, 1979.

Primary Examiner—Herbert J. Lilling
Attorney, Agent, or Firm—Donald M. Sell; James A. Smith; David R. Cleveland

[57]

ABSTRACT

This invention is a dental filling composition for making dental restorations. More particularly, the invention provides a radiopaque dental filling material. Specifically, the dental filling material contains a zinc-containing glass as the component imparting opacity to X-rays.

20 Claims, No Drawings

DENTAL FILLING COMPOSITION UTILIZING ZINC-CONTAINING INORGANIC FILLER

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

DESCRIPTION

Cross-Reference to Related Application

This application is a continuation-in-part of my co-pending application Ser. No. 184,916, filed Sept. 8, 1980, now abandoned.

BACKGROUND ART

A variety of substances has been used over the years to repair damaged teeth. The best known currently include silver amalgams, which are frequently first encountered at an early age as a filling for small cavities, even in deciduous teeth. Gold alloys are a particularly valuable filling material, used frequently when a tooth has been considerably damaged, such as after several cavities have occurred and a lot of tooth must be restored. Frequently, for example, several smaller extending cavities, e.g. in the occlusal surface, will be combined and a restoration made with a single gold inlay or onlay. The gold alloys have gained an excellent reputation for strength, reliability and long life in service. However, both the gold alloys, and the other metals, such as the stainless steels, which have been technically successful in dental reconstructions and crowns, do not impart a natural tooth appearance.

Gold and other metallic-looking restorations are used for molars and teeth which are not immediately open to view when the wearer opens his mouth or smiles. For anterior teeth, however, current practice is to use materials closer in appearance to natural teeth. These are known colloquially as porcelain or plastic fillings. They are composite materials characterized by containing usually predominantly inorganic materials, normally finely divided powders, inert to the oral environment, bound together with polymeric material. The inorganic materials are frequently finely-ground *fused* oxides, particularly glasses, or crystalline quartz, while the polymer moiety is commonly a polyacrylate. These composite systems are available, for example, as pastes which are polymerized in situ, after having been activated, e.g. by adding a catalyst to initiate a polymerization reaction, just before being placed in the prepared tooth.

Fillings and restorations of this kind can be made to look much like natural teeth. In particular, the color of the restoration can be adjusted to a shade quite close to that of a patient's natural teeth by tinting with pigments. In addition, the translucency or pearly sheen of the natural tooth can also be approximated through adjustment of the relative refractive indices of the materials used in the restoration. When color and refractive indices are well matched, it is possible to obtain a restoration that is barely perceptible to the glance. However, the attainment of good color and overall appearance is very difficult to achieve in practice. This is particularly true when one desires also to optimize other features of a good restoration, particularly radiopacity.

It is highly desirable for a filling or other restoration to be radiopaque, for it is by X-ray examination that a dentist determines whether or not a filling remains

sound. From radiographs a dentist determines the condition of a filling, e.g. whether it has cracked, or whether decay is occurring at the interface between the tooth and the filling. Fillings and restorations which are made of metal are readily observable in X-rays. Fillings of the porcelain/plastic art are not observable by X-rays unless they have radiopaque materials therein.

