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FUSED PORCELAIN-TO-METAL TEETH

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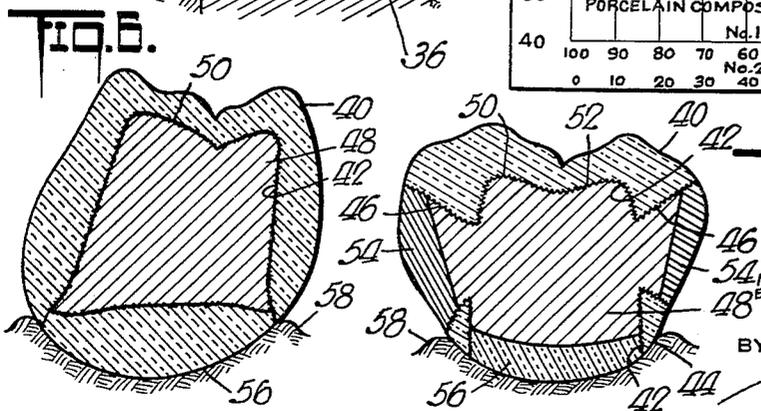
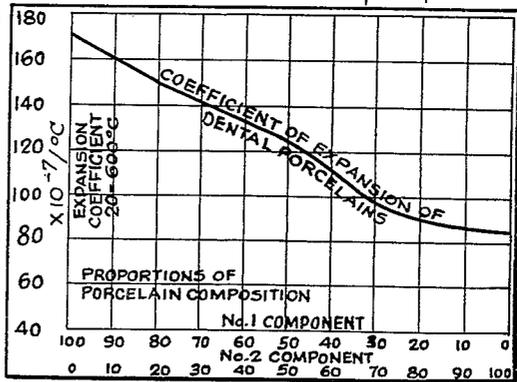
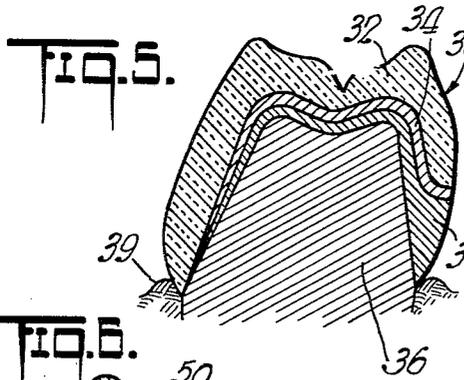
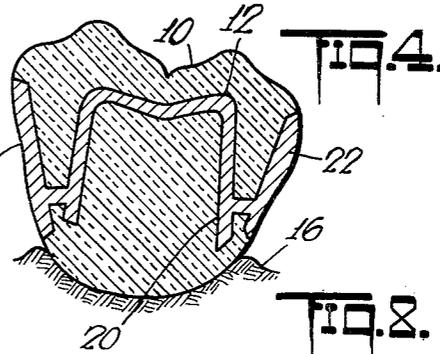
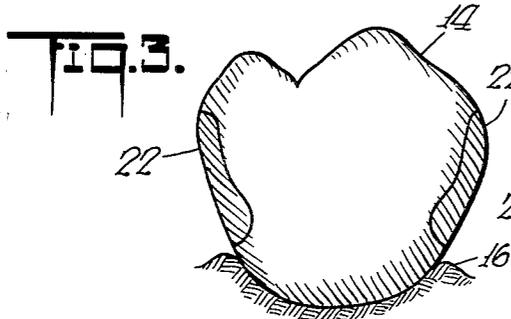
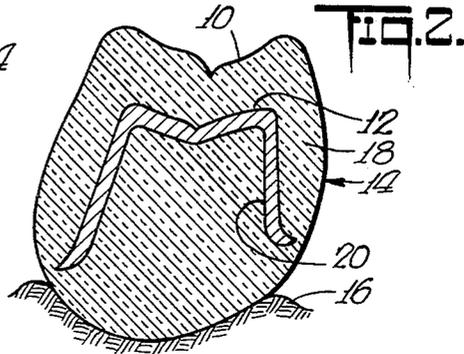
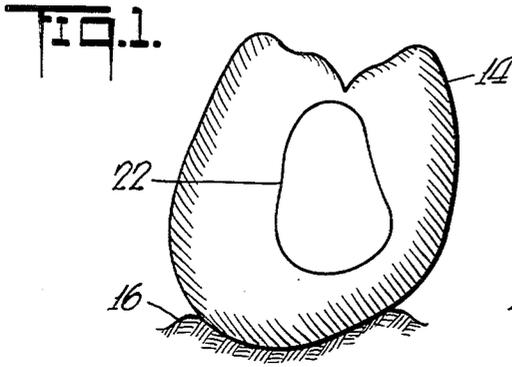


FIG. 7.

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FUSED PORCELAIN-TO-METAL TEETH

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or later extraction, is the only mechanical guarantee against secondary decay and ultimate extraction. It is a basic requirement in the practice of full mouth rehabilitation. It is also one of the few effective remedies in cases of rampant caries.

The value of the technique of applying porcelain to a metal substrate can be appreciated from the following:

(a) No metal need show in the oral cavity, as it may be entirely covered with porcelain to yield a natural restoration in appearance.

(b) The restoration is far more resistant to wear than the prior plastic and metal restoration.

(c) The color permanency and dimensional stability of the porcelain restoration far exceed that of the prior plastic and metal restoration.

Our invention enables the spread of the most reliable dentistry to the largest numbers of patients previously unable to avail themselves of lasting full coverage in porcelain due to cost, thereby stimulating the skills and interest of the profession where formerly it was often felt futile to propose such treatment. Extensive corrections of the bite to balanced occlusion for the treatment of periodontoclasia will be more readily undertaken. It enables and encourages the use of fixed bridgework instead of removable bridgework, thus avoiding many causes of periodontoclasia and providing a chewing surface closer in natural function, not only in appearance, to that of natural teeth. Where required, it may also be employed in making removable restorations.

