الجامعة السورية الخاصة
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DENTAL MATERIALS

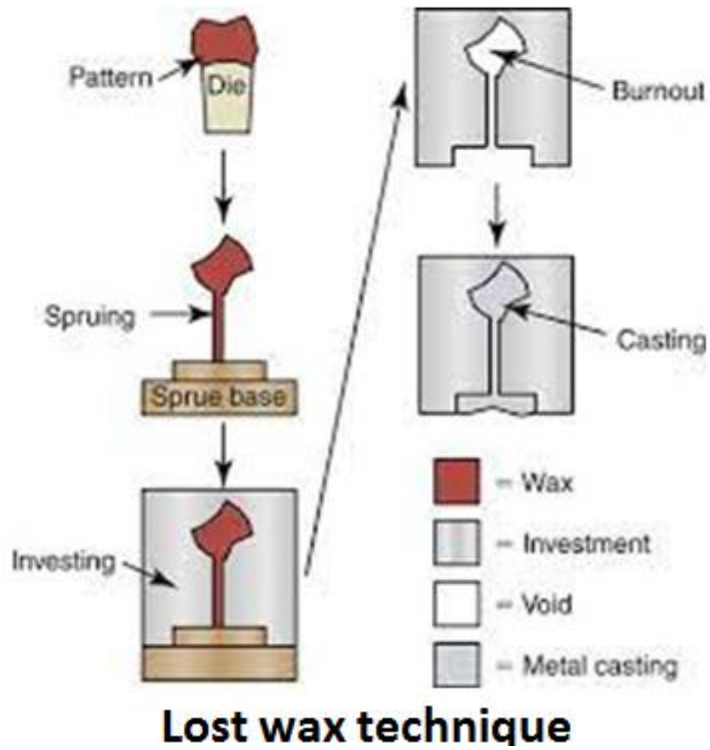
Investments and Dental Alloys

Investing and Casting

Lost-wax castings have been made since ancient times. In this technique, wax patterns are converted to cast metal patterns.

The process consists of surrounding the wax pattern with a mold made of heat-resistant investment material, then eliminating the wax by heating, and introducing molten metal into the mold through a channel called the *sprue.*

In dentistry, the resulting casting must be a highly accurate reproduction of the wax pattern both in surface details and in overall dimensions. Small variations in investing or casting can significantly affect the quality of the definitive restoration.



Several investment materials are available for fabricating a dental casting mold. These typically consist of a refractory material (usually silica) and a binder material, which provides strength. Additives are used by the manufacturer to improve handling characteristics.

When investments are classified by binder, three groups are recognized:

1. gypsum-bonded investments
2. phosphatebonded investments
3. silica-bonded investments.

Each has specific applications. The gypsum-bonded investments are used for castings made from American Dental Association (ADA) type II, type III, and type IV gold alloys.
The phosphate-bonded materials are recommended for

metal-ceramic frameworks and removable dental prostheses. The silica-bonded investments are rarely used nowadays.

GYPSUM-BONDED INVESTMENTS

Gypsum is used as a binder, along with cristobalite or quartz as the refractory material, to form the mold. The cristobalite and quartz are responsible for the thermal expansion of the mold during wax elimination. Because gypsum is not chemically stable at temperatures exceeding 650°C (1202°F), these investments are typically restricted to castings of conventional types II, III, and IV gold alloys.

Expansion:

Three types of expansion can be manipulated to obtain the desired size of casting: setting, hygroscopic, and thermal.

Setting Expansion. As the gypsum investment sets after mixing, it expands and slightly enlarges the mold. The pattern, metal casting ring, and compressibility of the ring liner all influence this expansion.

The water-to-powder ratio can be altered to reduce or increase the amount of setting expansion. The use of less water increases the setting expansion and results in a slightly larger casting. Use of an additional ring liner increases the setting expansion, as does a slight increase in mixing time.

Hygroscopic Expansion. Hygroscopic expansion occurs when water is added to the setting gypsum investment immediately after the ring has been filled.
To accomplish this, the ring is usually submerged in a water bath at 37°C (100°F) for up to 1 hour immediately after investment.

Thermal Expansion. As the mold is heated to eliminate the wax, thermal expansion occurs.
The silica refractory material is principally responsible for this because of solid-state phase transformations.
These transitions produce a volume increase inthe refractory components.