Currently, dental filling materials are rendered radiopaque by incorporating barium into the inorganic powder moiety of the filling material. The most effective radiopaque agents are elements of high atomic number (i.e. the "heavy elements" of the periodic table); it is unfortunate, however, that most of these elements are either radioactive or toxic, such as thorium or lead. Barium is toxic also, but in certain medical uses it is present in a form so highly insoluble that the body is unable to metabolize enough of it to become intoxicated. In dental applications barium glasses have been used as components of dental restorations, on the hypothesis that barium ions within the structure of a glassy matrix will not be available to oral fluids (saliva, beverages, etc.) and will not, therefore, pose a problem of toxicity. Examples of the use of barium glass in dental restorations can be found in U.S. Pat. Nos. 3,801,344; 3,808,170; 3,826,778; 3,911,581; 3,959,212; 3,975,203 and 4,032,504. Unfortunately, in practice, the barium glasses are not as stable as had originally been hoped, and they have not, therefore, found favor in the art on account of the risk they pose of poisoning the patient (see, e.g. U.S. Pat. No. 3,971,754). A further problem encountered with the barium glasses is that of matching refractive indices to that of the other components of the restoration. For example, it would be desirable to use components with refractive indices in the range of about 1.5 to 1.6 (so as to closely match the refractive index of commonly used organic binders) but most barium glasses with refractive indices in this range are unsuitable for dental use according to U.S. Pat. No. 4,032,504. It is difficult, therefore, to prepare restorations containing barium glass which present an unobtrusive appearance when used for anterior surface repair. An additional problem of the barium glasses is their alkalinity. Typically, barium glasses show alkalinity values of pH 9 or greater, whereas a pH of 7 is preferred. Highly alkaline fillers appear to degrade the siloxane coating resulting from etching of the prepared tooth cavity and also cause rapid decomposition of any peroxide catalyst present in the dental restorative composition during storage.

Recent efforts in the field of dental restoration materials have resulted in the use of fillers other than barium-containing compounds as an X-ray detectable component. For example, U.S. Pat. No. 3,971,754 describes the use of certain oxides or carbonates, particularly those of lanthanum, strontium, tantalum and, less usefully, hafnium. These salts are mixed with glass-making components at the time the glass is made, yielding a lanthanum, strontium, tantalum or hafnium glass which possesses a measure of radiopacity. U.S. Pat. Nos. 3,973,972 and 4,017,454 describe glass ceramics which possess both a low coefficient of thermal expansion (an advantage in dental fillings) and a useful degree of radiopacity, by virtue of a high content of rare earth elements, particularly lanthanum. The rare earth elements absorb X-rays in the wavelength range of 0.2-0.3 Å, a range commonly available from dental X-ray machines. However, the cost and problems with availability of these rare

earth fillers make them generally unsuitable for commercial use.

In another approach to preparing radiopaque composites for dental use, organic halide (e.g. an alkyl iodide) has been incorporated into plastic materials (e.g. acrylate polymers), from which molded articles are made (e.g. U.S. Pat. No. 3,715,331). However, the articles molded from such compositions lack the strength of restorations made from glass or ceramic materials.

U.S. Pat. No. 4,250,277 describes a glass composition used for crosslinking polycarboxylic acid cement, wherein the glass contains zinc oxide and a large amount of boric oxide, in addition to other ingredients. This glass, however, is too water soluble to be useful in dental restorative compositions and prosthetic devices.

U.S. Pat. No. 4,215,033 describes a composite dental material containing a glass which in one embodiment is described as single phase. However, this patent does not appear to recognize that a single phase glass containing zinc oxide can be made radiopaque. Also, the single phase glass composition described in this patent is very difficult to make. Furthermore, such glass does not contain any aluminum fluoride.

DISCLOSURE OF INVENTION

In accordance with the present invention there is provided a dental filling composition comprising a polymerizable resin binder and a finely divided inorganic glass filler which is X-ray opaque and single phase, wherein said X-ray opaque inorganic glass filler consists essentially of, in percent by weight:

Zinc oxide	20 to 35%	
Silica	45 to 65%	
Boric oxide	3 to 15%	
Aluminum oxide	[0 to 10%]	} combined weight of at least about 10%
Aluminum fluoride	[At least 2%]	
Alkali metal oxide or alkaline earth metal oxide	0 to [3%]	5%

wherein the [combined] weight of [aluminum oxide and] aluminum fluoride is [at least about 10%,] sufficient to contribute to the melt fluidity of the glass and enable it to be poured in the form of thin filaments for rapid cooling thereof, and wherein said glass exhibits an "X-ray absorption characteristic" of at least 1/16 inch.