Metals having a successful history in dental prosthetics are noble, such as gold, silver, platinum, etc., and the passive base metals, such as austenitic stainless steel, the high cobalt chrome alloys, etc. The base metals oxidize strongly at the porcelain fusion temperatures (1650° to 2400° F.). The oxides are non-adherent, and in addition the metals such as cobalt, chromium and nickel, have oxides which are very strong chromophores and discolor the porcelain. Many of the remaining noble metals, such as some of the gold and silver alloys have melting points well below the fusing range of high fusing porcelains. Therefore, these porcelains cannot be fused without melting these metals.

Among the objects of our invention, therefore, is to provide methods of utilizing noble and passive metals as a support for a porcelain covering even though the fusion temperature of the metal is lower than that of the porcelain, and to provide a method of preventing non-adhering and discoloring oxides from forming when the porcelain is applied to the base metal.

The physical and optical requirements of dental porcelains are exacting in their demands upon color range, translucency and opacity.

A dental porcelain consists of at least three separate and distinct porcelain bodies. The body porcelain is used to construct the principal bulk of the artificial tooth structure. The translucency porcelain, which fuses to a relatively clear, glass-like material, is used to provide translucency in the incisal tips of the artificial tooth structure. It may also be used to reduce the opacity of the body porcelain. The opaque porcelain is used to mask out the dark metal substrate. Its use is essential where the body porcelain is thin and in general is beneficial to the over-all color esthetics of the porcelain reconstruction. A means must therefore be provided to adjust these three separate and distinct porcelains of varying optical requirements to provide substantially identical expansion coefficients, and accordingly, the provision of such means constitutes another object of our invention.

These objects are attained, and others accomplished, as will be apparent from the products and methods described in the following specifications, particularly pointed

Our invention relates to an artificial tooth structure of the type wherein a metal substrate is secured to a porcelain covering, which composite structure is used to cap existing teeth or replace missing teeth.

Dental porcelains may generally be classified as high and low fusing porcelains. The high fusing porcelains fuse above 1800° F. The ideal porcelains are the high fusing porcelains which have been found to be more resistant to thermal and mechanical shock and to erosion by mouth fluids. At present the only known high fusing dental porcelains have a coefficient of expansion up to their annealing range of about $75 \times 10^{-7}/^{\circ}\text{C}$. These have been fused to metals having the nearest coefficient of expansion, namely, the iridio-platinum alloys, which have expansion coefficients of about $100 \times 10^{-7}/^{\circ}\text{C}$. up to the annealing temperature of the porcelain. The thermal expansion coefficients of the platinum alloys and the prior high fusing dental porcelains are sufficiently divergent so that when fused to an unyielding metallic substrate, the porcelain covering is placed in a high state of stress. Little additional stress is needed in service to initiate fracture in the porcelain.

The lower fusing porcelains (below 1800° to 1650° F.) are less desirable but are useful for additions, repairs or changes to high fusing porcelains and for fusing to low fusing substrates such as gold alloys. Hitherto lower fusing porcelains have also been unsuccessful when fused to gold alloys because of the disparity in expansion coefficients. In addition the lower fusing porcelains contained borax which resulted in excessive solubility and poor color properties.

There are additional shortcomings in the use of the prior materials. It is difficult to grind through the porcelain to the metal substrate without chipping and fracturing the thinned-out porcelain most nearly adjacent to the metal. This is due to the high state of stress at the porcelain-metal interface which the porcelain becomes progressively less able to endure as it becomes thinner.

A further limitation is that prior porcelains are not optically suitable for covering the metal substrate because they cannot compensate for adverse optical qualities introduced into the semi-translucent body by the proximity of the metal substrate.

The other dental metals, such as palladium, gold, and the base metals, possess expansion coefficients which are considerably higher than the iridio-platinum alloys, and accordingly have an even greater disparity between the coefficients of expansion of the metal and the existing high fusing dental porcelains, resulting in greater stresses in the porcelain.

As a consequence, the dental profession has limited the use of porcelain to an esthetic role mainly in the anterior teeth, and has relied entirely on gold crowns and bridgework for the rest of the mouth, for whatever strength was required.

While the shortcomings enumerated above have been prohibitive to the practice of this technique of dental prosthetics, its potential for the advancement of dentistry has been sufficiently great to require the removal of these limitations. Authorities agree that full coverage of a tooth which has been treated for decay or is susceptible to decay or is to be saved from immediate

out in the claims and illustrated in the attached drawings in which:

FIG. 1 is a proximal view of a porcelain covered pontic molar tooth having a metal substrate core, made in accordance with our invention.

FIG. 2 is a bucco-lingual cross-section of the same.

FIG. 3 is a lingual view of the same.

FIG. 4 is a mesio-distal cross-section of the same.

FIG. 5 is a bucco-lingual cross-section of a jacket construction indicating the use of our technique to cover a prepared natural tooth.

FIG. 6 is a bucco-lingual cross-section of a pontic molar tooth wherein the metal substructure is cast into the porcelain cover.

FIG. 7 is a mesio-distal cross-section of the same with solderable inserts.

FIG. 8 is a chart indicating the proportions of our component materials to be used for obtaining a final porcelain having a preselected expansion coefficient.

We employ in our porcelain, certain basic components, the proportions of which may be calculated to produce a porcelain body with a coefficient of expansion which matches that of the metal of our selection.