PHOSPHATE-BONDED INVESTMENTS:

Because most metal-ceramic alloys fuse at approximately 1400°C (≈ 2550°F) (as opposed to conventional gold alloys at 925°C [≈1700°F]), additional shrinkage occurs when the casting cools to room temperature. To compensate for this, a larger mold is necessary. The added expansion can be obtained with phosphatebonded investments.

The principal difference between gypsum-bonded and phosphate-bonded investments is the composition of the binder and the relatively high concentration of silica refractory material in the latter.

The binder consists of magnesium oxide and an ammonium phosphate compound.
In contrast to gypsum-bonded products, this material is stable at burnout temperatures above 650°C (1202°F) which allows for additional thermal expansion.
Investment strength increases with increasing temperature .
Most phosphatebonded investments are mixed with a specially prepared suspension of colloidal silica in water. (Some, however, can be mixed with water alone.)

Expansion

In comparison with gypsum-bonded investments, phosphate-bonded investments offer greater flexibility in controlling the amount of expansion.

The liquid-to powder ratio needs only slight modification to effect a significant change in setting expansion.

Working Time

Phosphate-bonded investments have a relatively short working time in comparison with gypsum materials.
Their exothermic setting reaction accelerates as the temperature of the mix rises during manipulation.
The filled ring feels warm to the touch even shortly after it has been filled.

Selecting an Investment Material

After the choice of casting alloy has been made, the investment material can be selected.

Ideal Properties:

An ideal investment should incorporate the following features:

- Controllable expansion to compensate precisely for shrinkage of the cast alloy during cooling
- The ability to produce smooth castings with accurate surface reproduction and without nodules
- Chemical stability at high casting temperatures
- Adequate strength to resist casting forces
- Sufficient porosity to allow for gas escape

Gypsum-bonded Investments:

Gypsum-bonded investments satisfy most of the requirements for an ideal material, although they are not suitable for casting metal-ceramic alloys because the gypsum is unstable at the high temperatures required and sulfide contamination of the alloy can occur.

Factors that increase expansion of gypsum-bonded investments include the following:

- Use of a full-width ring liner
- Prolonged spatulation
- Storage at 100% humidity
- Lower water-to-powder ratio
- Use of a dry liner
- Use of two ring liners

Phosphate-bonded Investments.

Phosphate-bonded investment materials offer certain advantages over gypsum-bonded investments.

They are more stable at high temperatures and thus are the material of choice for casting metal-ceramic alloys.

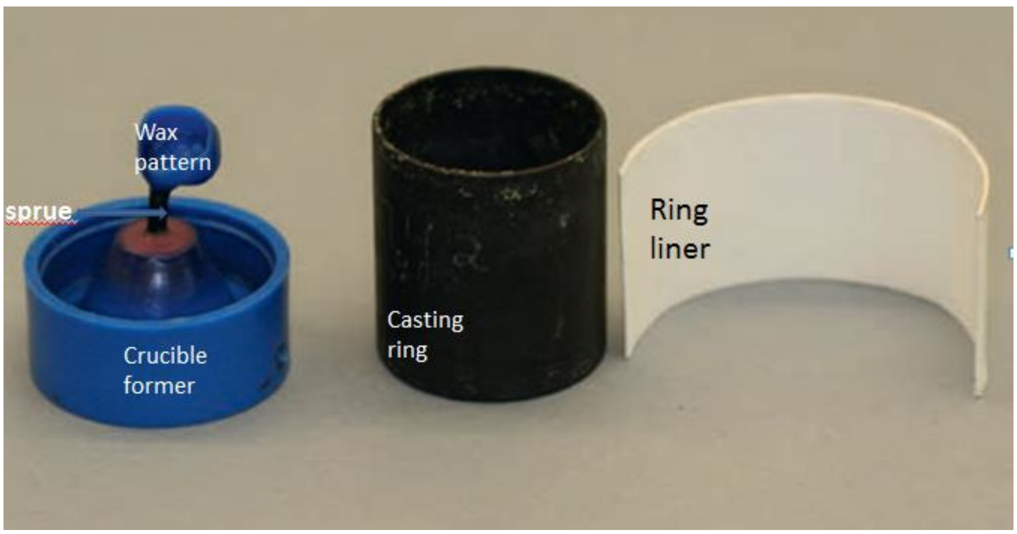
However, castings made with phosphate-bonded investments are rougher than those made with gypsum-bonded Investments and are more difficult to remove from the investment.