This glass composition is also described in applicant's copending application Ser. No. 288,290, filed of even date, incorporated herein by reference, which is a continuation-in-part of my earlier application Ser. No. 184,917, filed Sept. 8, 1980.

DETAILED DESCRIPTION

It has been discovered that glasses containing high levels of zinc can be prepared which possess physical characteristics (e.g. refractive index, pH, coefficient of expansion) making them especially suitable for use in dental restorative compositions. Moreover, these glasses have been found to be radiopaque and to be capable of being made into dental composites which have greater radiopacity than those made with barium, the best known radiopacifying agent used heretofore. This is quite surprising, considering barium has an atomic number of 56, iodine an atomic number of 53, the lanthanides having atomic numbers of 57 to 71, and zinc having an atomic number of only 30. Moreover, it has been found possible to make the new zinc glasses with

refractive indices in the desired range for dental restorative compositions. In addition, the new glasses can be prepared at a pH close to 7. This is a highly desirable feature in regard to the preparation of high quality dental composites. In particular, when the glass is near neutral in pH (i.e. 6.5 to 8), the stability of the dental composite is significantly enhanced. Improved color stability, and reliable setting characteristics are obtained after the activated composite is emplaced in the tooth being required. The new glasses are significantly better than the barium glasses of the prior art in this regard.

It is believed that the problems encountered with the barium glasses are contributed to by the relative alkalinity of these materials. Barium is an alkaline earth element in the periodic system, and, therefore, more electropositive than zinc, which is a transition element. The higher pHs characteristic of the barium glasses cause decomposition of the peroxide catalysts normally used in these formulations and thus greatly reduce storage stability. A significant advantage of the new glasses, which is an improvement over any known heretofore, is that they contain an element, namely, zinc, that has been in regular dental use for many years. Zinc oxide-containing ointments have been used in medicine as safe and mild antibacterial agents and zinc oxide has long been used as a component in dental cements or adhesives. These latter agents are used for cementing prostheses, onlays, bridges, crowns, and the like, to the teeth. In this use they have proved safe and effective over many years. In other words, zinc compounds have a long history of being safe to use in the oral cavity, and are thus vastly preferable to use compared with those of unknown safety or known toxicity, such as compounds of barium.

The new single phase glasses used in this invention have the following composition in percent by weight:

Zinc oxide (ZnO)	20 to 35%	
Silica (SiO ₂)	45 to 65%	
Boric oxide (B ₂ O ₃)	3 to 15%	
Aluminum oxide (Al ₂ O ₃)	[0 to 10%]	} combined weight of at least about 10%
Aluminum fluoride (AlF ₃)	[At least 2%]	
Alkali metal oxide or alkaline earth metal oxide	0 to [3%]	5%

wherein the [combined] weight of [aluminum oxide and] aluminum fluoride is [at least about 10%,] sufficient to contribute to the melt fluidity of the glass and enable it to be poured in the form of thin filaments for rapid cooling thereof, and wherein the glass exhibits an "X-ray absorption characteristic" of at least 1/16 inch. The alkali metal oxide or alkaline earth metal oxide may be, for example, sodium oxide, potassium oxide, lithium oxide, calcium oxide, magnesium oxide, or the like, or combinations thereof, so long as the combined weight of such oxides does not exceed about 3% of the glass, thus maintaining the pH of the glass in the desired range of about 6.5 to 8. Of course, as will be recognized by those skilled in the art, various other ingredients may also be present in minor amounts so long as the resulting glass exhibits the desired X-ray opacity and the desired pH. However, it is highly preferred to avoid the inclu-

sion of toxic metals such as lead, cadmium, mercury, arsenic, etc.

A preferred embodiment of the new glass for use in dental restoratives intended for anterior applications has the following composition:

Zinc oxide	25 to 28%
Silica	46 to 48%
Boric oxide	6 to 9%
Aluminum oxide	1 to 3%
Aluminum fluoride	17 to 19%

wherein the combined weight of aluminum oxide and aluminum fluoride is not greater than about 20%, and wherein the glass exhibits an X-ray absorption characteristic of at least 3/32 inch.