The following is one method of manufacturing the components of our high fusing porcelain:

No. 1 Component

Our No. 1 component is made up of a frit, and a high orthoclase feldspar having for example, a theoretical computed composition of 16.17% parts of albite and 83.83% parts of orthoclase having a composition of ingredients about as follows:

	High Orthoclase Spar, percent	Frit, percent
SiO ₂	65.6	50
Al ₂ O ₃	18.4	7
Na ₂ O.....	2.6	8
K ₂ O.....	13.2	20
CaO.....	0.1	10
MgO.....	0.1	5
	100.0	100

A mixture of 15% parts by weight of the powdered frit to 85% of the powdered feldspar results in a component by analysis, as follows:

	Percent by weight
SiO ₂	63.40
Al ₂ O ₃	16.70
CaO.....	1.50
MgO.....	0.80
Na ₂ O.....	3.41
K ₂ O.....	14.19
	100.00

The mixture is fired for about two hours at 2400° F. (about cone 12), or until the mixture is in a vitreous state. It is thereafter cooled and powdered to approximately 2 to 5% on 200 mesh. Its fusion point is about 2000° F. This is our No. 1 component. If the percentage of powdered frit is decreased, the fusing point of the final porcelain will be increased and the expansion coefficient will be decreased.

No. 2 Component

This consists of a mixture of about 75% of an ordinary clear feldspar and about 25% silica, which has the following composition:

	Percent by weight
SiO ₂	73.50
Al ₂ O ₃	14.40
CaO.....	0.25

	Percent by weight
MgO.....	0.10
Na ₂ O.....	1.75
K ₂ O.....	10.00
	100.00

This mixture is fired for about two hours at 2400° F. (about cone 12), or until the free silica is absorbed, and thereafter cooled and similarly powdered. Its fusion point is about 2400° F. This is our No. 2 component. If the percentage of silica is decreased, the fusing point of the final porcelain product will be decreased. For example, if only 15% silica is added in making the No. 2 component, the fusing point will be about 2300° F.

Example No. 1.—High Fusing Porcelain No. 1

A mixture of equal parts of the powdered No. 1 component and the powdered No. 2 component results in the following composition:

	Percent by weight
SiO ₂	68.45
Al ₂ O ₃	15.55
CaO.....	0.90
MgO.....	0.45
Na ₂ O.....	2.55
K ₂ O.....	12.10
	100.00

The above represents the analyzed chemical composition of this specific high-fusing, high-expansion porcelain. It has an expansion coefficient of slightly less than 125×10⁻⁷/° C. and a fusing range around 2100° F.

This porcelain is suitable for matching without change of expansion properties from biscuit bake through the various degrees of vitrification and glaze, to a palladium metal alloy substrate having a coefficient of expansion of 125×10⁻⁷/° C. which has the coefficient composition:

	Percent by weight
Palladium.....	93.5
Ruthenium.....	6.5
	100.0

No. 1a Component—Alternative

We have found another method of making our high fusing dental porcelain, as follows: First we fire the high orthoclase spar, for example, one having a theoretical computed composition of 16.17 parts of albite and 83.83 parts of orthoclase for about 2 hours at 2400° F. (about cone 12), or until all the material is in a vitreous state. It is then cooled and powdered as aforesaid. This furnishes an alternative material for Component No. 1 in the method of manufacturing the components of our porcelains.

Between 1 and 5% of potash may be added in the form of potassium carbonate to the high orthoclase spar if an insufficient amount of orthoclase is present. Instead of the potassium carbonate, a powdered fusion product may be added containing about one part by weight of K₂O to about 2½ parts by weight of SiO₂.

The resulting mixture of the alternative Component No. 1a with the original Component No. 2 is suitable for our purposes and in equal amounts yields a porcelain with completely satisfactory optical and mechanical properties, a fusion range of about 2100° F., and an expansion coefficient of slightly less than 125×10⁻⁷/° C. This is suitable for the palladium alloy of Example 1 and may be used for our purpose.

Example No. 2.—High Fusing Porcelain No. 2

The relationship between the No. 1 component and the No. 2 component is adjusted to provide the increased coefficient expansion over that of Example 1. For this alloy, we may use 90% of our No. 1 component and 10%

of our No. 2 component. The composition of the mixture is as follows:

	Percent by weight
SiO ₂	65.42
Al ₂ O ₃	16.24
CaO	1.25
MgO	0.66
Na ₂ O	3.07
K ₂ O	13.36
	100.00

The above represents the analyzed chemical composition of this high fusing porcelain having an expansion coefficient slightly below $165 \times 10^{-7}/^{\circ} \text{C}$.

This porcelain is suitable for matching to a cobalt chrome alloy substrate having a coefficient of expansion of $165 \times 10^{-7}/^{\circ} \text{C}$. which has the following composition.

	Percent by weight
Chromium	27.00
Molybdenum	6.00
Nickel	2.00
Iron	1.00
Carbon	0.25
Manganese	0.60
Silicon	0.60
Cobalt	62.55
	100.00

In the case where cobalt-chrome alloys are used, we achieve a very low cost, high strength dental construction of relatively light weight. However, the process of fusing porcelain to cobalt-chrome alloys necessitates a different technique of fusion. We prefer to make the fusion under high vacuum in order to avoid oxidation because the oxides of cobalt-chrome, nickel, iron, etc. are strong chromophores for porcelain and discolor it. In addition, the oxides are frequently non-adherent and destroy the bond at the porcelain-metal interface. While vacuum firing is one method of avoiding oxidation, other methods are also useful, such as firing in a reducing or neutral atmosphere. In addition, oxidation may be suppressed by a heavy coat of some non-oxidizable metal, such as gold, which may be diffused into the cobalt-chrome alloy by high temperature vacuum firing.