Because phosphate-bonded investments have lower porosity, complete mold filling is more difficult.
Castings also are more likely to have surface nodules, which must be removed. (Vacuum mixing and a careful investing technique help reduce but do not eliminate the occurrence of nodules.)

INVESTING

Vacuum mixing of investment materials is highly recommended for consistent results in casting with minimal surface defects, especially when phosphatebonded investments are used.

Good results are possible with brush application of vacuum-mixed investment or when the investment is poured into the ring under vacuum pressure. Vacuum mixing with brush application of the investment is the suggested mode.



When the investment has set, the “skin” at the top of the ring is trimmed off. **B,** The rubber crucible former is
removed, and any loose particles of investment are blown off

Wax Elimination

wax burnout

The ring is then placed in the furnace for the recommended burnout schedule

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DENTAL ALLOYS

DESIRABLE PROPERTIES OF DENTAL CASTING ALLOYS

1- BIOCOMPATIBILITY

The alloy must tolerate oral fluids and not release any harmful products into the oral environment. When components of an alloy are released in the oral environment, they can cause a toxic or allergic reaction.

2- TARNISH AND CORROSION RESISTANCE

corrosion is the physical dissolution of a material in the oral environment and tarnish is a thin film of a surface deposit that is adherent to the metal surface. Corrosion resistance is derived from the use of noble metals that do not react in the oral environment (e.g., gold and palladium) or by the ability of one or more of the metallic elements to form an adherent passivating surface film.

THERMAL PROPERTIES

The melting range of the casting alloys must be low enough to form smooth surfaces with the mold wall of the casting investment .To achieve an accurate fit of cast prostheses, oversized dies for waxing and controlled mold expansion are needed to compensate for casting shrinkage of the alloy and provide space for the luting cement. For metal-ceramic prostheses, the alloys must have closely matching thermal expansion coefficients to be compatible with given porcelains, and they must tolerate high processing temperatures without deforming via a creep process.

3- STRENGTH REQUIREMENTS

The alloy must have sufficient strength for the intended application.

Alloys for bridgework require higher strength than alloys for single crowns.

Alloys for metal-ceramic prostheses are finished in thin sections and require sufficient stiffness to prevent excessive elastic deflection from functional forces.

4- FABRICATION OF CAST PROSTHESES AND FRAMEWORKS

The molten alloy should flow freely into the most intricate regions of the investment mold, without any appreciable interaction with the investment material, and wet the mold surface without forming porosity within the surface or subsurface regions of the alloy.

This property is also termed *castability*.

5- PORCELAIN BONDING

To achieve a sound chemical bond to ceramic veneering materials, the alloy must be able to form a thin adherent oxide, preferably one that is light in color so that it does not interfere with the esthetic potential of the ceramic.

6- ECONOMIC CONSIDERATIONS

For the dental laboratory owner who must guarantee the cost of prosthetic work for a certain period of time, the cost of fabricating prostheses must be adjusted periodically to reflect the fluctuating prices of casting metals, mostly those of high noble and noble metal alloys.

FUNCTIONAL MECHANICAL PROPERTIES OF CASTING ALLOYS

The strength of an alloy is an important factor in ensuring that the prosthesis for which it is used will serve its intended functions effectively, safely, and for a reasonable time.
In a general sense, mechanical properties are the measured responses of materials under an applied force or distribution of forces, such as elastic deformation, plastic deformation, or a combination of both.
The level of strength needed depends on the intended categories of application and types of prostheses to be made.
The following are important functional characteristics of casting alloys.

ELASTIC MODULUS:

This property represents a proportional constant between stress and strain during the elastic deformation of a material.
One characteristic of a material with high elastic modulus is its rigidity or stiffness.
For a dental prosthesis, it is equivalent to its flexure resistance. For long-span FDPs, resistantce to flexure is important. When such a prosthesis flexes during loading of the pontic, the mesiodistal bending moment exerted on the abutment teeth can act as a dislodging force, lifting the mesial and distal aspects of the prosthesis.