The compositions given above are written in terms of the salts (e.g. oxides and fluorides) which are used in preparing the melt from which the glass is obtained upon cooling. This is a common practice in the glass-making art. There is, of course, no oxide, fluoride, or other simple salt in the resultant glass. Glasses used in this invention all possess a useful degree of radiopacity.

The refractive index of the glass may be varied, depending upon the particular amount of each ingredient present. It is preferred that the refractive index of the glass filler be substantially the same as that of the binder resin when the glass is used in a dental filling composition, i.e. within about 0.05, when the composition is used in anterior applications. When the binder resin comprises the well known BIS-GMA, the refractive index for the glass filler is preferably 1.556+0.05. Matching of the refractive indices of the glass filler and the binder resin is less important when the composition is intended for posterior dental applications.

When BIS-GMA resin is diluted with another acrylic resin (e.g. triethyleneglycol dimethacrylate) to facilitate higher filler loadings to make a composition having particular use for posterior filling applications, the resultant resin mixture may have a refractive index of 1.545, for example. Consequently, for such an application it may be preferred to use a glass composition having a refractive index of 1.545 if close matching of the resin and filler is desired. When it is desired to prepare a dental filling composition which is light curable it is important to obtain a close match of the refractive indices of the polymerizable resin and the glass filler so that complete and rapid cure of the resin will be achieved when it is exposed to the activating light. Of course, when the composition is intended for use elsewhere in the body (i.e. where esthetics are not a factor) and where the composition is not light curable, there is no need to attempt matching the refractive index of the glass to the refractive index of the binder resin.

Radiopacity, which reflects the material's ability to attenuate X-rays, is conveniently measured by comparing the X-ray film image density values of a disc of the cured composite of a standard thickness, e.g. 0.040 inches, with corresponding values of a known standard. Film image density measurements are made with a suitable densitometer, such as a Macbeth Transmission Densitometer, Model TD 504, with visible light filter (manufactured by Macbeth Div. of Kollmorgen Corp., Newburgh, N.Y.) A convenient standard is a stepped aluminum wedge, for example, a ten step wedge having a thickness of 1/32 inches at the thinnest step increasing to 5/16 inches at the thickest step. One empirically determines the X-ray film image density values corre-

sponding to steps on the wedge, which indicate degrees of X-ray beam attenuation which provide, in actual practice, proper differentiation between a composite restoration and the surrounding tooth structure. A proper level of radiopacity will permit one skilled in the art to differentiate between the restoration and primary and recurrent caries in the tooth structure, and will also visualize defects in the restoration itself. By way of illustration, using a wedge, the glasses of this invention when tested in this manner give values of 1/16 inch at 26% ZnO; 3/32- $\frac{1}{2}$ inch at 26.5-28% ZnO. Typical barium glasses of the prior art, tested under identical conditions give values of 1/16-3/32 inch. The typical "plastic" or "porcelain" filling materials (containing quartz or borosilicate filler) common in contemporary dental practice give values of zero. A silver amalgam gives a value of > 5/16 inch. It will be understood, of course, that these values are completely empirical. Using different wedges and experimental apparatus, the actual numbers one gets may be different. For the purposes of this invention, useful glasses exhibit an X-ray absorption characteristic of at least 1/16 inch.

Insofar as the preparation of the zinc glass is concerned, standard techniques well-known in the glass-making art are used. See, for example, *The Handbook of Glass Manufacture*, Fay and Tooley, Volume I (1974). After the melt has cooled, the glass is comminuted to a size that passes through a 325-mesh standard sieve (44 microns). For grinding the glass into smaller sizes a ball mill is used, and grinding aids such as ammonium carbonate or alcohols may be present in an amount of approximately 0.5% based on the weight of the glass.