In addition to firing the porcelain to the metal as is shown in FIGS. 2, 4 and 5, the porcelain covering alone may be fired in the desired shape, having suitable openings for casting the molten metal body therein, as is shown in FIG. 7. By this other method, explained in greater detail hereinafter, the oxidation and discoloration may be prevented.

It is understood that other proportions of the Nos. 1 and 2 components will give other expansion coefficients and other fusing ranges within the limits needed for the selected expansion characteristics. A chart illustrating the proportions in terms of expansion coefficients is shown in FIG. 8. Actually the range of proportions varies between 25% of the No. 1 component and 75% of the No. 2 component as the lower coefficient of expansion (about $90 \times 10^{-7}/^{\circ} \text{C}$.) fusing range about 2400° F. to 100% of the No. 1 component (about $170 \times 10^{-7}/^{\circ} \text{C}$.) fusing range about 2000° F.

The high fusing dental porcelains of our invention with expansion coefficients between 90 and $170 \times 10^{-7}/^{\circ} \text{C}$. and fusing ranges between 2400° F. and 2000° F. will have the following approximate range in composition:

	Percent by weight
SiO ₂	63.0 to 73.0
Al ₂ O ₃	14.0 to 17.0
CaO	0.5 to 1.5
MgO	0.2 to 0.8
Na ₂ O	2.0 to 3.5
K ₂ O	11.0 to 15.0

MEDIUM FUSING PORCELAINS

A medium-fusing porcelain may be manufactured by a similar method.

For example, the No. 1 component previously disclosed may be blended with a No. 3 component, a counterpart to the No. 2 component previously described.

Specifically, the No. 3 component may be made as follows:

	High Ortho- class Spar of No. 1 Component percent	Frit, percent
15 SiO ₂	65.6	70.00
Al ₂ O ₃	18.4	5.00
Na ₂ O	2.6	16.50
K ₂ O	13.2	-----
CaO	0.1	5.00
MgO	0.1	3.50
	100.0	100.00

A one-to-one mixture of the above two powdered materials fused at 2200° F. for two hours and powdered, provides our No. 3 component, having the following composition:

No. 3 Component

	Percent by weight
30 SiO ₂	67.80
Al ₂ O ₃	11.70
Na ₂ O	9.55
K ₂ O	6.60
CaO	2.55
MgO	1.80
	100.00

This fusion product when powdered will fuse at about 1650° F.

Example No. 3.—Medium Fusing Porcelain No. 1

A medium fusing porcelain may now be obtained by a one-to-one combination of the powdered No. 1 component and the powdered No. 3 component. Such a medium fusing porcelain will have a final composition about as follows:

Medium Fusing Porcelain No. 1

	Percent by weight
50 SiO ₂	65.60
Al ₂ O ₃	14.20
Na ₂ O	6.47
K ₂ O	10.40
MgO	1.30
CaO	2.03
	100.00

This medium fusing porcelain fuses at approximately 1725° F. and has a coefficient of expansion of $125 \times 10^{-7}/^{\circ} \text{C}$. As such it is suitable for the application cited in Example No. 1.

By varying the ratio between the No. 1 and No. 3 components, other expansion coefficients and fusing ranges may be attained, similar to example No. 2 as follows:

Example No. 4.—Medium Fusing Porcelain No. 2

A mixture of seven parts by weight of No. 1 component and three parts of No. 3 component will have a coefficient of expansion of $140 \times 10^{-7}/^{\circ} \text{C}$. and a fusing range of about 1750° F. This is suitable for fusing to an alloy having a composition: Gold 80%, platinum 20%. This alloy has a coefficient of expansion of slightly above $140 \times 10^{-7}/^{\circ} \text{C}$., and a fusing temperature of about 2200° F. Formulating a chart, similar to the chart shown in FIG. 8 but limited to combinations of No. 1 and No. 3 components, we find that the coefficients of expansion

vary in substantially the same manner as is illustrated for the No. 1 and No. 2 components, and the fusing ranges are between 2000° F. for about 100% No. 1 component, to 1650° F. for 100% of the No. 3 component, with an expansion coefficient of about $80 \times 10^{-7}/^{\circ} \text{C}$.

No. 4 Component—(Alternative No. 1 Component)

An example of the alternative Component No. 1 using 10% of potassium carbonate and 90% of high orthoclase spar has the theoretical composition as follows:

	Percent by weight
SiO ₂ -----	61.00
Al ₂ O ₃ -----	17.10
Na ₂ O -----	2.37
K ₂ O -----	19.31
CaO -----	0.11
MgO -----	0.11
	100.00

This may be used in place of Component No. 1 but having a lower fusion temperature of about 1950° F.

We have also found that lithia (Li₂O) may be employed to accomplish results similar to the use of potash. It may be introduced into the spar either as a frit or as lithium carbonate. On a weight for weight basis, lithia is twice as effective as K₂O, and therefore one half the amount of lithia may be used for the amount of potash indicated for obtaining the lower fusing ranges and increasing the thermal expansion.

For example, to a high orthoclase feldspar i.e. 16.17% albite and 83.83% orthoclase, having an oxide composition of about:

	Percent by weight
SiO ₂ -----	65.60
Al ₂ O ₃ -----	18.40
Na ₂ O -----	2.55
K ₂ O -----	13.20
CaO and MgO -----	0.25
	100.00

is added 5% of Li₂CO₃ (lithium carbonate). This is fired at 2200° F. for two hours or until vitrification results and this gives the following approximate composition, which is our

No. 5 Component—(Alternative No. 1 Component)

	Percent by weight
SiO ₂ -----	64.30
Al ₂ O ₃ -----	18.10
Na ₂ O -----	2.50
K ₂ O -----	12.90
CaO and MgO -----	.20
Li ₂ O -----	2.00
	100.00

No. 5 component has a lower fusion temperature i.e. 1800° F. and a coefficient of expansion of above $170 \times 10^{-7}/^{\circ} \text{C}$.