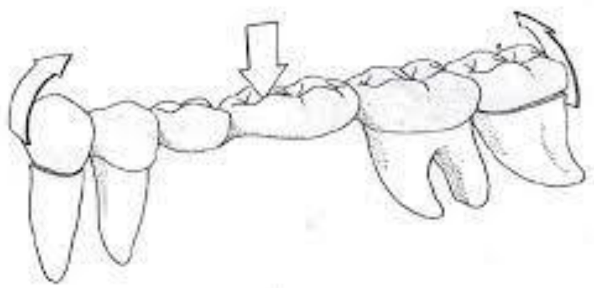
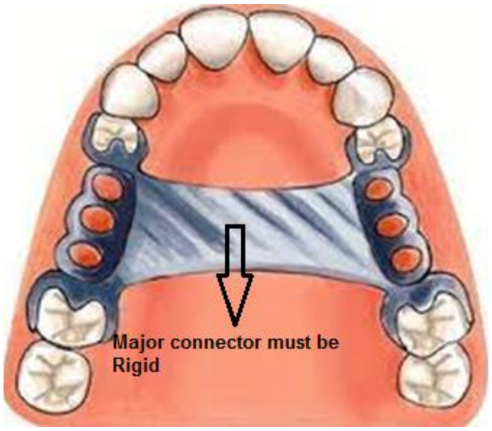


Figure 5: Irrational illustration of bridge bending.

Furthermore, a flexing bridge can induce lateral forces on the abutment teeth, resulting in the loosening of teeth.

For a metal-ceramic prosthesis, the overlying brittle porcelain will fail catastrophically when the metal substructure flexes beyond the flexural strength limit of the ceramic.

Elastic modulus is also important for the major connectors of removable partial dentures, which must have enough rigidity to prevent flexure during placement and function of the prosthesis.



Resistance to flexure also allows clasps to fit into areas of minimal undercuts and still provide adequate retention.

The elastic moduli of base metal alloys, excluding titanium alloys, are up to twice as high as those for some popular noble metal alloys.

YIELD STRENGTH

Yield strength reflects the capacity of a cast prosthesis to withstand mechanical stresses <u>without permanent deformation</u>.
Ideally, the alloys should have a high yield strength, so that a great deal of stress must be applied before a permanent change in dimensions occurs.

Generally, alloys with tensile yield strengths above 300 MPa function satisfactorily in the mouth.

DUCTILITY

This mechanical property represents the amount of plastic deformation under tensile stress that an alloy can undergo before it fractures. If the force applied is in compressive mode, the property is called *malleability*.

A reasonable amount of ductility and malleability are essential if the clinical application requires some plastic deformation of the cast structure, as is needed for clasp and margin adjustment and for burnishing.

Hardness:

is a measure of the resistance of the surface to Indentation . Hardness of the metal should be high enough to resist scratching and abrasion and also to maintain the smoothness of the prosthesis in the oral environment.

A hard restoration surface can also cause excessive wear of the opposing dentition or restoration(s) and requires more energy in grinding and polishing of the restorations.

FATIGUE RESISTANCE

This phenomenon occurs when a material is subjected to repeated loading and unloading below its elastic limit.
Most fractures of prostheses and restorations develop progressively over many stress cycles. When the load is above a certain threshold, it initiates cracks from surface flaws of the material. Eventually a crack propagates to a critical size, and sudden fracture occurs.

Alloy Classification by Noble Metal Content—American Dental Association ADA

Classifying noble and base metal casting alloysaccording to the mechanism for *corrosion resistance* is the preferred method of categorization.

The gold-based and palladium-based noble metal casting alloys achieve corrosion resistance because of the inherent nobility of the gold and palladium atoms, which do not form stable oxides at room temperature.

In contrast, the conventional base metal casting alloys—in which nickel and cobalt are the principal elements and chromium is present to provide corrosion resistance—oxidize rapidly to form a chromium oxide surface layer that blocks the diffusion of oxygen and prevents corrosion of the underlying metal (passivation).

Titanium and titanium alloys also oxidize rapidly, and the thin surface layer of titanium oxide provides corrosion resistance.

TABLE 16-1 Alloy Classification by Noble Metal Content—American Dental Association (1984)

Alloy Type	Total Noble Metal Content
High noble (HN)	Must contain ≥40% Au and ≥60% by weight of noble metal elements*
Noble (N)	Must contain ≥25% by weight of noble metal elements
Predominantly base metal (PB)	Contains <25% by weight of noble metal elements

*Noble metal elements include Au, Pd, Pt, Rh, Ru, Ir, and Os.