When making dental composite restorative, the glass powder is then prepared for incorporating into an organic binder matrix by treating the surface with a silane compound. This is a well-known technique for rendering relatively polar materials, such as siliceous powders, more compatible with relatively non-polar materials, such as organic polymers.

The zinc glass is then mixed into a dental paste. The paste may be formed of any of the polymerizable resin systems useful in dentistry. Especially useful resin systems comprise free-radically polymerizable materials such as the polyfunctional acrylate systems. Particularly useful in the system is BIS-GMA, a well-known material which is the reaction product of bisphenol-A and glycidyl methacrylate, widely used in dentistry. Other commonly used resin binders include polyurethanes, methyl methacrylate, and isobutyl methacrylate.

The zinc glass may be used alone or it may be blended with other suitable materials, such as inert glass powders, when mixed into the binder—depending, for example, on the degree of radiopacity desired in the final composite. Along with the glass, other materials may also be mixed into the paste, such as pigments for making the restoration match the patient's natural tooth color, and reagents like hydroquinone monomethyl ether, as an inhibitor of premature polymerization of the binder. Immediately before use, and after the dentist has prepared the tooth for receiving the restoration, the paste is activated by mixing into it the appropriate amount of catalyst, such as benzoyl peroxide. For example, the dental restorative composition may be in the form of two pastes (one paste containing filler, resin binder and catalyst while the other contains filler, resin binder and accelerator), or a liquid resin and powdered filler system, or a paste-liquid resin, or any other desired

form. The mixed composition is promptly emplaced in the tooth, hardening in the manner characteristic of the resin binder and catalyst system being used. For example, using the well-known BIS-GMA/benzoyl peroxide system, the composite becomes grossly rigid in about 5 minutes and may be finely ground and polished, to give the finished restoration, in about 10 minutes. At any time after emplacement, but more particularly after significant time has elapsed, such as many months or years afterwards, the condition of the restoration and the adjacent tooth structures can be determined by diagnostic dental X-rays.

Curable compositions which contain the novel glass and which are useful in other applications (e.g. medical and dental prostheses, pit and fissure sealants, hard tissue cements) may be prepared in similar fashion using polymerizable resin binders.

The invention is further illustrated by means of the following representative examples wherein the term "parts" refers to parts by weight unless otherwise indicated.

EXAMPLE 1

Silica (47 gms), zinc oxide (26 gms), boric oxide (8 gms), aluminum oxide (1 gm) and aluminum fluoride (18 gms) are thoroughly mixed, as fine powders, in a silica-lined crucible. The mixture is heated in a muffle furnace at 1450° until the powder has become a transparent melt.

The molten glass is then removed from the crucible through a small hole in the crucible wall, by tilting the crucible and allowing a thin stream of glass to flow through, giving a filament of glass of about 1/32 inch diameter. This filament is quenched rapidly in cold water, to give a completely clear glass (as opposed to being opalescent). Mere air cooling of the glass is not sufficiently rapid to prevent phase separation.

The clear glass is then ground, e.g. in a ball mill, to a mean particle size range of 0.5-15 μm.

EXAMPLE 2

Gamma-methacryloxy-propyltrimethoxy silane (2 gms) is mixed with glacial acetic acid (0.033 gms) and water (44.4 gms) in a plastic beaker. Glass powder (100 gms for example, from Example 1) is added to the mixture, and the system is stirred for 1.5 hours at room temperature. The glass slurry is dried by warming it at 140° F. (60 C.) for 24 hours, followed by heating it in an oven for 2.5 hours at 240° F. (115° C.).