The above Component No. 5 is added 50/50 to our No. 3 component, which gives our alternative medium fusing porcelain with the following composition:

Example No. 5.—Medium Fusing Porcelain No. 3

	Percent by weight
SiO ₂ -----	65.7
Al ₂ O ₃ -----	15.0
Na ₂ O -----	6.0
K ₂ O -----	9.3
CaO and MgO -----	2.0
Li ₂ O -----	2.0
	100.0

This has a coefficient of about $140 \times 10^{-7}/^{\circ} \text{C}$ and a fusing temperature of about 1750° F. This is also suitable for fusing to the gold alloy base of Example No. 4.

Lower fusing porcelains having maturing ranges between 1650° F. and 1800° F. may be made by methods similar to procedures previously described. Two new components, designated No. 6 and No. 7 are employed.

The No. 6 component is made by taking 90 parts of the feldspar of the No. 1 component, adding to it 5 parts of the frit employed in the No. 1 component, and 5 parts of lithium carbonate. This mixture is fired for two hours at 2200° F. or until a vitreous state results. It is thereafter ground to pass about 95% through a 200 mesh screen. This No. 6 component has the following composition:

	Percent by weight
SiO ₂ -----	63.41
Al ₂ O ₃ -----	17.45
K ₂ O -----	13.28
Na ₂ O -----	2.84
Li ₂ O -----	2.06
CaO -----	0.61
MgO -----	0.35
	100.00

This No. 6 component has a thermal expansion of about $170 \times 10^{-7}/^{\circ} \text{C}$ and a fusing point of about 1650° F.

The No. 7 component employed in our low fusing porcelain is made by taking 30 parts of the feldspar used to make the No. 1 component, and 70 parts of a common frit having the following composition:

	Percent by weight
SiO ₂ -----	70.0
Al ₂ O ₃ -----	5.0
Na ₂ O -----	16.5
CaO -----	5.0
MgO -----	3.5
	100.0

This mixture of frit and feldspar is fired for two hours at 2200° F. or until a vitreous state results. It is thereafter ground to pass about 95% through a 200 mesh screen.

This No. 7 component has a thermal expansion of about $85 \times 10^{-7}/^{\circ} \text{C}$, and a fusing point of about 1800° F. The composition is as follows:

No. 7 Component

	Percent by weight
SiO ₂ -----	68.68
Al ₂ O ₃ -----	9.02
K ₂ O -----	3.96
Na ₂ O -----	12.33
CaO -----	3.53
MgO -----	2.48
	100.00

Example No. 6.—Low Fusing Porcelain

A mixture of 6 parts by weight of our No. 6 component and 4 parts by weight of our No. 7 component constitutes a low fusing (1650° F.) porcelain having the following composition:

	Percent by weight
SiO ₂ -----	65.518
Al ₂ O ₃ -----	14.078
K ₂ O -----	9.552
Na ₂ O -----	6.636
Li ₂ O -----	1.236
CaO -----	1.778
MgO -----	1.202
	100.000

This low fusing porcelain No. 6 has a thermal expansion of about $130 \times 10^{-7}/^{\circ}\text{C}$. As such it is suitable for addition to or repair of high or medium fusing porcelain, Examples Nos. 1 and 3.

By varying the ratios between the No. 6 and No. 7 components, other thermal expansion coefficients and fusing ranges may be obtained.

The dental lower fusing porcelains of our invention with expansion characteristics between $80 \times 10^{-7}/^{\circ}\text{C}$, and $170 \times 10^{-7}/^{\circ}\text{C}$, and having a fusing range between 1650° F. and 1950° F. respectively, will have the following approximate range in composition:

	Percent by weight
SiO ₂ -----	61 to 67.8
Al ₂ O ₃ -----	17.1 to 11.7
CaO -----	0.1 to 2.6
MgO -----	0.1 to 1.8
Na ₂ O -----	2.37 to 9.6
K ₂ O -----	19.3 to 6.7

Where the lithia (Li₂O) has been used in the No. 5 and No. 6 components, the amount of lithia should be included in the above constituents and the range is between 0% and 5%.

This will reduce the above components by from 0% to 5% when lithia is used.

From the foregoing, our porcelain composition, having a coefficient of expansion from $80 \times 10^{-7}/^{\circ}\text{C}$. to $170 \times 10^{-7}/^{\circ}\text{C}$. and a fusing range between 1650° F.—2400° F., will have the following constituents and range:

	Percent by weight
SiO ₂ -----	61.0-73.0
Al ₂ O ₃ -----	11.7-17.1
K ₂ O -----	6.7-19.3
Na ₂ O -----	2.0-9.6
CaO -----	0.1-2.6
MgO -----	0.1-1.8

It is also true here that where lithia (Li₂O) is used in the preparation of our porcelain in the amounts of between 0% and 5%, that the foregoing minimum values will be reduced by 0% to 5% in like percentage.

These dental porcelains may be brought to a glaze without danger of losing the fine contours and carvings that may be used to set up an ideal reproduction. This is possible only when an adequate fusing range exists, i.e. a high viscosity at glazing temperature.

Our porcelains are adjusted to have an expansion coefficient slightly lower than the metal base. By this means the porcelain is placed in compression where it is strongest, rather than in tension, where it is weakest. Small amounts of clay and coloring oxides from 0% to 5% by weight may be added, depending on the opacity and color desired.

The use of base metals which readily oxidize at high fusing temperatures, is possible with our method, for we have found that when the base metals are quickly cast into the high fusing porcelain at the plastic temperature of about 1600° F., the oxidation does not take place in the short period of time that the metal is heated and uncovered, with the result that the porcelain is free from the effects of oxidation and discoloration.