High-Noble Alloys

The high-noble alloys are gold based and contain a minimum of 60% by weight of noble elements; at least 40% is **gold**.
There are three systems in this class:
goldplatinum- palladium (**Au**-**Pt**-**Pd**),
gold-palladium-silver (**Au**-**Pd**-**Ag**),
and gold-palladium (**Au**-**Pd**),
in the historical order of their development

Gold-Platinum-Palladium

Although these alloys have excellent corrosion resistance, they are susceptible to some dimensional changes during the porcelain firing cycles and are not recommended for multipleunit FDPs.

Gold-Palladium-Silver

gold content was reduced to approximately 50%, have excellent mechanical properties and porcelain adherence

Green discoloration (resulting from diffusion of silver atoms into the porcelain) has been reported for some Au-Pd-Ag alloy–porcelain combinations.

Gold-Palladium.

Gold-palladium alloys that are silver free were developed during the late 1970s and have become very popular.
unlike that of Au-Pd-Ag alloys. The Au-Pd alloys have excellent mechanical properties, elevated temperature creep behavior, and porcelain adherence, without the green discoloration associated with Au-Pd- Ag alloys

the Au-Pd and Au-Pd-Ag alloys, in comparison with the Au-Pt-Pd alloys, generally have higher values of yield strength and elastic modulus, along with lower density. Consequently, FDPs fabricated from alloys in the former two groups are more resistant to masticatory forces and undergo less bending deflection.

They are also economically advantageous in that more restorations can be made per unit of alloy cost. Selection of the proper porcelain for Au-Pd-Ag alloys is essential if discoloration problems are to be avoided.

Noble Alloys

Noble alloys have a minimum of 25% by weight of noble metal, with **no** requirement for gold percentage, and are palladium based.
The yield strength and hardness values are greater than high-noble alloys which make them suitable for making crowns and bridges.

There are three alloy systems in this class:
palladium-silver (Pd-Ag),
palladium-copper gallium (Pd-Cu-Ga),
Palladium-Gallium

Palladium-Silver.

Because of their high silver content (approximately 30% to 35% by weight), these alloys have been called *semiprecious*

Because of their high silver contents, porcelain greening and furnace contamination can result during fabrication of such FPDs, unless the porcelain is carefully selected.

Nevertheless, these alloys are frequently chosen as a *compromise* between the more expensive high-noble alloys and the relatively inexpensive base metal alloys.

Predominantly Base Metal Alloys:

Having less than 25% by weight of noble metal with no requirement for gold. Of these alloys, are nickel-chromium (Ni-Cr) alloys, and cobalt-chromium (Co-Cr) alloys

One benefit of these alloys is that their values of elastic modulus are much higher than those of the noble metal alloys.
Therefore, long-span fixed prostheses fabricated from Ni-Cr alloys undergo much less flexure than do similar prostheses fabricated from noble metal alloys, and the brittle dental porcelain component is less likely to fracture. In addition , they have higher values of hardness and yield strength than nobel and high nobel alloys

They may be used for:

-crowns and bridges (with or without ceramic)
-partial dentures
-Dental implants.

Nickel-Chromium:

An alloy used widely for porcelain fused to metal restorations

Its composition is :
60-82% nickel
12-26% chrome

Many Ni-Cr alloy formulations contain up to 2% by weight of beryllium. The major reason for incorporating this element in the alloy is to: 1- lower the melting range and to 2- decrease the viscosity of the molten alloy, thereby improving its castability.

Beryllium also provides strengthening and affects the thickness of the oxide layer when the alloy is oxidized for porcelain firing.

Nickel:
Acute effects of exposure to nickel include skin sensitization that can lead to chronic eczema. Therefore, as a health precaution, an operator should wear a mask and use efficient suction when grinding and finishing a dental nickel-based alloy.

It has been reported that 9% of the female population and 0.9% of the male population are sensitive to nickel.