EXAMPLE 3

Two pastes, A and B, are prepared, having the following compositions:

Ingredient	Paste A	Paste B
BIS-GMA resin	14.48 gm	14.67 gm
Triethylene glycol dimethacrylates	4.67	4.63
Silane-treated filler (from Example 2)	80.0	80.0
Benzoyl peroxide	—	.21
Dihydroxyethyl p-toluidine	.46	—
"Tinuvin P", a UV absorber	.16	—
Phenylsalicylate glycidyl methacrylate adduct, a UV absorber	.14	.16
Butylated hydroxytoluene	—	.16
Bisphenol A	—	.14
Pigments-titanium dioxide and iron oxides - yellow raw	.17	.17

-continued

Ingredient	Paste A	Paste B
sienna, burnt umber), ottalume		
TOTAL	100.00 gm	100.00 gm

The pastes are prepared as follows:

For each paste, A and B, two preliminary mixes are made. The glass (from Example 2) and the pigments are mixed thoroughly to give an evenly colored powder. This mix is the same for each paste. The resins, accelerator, UV absorbers and inhibitor are mixed to give the mix for paste A. The resins, catalyst, UV absorber, and inhibitor are mixed to give the mix for paste B. After the two mixes, glass and resin based respectively, have been prepared, the procedure for preparing each paste, A and B, is the same.

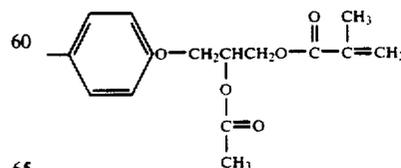
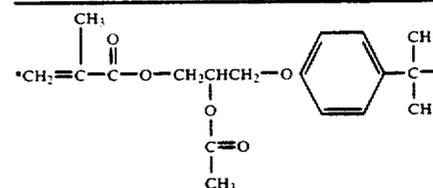
Each resin mix is added to a vessel and then the respective glass mix is added. The two mixes are first roughly blended together, such as by shaking, and are then thoroughly mixed preferably by prolonged mechanical mixing.

The resultant homogeneous pastes, A and B, are the precursors to the [dental] dental restorations made from the materials of this invention. Pastes A and B are kept separate until immediately before the appropriate repair is made in a tooth which has been prepared to receive it. They are then mixed together thoroughly and promptly emplaced in the manner well-known in dental art.

EXAMPLE 4

Using the procedure of Example 3, two pastes, A and B, are prepared having the following compositions:

Ingredient	Paste A	Paste B
Diacetyl BIS-GMA resin*	19.20 gm	19.57 gm
Silane treated filler (from Example 2)	80.0	80.0
Benzoyl peroxide	—	.24
Dihydroxyethyl p-toluidine	.47	—
"Tinuvin P" - a UV absorber	.16	—
Butylated hydroxytoluene	—	.02
Pigments - titanium dioxide and iron oxides (yellow, raw sienna, burnt umber), ottalume	.17	.17
TOTAL	100.00 gm	100.00 gm



The two pastes, when mixed together, form a very useful dental restorative composition.

EXAMPLE 5

The glass filler of Example 1 was ball milled to a mean particle size of 4.5 microns and silane treated according to the method described in Example 2. A [lightcurable] light-curable paste was prepared having the following [compositions] composition

Ingredient	Parts
BIS-GMA resin	5.655
Triethylene glycol dimethacrylate	5.655
Triphenyl antimony	.002
N,N—diethylaminoethyl methacrylate	.47
dl - camphoroquinone	.048
Silane treated filler + 1.58% by weight "Aerosil R-972"	88.0
Pigments - titanium dioxide, iron oxides (yellow, raw sienna, burnt umber) and ottalume	.17
TOTAL	100.00

The paste is prepared as follows:

The milled and treated filler (from Example 2), Aerosil R-972 (colloidal silica, commercially available from DeGussa Corporation, average particle diameter of 16 millimicrons, surface area of 110 square meters/gram) and the pigments are blended to give an evenly colored powder. The resins, inhibitor, accelerator and photoinitiator are mixed in a dark area in a vessel excluding light. The filler blend is then added to the mixing vessel containing the resin mix. The filler, resins and other components are then thoroughly mixed by prolonged mechanical mixing, with the entire operation carried out in the absence of light.