The inside of the porcelain may be suitably roughened, as at 50, in FIG. 7 to provide additional mechanical keys into which the metal will interlock for increased bond strength. Gold filings 52 may be fired into the inner surfaces of the hollow porcelain covering to provide a further interlock between the porcelain and the metal core.

Where base metals are used, we have discovered that we can pre-position sections 54 of gold solder, or a solderable metal, in the mesial and distal faces at the ends of the passageways and cast the base metal into the bore and passageways against the pre-positioned sections. The base metal will fusion weld to the solder sections (which

may be in the form of disks) and provide a pontic tooth having a base metal core with exposed precious metal surfaces suitable for connection to adjacent teeth. The opening 42 where the base metal is cast into the tooth is covered with a suitable porcelain plug 56 fused thereto to provide a porcelain contact with the tissue of the mouth at the gum line 58.

The ceramic teeth of our invention are thus provided with porcelain having the requisite color, range, translucency, opacity, insolubility, mechanical strength, maturing range, fusion range and a matched coefficient of expansion to the metal substrate.

By proper manipulation and processing of the ingredients of the porcelain, it is possible to obtain coefficients of expansion and fusing ranges which will match the coefficient of expansion of the noble and base metals used in the mouth.

For covering existing teeth, preferably the metal substrate should possess an outer surface generally conforming to the outer surface of the dentine structure of the natural tooth. In FIG. 2, there is shown, in cross-section, the occlusal portion 10, a metal core 12 in a typical molar restoration 14 in position on the gums 16. Such a restoration may be a pontic as shown in FIGS. 1 to 4, or a crown, such as the molar crown for a natural tooth, as shown in FIG. 5.

In each case the metal core 12 is generally positioned just below the outer surface to provide a reinforcing structure substantially throughout the entire layer of the porcelain covering 18 to support it against failure. By matching the coefficients of expansion of the metal to that of the porcelain, a relatively thin covering of the porcelain may, for the first time, be employed for teeth, which covering is free of tension and excessive compression and therefore will not crack as does present commercial dental porcelain used on similar metal substrates.

In manufacturing a molar pontic 14 as is shown in section, FIG. 2, on the gums 16, the core 12 may be made hollow as at 20 to reduce the weight of the metal, and therefore the cost, and to provide better retention for the porcelain. The pontic illustrated is provided with wing sections 22 which extend to the surfaces, forming metal contact areas for attachment to metal areas on adjacent supporting teeth.

The molar crown 30 illustrated in FIG. 5 comprises the outer porcelain cover 32 fused to the metal core 34. In such case the tooth structure 36 is prepared in the slightly tapered form illustrated. A taper of about 5° is satisfactory. The crown 30 is fitted over a wax impression of the tooth, not shown, which is subsequently cast in gold or other suitable metal 38 to closely fit the margins adjacent to the gums 39. By this means, the stock molar crown now has a perfect fit for the tooth 36 to which it is cemented. Metal foil can be used in place of the wax and fused to the crown. Details of such a construction are shown, described and claimed in a co-pending application Serial No. 443,872, filed July 16, 1954.

We employ a mold (not shown) for making our teeth, which mold defines the outer configuration of the porcelain tooth we are making in the proper size and shape. Thereafter, we insert the proper size and type of metal core therein and position it with respect to the mold in a manner known to the art of molding. The porcelain contains a binder, such as starch and water, which places the porcelain in condition for molding and for retaining its shape when the forms are removed and the tooth inserted in the baking ovens where the porcelain and metal are fused to each other.

In making high fusing porcelain dental constructions we prefer to fire the teeth for about one half hour at a temperature of 2000° F., or about cone 62. This is the equivalent of the 2150° F. porcelain fired for a few minutes.

In the manufacture of porcelain coverings into which

metal is cast, as shown in FIGS. 6 and 7, we first bake the porcelain covering 40 in the desired size and shape. The porcelain covering is provided with a hollow bore 42 extending from the saddle area 44, following generally the outline and position of the dentine structure of the tooth. Lateral passageways 46 lead from the central bore to the mesial and distal sides, respectively, of the tooth to provide for connections to adjacent teeth. The metal 48 is then cast into the porcelain covering, as will be hereinafter described.

We have discovered that it is possible to cast metal directly into the porcelain, provided the porcelain is in its plastic range, which is around 1600° F. for the high fusing porcelain. In such instance, the hollowed-out tooth covering is handled like a wax pattern for lost wax castings. That is, the hollows are filled with wax, the wax is sprued, invested, the wax burnt out, and metal cast in centrifugally, or otherwise.

Manufacture is very much simpler and cheaper by this method of fabrication. Base metals may be cast into the porcelain without oxidation sufficient to impair the porcelain-to-metal bond. This process also prevents discoloration of the porcelain.

The metal is heated in excess of its melting point, which in the case of the cobalt-chrome alloy, is approximately 2600° F., and casts centrifugally or by other means into the investment containing the hollowed-out tooth covering. The porcelain is first heated to its plastic temperature, say about 1600° F., at which temperature the molten metal is poured into the porcelain covering. At this temperature, the covering is plastic and therefore capable of enduring extreme thermal shock without fracture. It is then slowly cooled to room temperature.

By our process, it is possible to prepare dental bridges made of porcelain-covered metal-reinforced teeth that have no metal showing; which have a controlled color, brilliance and hue; of great strength; that are biologically compatible; that are simple in construction; that may be readily soldered; and that are designed to furnish maximum support to the porcelain to minimize breakage.