Cobalt-Chromium:

The potential health problems associated with beryllium- and nickel-containing alloys have led to the development of another alternative base metal alloy system: cobalt-chromium

Co-Cr alloys have higher hardness than do the Ni-Cr alloys (as a result of the high content of chromium), which suggests that finishing restorations made with the former alloys may be more difficult. Chromium has high affinity to Oxygen which leads to chromium oxide layer surrounding freshly exposed metal, that protect it from corrosion.

Its main composition is :

50-70% Cobalt

20-32% Chrome It is mainly used in removable partial dentures (RPD).

Characteristic	Noble Alloys			Predominantly Base Alloys					
	PALLADIUM-GALLIUM (Pd-Ga)			NICKEL-CHROMIUM (Ni-Cr)			COBALT-CHROMIUM (Co-Cr)		
	LEGACY (JELENKO)	*PROTOCOL (IVOCLAR VIVADENT)*	*ARGELITE 80 + 5 (ARGEN)*	*ARGELOY N.P. (ARGEN)*	*ARGELOY N.P. (BE-FREE) (ARGEN)*	*4ALL (IVOCLAR VIVADENT)*	*GENESIS II (JELENKO)*	*ARGELOY N.P. SPECIAL (ARGEN)*	*D.SIGN 30 (IVOCLAR VIVADENT)*
Composition (weight %)	Pd: 85.1 Ga: 10 In: 1.2 Ag: 1.2 Au: 2 Ru: <1	Pd: 75.2 Ga: 6.0 In: 6.0 Au: 6.0 Ag: 6.5 Ru, Li: <1	Pd: 79.9 Ga: 6.3 In: 6.5 Au: 4.8 Ag: 1.8 Ru, Zn: <1	Ni: 76 Cr: 14 Mo: 6 Al: 2 Be: 1.8 C, Si, Fe: <1	Ni: 54 Cr: 22 Mo: 9 Fe: 4 Nb: 4 Ta: 4 C, Si, Al: <1	Ni: 61.4 Cr: 25.7 Mo: 11.0 Si: 1.5 Mn, Al, C: <1	Co: 52.6 Cr: 27.5 W: 12 Ru: 2.5 Ga: 2.5 Fe: 1.0 Cu: 1.0 Si, Nb, Ta: <1	Co: 59.5 Cr: 31.5 Mo: 5 Si: 2 B, Fe, Mn: <1	Co: 60.2 Cr: 30.1 Ga: 3.9 Nb: 3.2 Mo, Si, B, Fe, Al, Li: <1
Yield strength (MPa)	634 (S)	500 (AF)	585 (S)	552(S)	360 (S)	375 (AF)	517 (S)	710 (S)	520 (AF)
Elastic modulus (GPa)	117	103	120	192	160	200	172	280	234
Tensile strength (MPa)	793 (S)	—	815 (S)	1,138 (H)	580 (S)	—	765 (H)	765 (S)	—
Elongation (%)	18 (S)	34 (AF)	33 (S)	12 (S)	6 (S)	12 (AF)	15 (S)	5 (S)	6 (AF)
Vickers hardness number (VHN)	265 (AF)	235 (AF)	260 (AF)	240 (AF)	240 (AF)	235 (AF)	325 (AF)	430 (AF)	385 (AF)
Density (g/cm³)	11.4	11.0	11.5	7.8	8.6	8.4	8.8	8.8	7.8

Titanium and Titanium alloys

The use of commercially pure titanium (CP Ti) and titanium alloys for dental applications has increased significantly since a description of its applications was first reported in 1977.

These metals can be used for all-metal and metal-ceramic prostheses as well as for implants and removable partial denture frameworks. Titanium derives its corrosion protection from a thin passivating oxide film (approximately 10 nm thick), which forms spontaneously

with surrounding oxygen.

Titanium is considered ***the most biocompatible metal .***

Titanium has a high melting point (1668 °C) and high rate of oxidation above 900 °C.

It requires a special casting machine and an argon atmosphere

along with a casting investment consisting of oxides.

Special tools are required in the dental laboratory for finishing

and adjusting CP Ti castings in order to eliminate the weak outer layer near the surface.

The high melting temperature of titanium alloys makes them highly resistant to sag deformation when used as metal frameworks at porcelain sintering temperatures, and the accompanying relatively low thermal expansion coefficient demands special low expansion dental porcelains for bonding to titanium.

Titanium Alloys:

The most widely used titanium alloy in dentistry and for general commercial applications is Ti-6Al-4V.

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The end