A commercially available "KULZER TRANSLUX" irradiation device with a light guiding rod is used to cure the paste. Test samples are prepared by packing the paste into an open-ended Teflon mold with a cylindrical cavity. The loaded mold is then placed between 2 pieces of clear polyester film (each 25 microns thick). Test samples of prescribed thickness are then irradiated for a period of exposure necessary to polymerize or cure the resin in the paste. Barcol hardness measurements are made on the top and bottom of the test sample to determine the extent of polymerization. The following Barcol hardnesses are determined on cured test samples using two different sample thicknesses.

	Hardness	
	1 Min. Post Cure	1 Hr. Post Cure
2 mm sample thickness	81 - top side	91 - top side
20 sec. exposure	64 - bottom side	82 - bottom side
3 mm sample thickness	83 - top side	86 - top side
20 sec. exposure	56 - bottom side	74 - bottom side

Barcol hardness values in excess of 80 are considered outstanding. Standard, commercially available dental restorative composites typically have Barcol hardness values of 70-75 after 24 hours cure.

The filler loading levels of 88% attained with the zinc glass must also be considered to be extraordinary. Conventional radiopaque barium glass permits maximum filler loadings of 78-80% when using similar particle size distributions.

EXAMPLE 6

The glass filler of Example 1 was ball milled to a mean particle size of 1.8 microns and silane treated according to the method described in Example 2. A light-curable paste having the following composition was prepared using the procedure of Example 5:

Ingredient	Parts
BIS-GMA resin	7.09
Triethylene glycol dimethacrylate	7.09
Triphenyl antimony	.003
N,N—diethylaminoethyl methacrylate	.59
dl - camphoroquinone	.059
Silane treated filler + 10% by weight "OX-50" (colloidal silica commercially available from DeGussa Corporation, average particle diameter of 40 millimicrons, surface area of 50 square meters/gram)	85.0
Pigments - titanium dioxide, iron oxides (yellow, raw sienna, burnt umber) and ottalume	168
TOTAL	100.00

Barcol hardnesses were determined on 2 mm thick test samples of composition cured at two different exposure times:

	Hardness	
	1 Min. Post Cure	1 Hr. Post Cure
20 sec. exposure	83 - top side 22 - bottom side	—
30 sec. exposure	83 - top side 54 - bottom side	84 - top side 75 - bottom side

EXAMPLE 7

The glass filler of Example 1 was ball milled to a mean particle size of 4.5-5.0 microns. Radiopaque impression pastes, containing the ingredients listed below, were prepared by mixing the ingredients in a conventional Ross brand mixer:

Ingredient	Paste A	Paste B
Low molecular weight vinyl siloxane polymer (2300 cps)	2000 grams	1800 grams
Filler of Example 1 (not silane treated)	1700 grams	1700 grams
Chloroplatinic acid (catalyst)	4.2 grams	—
Hydrogen polysiloxane	—	70 grams

The concentration of the filler may be varied, as desired, to produce compositions having various viscosities. Compositions containing 30-40% filler are of low viscosity, while compositions containing 80-90% filler have a putty consistency.

I claim:

1. A dental filling composition comprising a polymerizable resin binder and a finely divided inorganic glass filler which is X-ray opaque and single phase, wherein said X-ray opaque inorganic glass filler consists essentially of, in percent by weight:

Zinc oxide	20 to 35%
Silica	45 to 65%

-continued

Boric oxide	3 to 15%
Aluminum oxide	0 to 10%
Aluminum fluoride	At least 2%
Alkali metal oxide or alkaline earth metal oxide	0 to 3%

wherein the compound weight of aluminum oxide and aluminum fluoride is at least about 10%, and wherein said glass exhibits an X-ray absorption characteristic of at least 1/16 inch.

2. A composition in accordance with claim 1, wherein said binder comprises a free-radically polymerizable resin.

3. A composition in accordance with claim 2, wherein said polymerizable resin binder comprises BIS-GMA.

4. A composition in accordance with claim 1, wherein the index of refraction of said glass filler and said resin are substantially the same.