By our invention, the dental profession can, for the first time, safely rehabilitate the entire mouth, or any part thereof, in porcelain. Thus the patient can receive the full benefits of porcelain, such as superior tissue tolerance, increased wear resistance vital in the treatment of pyorrhea, and improved color and dimensional stability over acrylic restorations now being used.

By the use of teeth employing our invention, we can correct the bite and balance occlusion in the case of periodontoclasia, so that the delicate and vital equilibrium obtained will be best maintained due to the relatively small amount of wear encountered compared to the wear of gold. This is essential to real and lasting success in the treatment, control and prevention of periodontoclasia.

We have thus described our invention, but we desire it understood that it is not confined to the particular forms or uses shown and described, the same being merely illustrative, and that the invention may be carried out in other ways without departing from the spirit of our invention, and, therefore, we claim broadly the right to employ all equivalent instrumentalities coming within the scope of the appended claims, and by means of which objects of our invention are attained and new results accomplished, as it is obvious that the particular embodiments herein shown and described are only some of the many that can be employed to attain those objects and accomplish these results.

We claim:

1. A dental construction comprising a rigid metal body and a porcelain covering, said covering containing high fusing optically translucent material having a coefficient of expansion slightly less than that of the metal body to put the porcelain covering under compression, said ma-

terial under compression comprising the following constituents and range:

	Percent by weight
SiO ₂ -----	63 to 73
Al ₂ O ₃ -----	14 to 17
CaO -----	0.5 to 1.5
MgO -----	0.2 to 0.8
Na ₂ O -----	2 to 3.5
K ₂ O -----	11 to 15

2. The method of preparing a dental construction which consists in baking a hollow porcelain covering in the shape of a tooth having a hollow portion and casting a metal into said hollow portion.

3. The method of claim 2, wherein the porcelain covering is heated to its plastic range when receiving the cast metal.

4. A dental construction comprising a metal base, and a porcelain covering in the shape of a tooth and secured to said metal base, said porcelain having a coefficient of expansion between 90 and 170×10⁻⁷° C. and slightly less than that of the metal base to put the porcelain covering under compression, said porcelain covering and metal capable of being fired to above 1800° F. and cooled to room temperature said material under compression comprising the following constituents and range:

	Percent by weight
SiO ₂ -----	63 to 73
Al ₂ O ₃ -----	14 to 17
CaO -----	0.5 to 1.5
MgO -----	0.2 to 0.8
Na ₂ O -----	2 to 3.5
K ₂ O -----	11 to 15

5. The dental construction of claim 4, wherein the porcelain comprises a homogeneous mixture of about 7½ parts of a frit consisting of about 50% SiO₂, 7% Al₂O₃, 10% CaO, 5% MgO, 8% Na₂O and 20% K₂O, and about 42½ parts of a powdered natural feldspar having about 80 parts of orthoclase and about 20 parts of albite, with substantially an equal amount of the fusion product of about 75% natural feldspar and about 25% silica.

6. The dental construction of claim 4, wherein the porcelain comprises about 50 parts of a feldspar containing about 80% orthoclase and 20% albite homogeneously mixed with about 50 parts of a fusion product containing about 75% natural feldspar and about 25% silica.

7. The method of preparing a dental construction, which comprises firing a spar containing about 80% orthoclase at a temperature of about 2400° F. until substantially all the material is in a vitreous state, powdering the same, and mixing the powdered spar with a powdered fusion product consisting of between 70 and 95% natural feldspar and between 5 and 30% silica fired to about 2400° F., and securing the mixture to a metal base having a coefficient of expansion between 90 and 170×10⁻⁷° C. and slightly more than that of the mixture to put the fused mixture under compression at a fusing temperature of above 1800° F. said material under compression comprising the following constituents and range:

	Percent by weight
SiO ₂ -----	63 to 73
Al ₂ O ₃ -----	14 to 17
CaO -----	0.5 to 1.5
MgO -----	0.2 to 0.8
Na ₂ O -----	2 to 3.5
K ₂ O -----	11 to 15

8. The method of claim 7, wherein a small amount of K₂O is added when firing the orthoclase spar.

9. The method of claim 7, wherein a small amount of a powdered fusion product is added containing about one part by weight of K₂O to about 2½ parts by weight of SiO₂.

10. The method of claim 7, wherein about 15 parts

by weight of a powdered frit consisting of about 50% SiO₂, 7% Al₂O₃, 10% CaO, 5% MgO, 8% Na₂O and 20% K₂O is added to about 85 parts by weight of the orthoclase spar.

11. The method of claim 7, wherein the ratio of the two fusion products is adjusted to give a pre-selected coefficient of expansion in the final fused product.

12. The dental construction of claim 1 wherein the mesial and distal surfaces of the porcelain covering contain passageways filled with the metal of the body.

13. The dental construction of claim 1 wherein the mesial and distal surfaces of the porcelain covering contain passageways which have exposed surfaces of solderable metal connected to the metal body.

14. The method of claim 2 wherein metal particles are added to the inner surface of the porcelain covering before the molten metal is cast therein.

15. The method of preparing a dental construction which comprises firing a spar containing not less than 80.0% orthoclase at a temperature not less than 2400° F. until all material is in a glassy state; cooling, and grinding the glassy material until it will pass through a No. 14 silk screen, mixing the ground material with a similarly ground product consisting of between 70.0% and 95.0% orthoclase spar and between 5.0% and 30.0% silica fired at a temperature of about 2400° F. until the silica is sufficiently absorbed to give the desired degree of translucency, applying the resulting mixture to a cleaned metal base containing palladium possessing a coefficient of expansion between 90 and 160×10⁻⁷/° C., suitably shaped, and firing the composite structure to temperatures of about 2100° F. sufficient to fuse the porcelain to the metal, and to give the porcelain a coefficient of expansion sufficiently close to that of the metal base to insure a seal and only sufficiently less to free the porcelain covering of tension.