5. A composition in accordance with claim 1, wherein said composition is in the form of two pastes, the first said paste comprising polymerizable resin binder, inorganic glass filler, and a catalyst, and the second said paste comprising polymerizable resin binder, inorganic glass filler, and an accelerator.

6. A composition in accordance with claim 5, wherein said filler represents at least about 70% by weight of each said paste.

7. A composition in accordance with claim 5, wherein said binder in each said paste comprises BIS-GMA.

8. A composition in accordance with claim 3, wherein said glass filler consists essentially of, in percent by weight:

Zinc oxide	25 to 28%
Silica	46 to 48%
Boric oxide	6 to 9%
Aluminum oxide	1 to 3%
Aluminum fluoride	17 to 19%

wherein the combined weight of aluminum oxide and aluminum fluoride is not greater than about 20%.

9. A dental filling composition comprising a polymerizable resin binder and a finely divided inorganic glass filler which is X-ray opaque and single phase, wherein said X-ray opaque inorganic glass filler consists essentially of, in percent by weight:

Zinc oxide	20 to 35%
Silica	45 to 65%
Boric oxide	3 to 15%
Aluminum oxide) combined weight of at least about 10%

-continued

Aluminum fluoride	0 to 5%
Alkali metal oxide or alkaline earth metal oxide	

wherein the weight of aluminum fluoride is sufficient to contribute to the melt fluidity of the glass and enable it to be poured in the form of thin filaments for rapid cooling thereof, and wherein said glass exhibits an X-ray absorption characteristic of at least 1/16 inch.

10. A composition in accordance with claim 9, wherein said combined weight of aluminum oxide and aluminum fluoride is not greater than about 20%.

11. A composition in accordance with claim 9, wherein said binder comprises a free-radically polymerizable resin.

12. A composition in accordance with claim 11, wherein said polymerizable resin binder comprises BIS-GMA.

13. A composition in accordance with claim 9, wherein the index of refraction of said glass filler and said resin are substantially the same.

14. A composition in accordance with claim 9, wherein said filler comprises 80-90% of the weight of said composition.

15. A dental filling composition comprising a polymerizable resin binder and a finely divided inorganic glass filler which is X-ray opaque and single phase, wherein said X-ray opaque inorganic glass filler consists essentially of, in percent by weight:

Zinc oxide	20 to 35%
Silica	45 to 65%
Boric oxide	3 to 15%
Aluminum oxide	0 to 10%
Alkali metal oxide or alkaline earth metal oxide	0 to 5%

and aluminum fluoride, wherein the combined weight of aluminum oxide and aluminum fluoride is at least about 10%, the weight of aluminum oxide is sufficient to contribute to the melt fluidity of the glass and enable it to be poured in the form of thin filaments for rapid cooling thereof, and said glass exhibits an X-ray absorption characteristic of at least 1/16 inch.

16. A composition in accordance with claim 15, wherein said combined weight of aluminum oxide and aluminum fluoride is not greater than about 20%.

17. A composition in accordance with claim 15, wherein said binder comprises a free-radically polymerizable resin.

18. A composition in accordance with claim 17, wherein said polymerizable resin binder comprises BIS-GMA.

19. A composition in accordance with claim 15, wherein the index of refraction of said glass filler and said resin are substantially the same.

20. A composition in accordance with claim 15, wherein said filler comprises 80-90% of the weight of said composition.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : Re. 32,073

DATED : January 28, 1986

INVENTOR(S) : Ronald M. Randklev

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 4, line 10, "required" should read -- repaired --.

Col. 11, line 9, "compound" should read -- combined --.

Col. 12, line 1, "Aluminum fluoride" should appear at Col. 11, line 59, so that both "Aluminum oxide" and "Aluminum fluoride" are within the bracket.

Signed and Sealed this
Eighth **Day of** *July 1986*

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer

Commissioner of Patents and Trademarks