16. The method of converting an ordinary spar consisting of between 70.0% and 90.0% orthoclase into a dental porcelain which comprises adding between 5 and 30% of silica, and firing the mixture until translucent, then cooling and grinding the subsequent frit, thereafter mixing the same with an orthoclase spar containing not less than 80% orthoclase which has been fired to a temperature of not less than 2400° F. until all the material is in a glassy state, and thereafter cooled and ground.

17. A dental construction comprising a metal base containing palladium in amounts sufficient to cause the metal base to possess a coefficient of expansion in excess of 90 and below 160×10⁻⁷/° C., and a porcelain covering having the shape of a tooth and fused to the metal base, said porcelain covering having a maturing range of between 1750° F. and 2400° F. and having a coefficient of expansion slightly less than that of the metal base to free the porcelain covering of tension, said metal base being sufficiently large to form a metal substrate immediately below the surface of the porcelain to reinforce the porcelain layer.

18. The method of manufacturing a dental porcelain which comprises adding a powdered fusion product consisting of about 7½ parts of 50% SiO₂, 7% Al₂O₃, 10% CaO, 5% MgO, 8% Na₂O and 20% K₂O and about 42½ parts of a powdered orthoclase feldspar having about 80 parts of orthoclase and about 20 parts of albite to a powdered fusion product of an orthoclase feldspar and silica mixed in the ratio of about three to one, the proportions of the two fusion products forming the dental porcelain when fused, having a coefficient of expansion between 90 and 160×10⁻⁷/° C.

19. A dental construction comprising a metal base, and a porcelain covering in the shape of a tooth fused to said metal base, having a coefficient of expansion between 90 and 160×10⁻⁷/° C. and slightly less than that of the metal to free the porcelain covering of tension said porcelain covering and metal capable of being fired to about 2150° F. and cooled to room temperature.

20. The dental construction of claim 19, wherein the

porcelain comprises a homogeneous mixture of about 7½ parts of a frit consisting of about 50% SiO₂, 7% Al₂O₃, 10% CaO, 5% MgO, 8% Na₂O and 20% K₂O, and about 42½ parts of a powdered orthoclase feldspar having about 80 parts of orthoclase and about 20 parts of albite with substantially an equal amount of the fusion product of about 75% natural feldspar and about 25% silica.

21. The dental construction of claim 19, wherein the porcelain comprises about 50 parts of a feldspar containing about 80% orthoclase and 20% albite homogeneously mixed with about 50 parts of a fusion product containing about 75% orthoclase feldspar and about 25% silica.

22. The method of preparing a dental construction, which comprises firing a spar containing about 80% orthoclase at a temperature of about 2400° F. until substantially all the material is in a glassy state, powdering the same, and mixing with a powdered fusion product consisting of between 70 and 95% orthoclase spar and between 5 and 30% silica fired to about 2400° F., and fusing the mixture to a metal base having a coefficient of expansion between 90 and 170×10⁻⁷/° C. at a temperature of about 2150° F., the coefficient of expansion of the porcelain being slightly less than that of the metal base.

23. A dental construction comprising a rigid metal body and a porcelain covering, said covering being made of high fusing optically translucent material having a coefficient of expansion slightly less than that of the metal body to put the porcelain covering under compression, said material under compression comprising the following constituents and range:

	Percent by weight
SiO ₂ -----	67.8 to 73
Al ₂ O ₃ -----	11.1 to 17.1
CaO -----	0.1 to 2.6
MgO -----	0.1 to 1.8
Na ₂ O -----	1.9 to 9.6
K ₂ O -----	6.3 to 19.3
Li ₂ O -----	0 to 5.0

24. The method of preparing a dental construction, which comprises firing a material containing a spar of not less than 80% orthoclase at a temperature of about between 2200° F. and 2400° F. until substantially all the material is in a vitreous state, powdering the same, and mixing with a powdered fusion product consisting of not less than 30% by weight of natural feldspar and a material containing the following constituents and range: SiO₂ (5 to 70% by weight), Al₂O₃ (0 to 5.0%), Na₂O (0 to 16.5%), CaO (0 to 5.0%), and MgO (0 to 3.5%), fired to not less than 2200° F., and securing the mixture to a metal base having a coefficient of expansion between 80 and 170×10⁻⁷/° C. and slightly more than that of the mixture to put the fused mixture under compression at a fusing temperature of not less than 1650° F. said material under compression comprising the following constituents and range:

	Percent by weight
SiO ₂ -----	57.8 to 73
Al ₂ O ₃ -----	11.1 to 17.1
CaO -----	0.1 to 2.6
MgO -----	0.1 to 1.8
Na ₂ O -----	1.9 to 9.6
K ₂ O -----	6.35 to 19.3
Li ₂ O -----	0 to 5.0

25. A dental construction comprising a metal base possessing a coefficient of expansion in excess of 80 and below 170×10⁻⁷/° C., and a thin porcelain covering having the shape of a tooth and fused to the metal base, said porcelain covering having a maturing range of between 1650° F. and 2400° F. and having a coefficient of expansion slightly less than that of the metal base to free the porcelain covering of tension, said metal base

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being sufficiently large to form a metal substrate immediately below the surface of the porcelain to reinforce the thin porcelain layer.

26. A dental construction comprising a metal base, and a porcelain covering in the shape of a tooth fused to said metal base, having a coefficient of expansion between 80 and $170 \times 10^{-7}/^{\circ}\text{C}$. and slightly less than that of the metal to free the porcelain covering of tension

said porcelain covering and metal capable of being fired to above 1650° F. and cooled to room temperature.

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