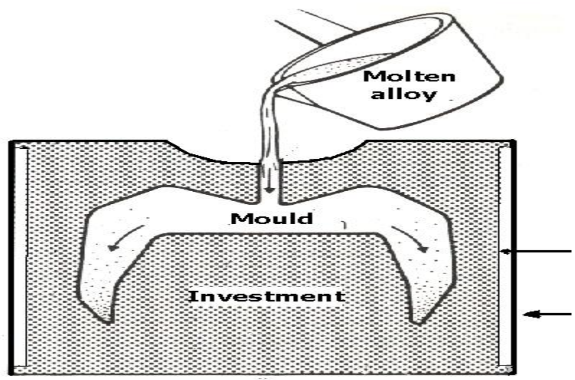
Investment Materials

An investment material can be described as a **ceramic material** that is suitable for forming a mold into which a metal or alloy is cast.

When a restoration or appliance is being made by a “**lost wax**” process, the wax pattern is embedded in an **investment material**. After the investment material has set, the wax is removed by **burn out process**, that creates a space in the investment called as **mold space**, which is filled by the material of which the restoration or appliance is to be made.



Ideal properties required for an investment

1. Should not react with wax and alloys.
2. Should be easily manipulated.
3. The inner surface of the mold should not breakdown at higher temperature.
4. At higher temperature, the investment must not decompose to give off gases that could corrode the surface of the alloy.
5. The investment should have enough expansion to compensate for shrinkage of the wax pattern and the metal that takes place during the casting procedure.
6. A dental casting investment should be porous enough to allow the air or other gases in the mold cavity to escape easily during the casting procedure.

7. The investment should produce a smooth surface and fine detail and margins on the casting.
8. Should have long shelf life.
9. Should be inexpensive.
10. Should have high compressive strength to withstand impact forces of molten alloy.

No single material is known that completely fulfills all of these requirements.

General composition of investment materials

Generally, an investment is a mixture of the following materials:

1. Refractory Material: Refractory material is usually a form of ***silicon dioxide*** such as quartz, tridymite or cristobalite or mixture of these.

Contraction of gypsum during casting can be eliminated by using the proper form of silica in the investment.

On heating silicon dioxide change their crystalline structures, this change in crystalline structure results in ***decrease in density*** *and* ***increase in volume that causes rapid increase in linear expansion***, which helps in compensating the casting shrinkage.

Combinations of different types of silica can also be used in dental investments (quartz or cristobalite). As per the type of silica is present in an investment it can be classified as "quartz or cristobalite investment".

2. Binder Material: Binder materials are used to form a coherent solid mass with refractory material. Most commonly used binders in dental investments are ***α-calcium sulfate hemihydrate, phosphate, and ethyl silicate.***

3. Modifiers: These include sodium chloride, boric acid, potassium sulfate, graphite, copper powder or/ and MgO; are added in a small quantity to modify some physical and mechanical properties of the investment.

In general, there are three types of investments, the choice of investment material depended on melting range of alloy and preference of clinician.

- Gypsum bonded investment (for conventional gold alloys)
- Phosphate bonded investment (for metal ceramic restorations)
- Ethyl silicate bonded investment (for casting of RPD with base metal alloy).

Classification Of Investments

1. Based on type of binder present:

a) Gypsum bonded investment: CaSO4 α-hemihydrate
b) Phosphate bonded investment: Monoammonium phosphate
c) Silica bonded investment: Ethyl silicate.

2. Based on refractory material:

a) Quartz investments
b) Cristobalite investments

3. Based on temperature of casting:

a) Low temperature investments
   - Gypsum bonded investment: CaSO4 α-hemihydrate

b) High temperature investments.
   - Phosphate bonded investment
   - Silica bonded investment: Ethyl silicate.

Gypsum Bonded Investments ($CaSO_4$ α-hemihydrate)

Gypsum is a mineral that is extracted in various parts of the world. Chemically the gypsum that is produced for dental purposes is nearly pure calcium sulfate dihydrate.

Uses: it is used to form mold for casting gold alloys for crown and bridges.

Composition:

Ingredient	Wt %	Functions
Calcium sulfate α-hemihydrate	25–45	• Acts as a binder. • Improves strength.
Silica	55– 75	•Refractory material and can withstand high temperatures. • Regulates the thermal expansion.
Modifiers ex. Boric acid, NaCl,	Trace	•Regulates the setting expansion and setting time. •Also prevents most of the shrinkage of gypsum, when it is heated above 300°C.
Reducing Agents ex. Carbon, powdered graphite	Trace	•To provide a nonoxidizing atmosphere in the mold when the gold alloy is cast.
Coloring Agents	Trace	Provides characteristic color

Properties:

1. Three types of expansion may develop: setting, thermal and hygroscopic expansion (Thermal, setting and hygroscopic expansion is about 1.3% - 2%).
2. It will decompose to sulfur dioxide and sulfur trioxide when heated above 700 C tending to embrittle the alloy therefore it is not used for casting Co / Cr or palladium alloys but used for gold alloy.

Setting Reaction

The most recognized theory of the mechanism of setting is the crystalline theory.

Setting Time

It is the time from the beginning of mixing until material hardens, it ranges between 5‑25 minutes.

Factors Influencing Setting Time

Theoretically, there are at least **three** methods by which such control can be achieved.

1. The solubility of hemihydrate can be increased or decreased by addition of potassium sulfate (accelerator) or Borax (Retarder).
2. The number of nuclei of crystallization can be increased or decreased, i.e. the greater the nuclei of crystallization, the faster the gypsum crystals form and the sooner the hardening of mass will occur.
3. The rate of crystal growth can be increased or decreased by addition of accelerator or retarder, the setting time can be accelerated or retarded.

Factors Controlled by Manufacturer

1. *Effect of Varying the Composition:* More amount of silica in the investment powder increases the manipulation time, initial setting time, because the particles of refractory filler interfere with the interlocking of growing gypsum crystals and making this less effective in developing a solid structure.

2. *Fineness:* The finer the particle size of the hemihydrate, the faster the mix hardens. (More number of gypsum nuclei hence more rapid rate of crystals).

3. Impurities: if the manufacturer adds gypsum, the setting time will be shortened because of increase in potential nuclei of crystallization.

Factors Controlled by Operator

In practice, these methods have been incorporated into the commercial products available. The operator can vary the setting time by altering w/p ratio and mixing speed.

1. W/P Ratio: The more the water that is used for mixing, the fewer nuclei are there per unit volume, i.e. setting time is prolonged.

2. Mixing: Within the practical limits, the longer and the more rapidly the mixing is done, the shorter is the setting time, i.e. some gypsum crystals form immediately as it is brought into contact with water. As the mixing begins, the formation of these crystals increases and at the same time the crystals are broken up by the mixing spatula and are distributed throughout the mixture which results in formation of more nuclei of crystallization, thus setting time is decreased.

3. Effect of Temperature: The temperature of the water used for mixing as well as room temperature affects setting time.

- Increased water temperature acts as an accelerator. But temperature above 50°C has a reverse effect.
- A change in temperature results in variation in the solubility of $CaSO_4$ hemihydrate and dihydrate, which may change the rate of chemical reaction.

Normal Setting Expansion (NSE)

The volumetric or linear increase in physical dimensions of an investment caused by chemical reactions that occur during hardening to a rigid structure is called normal setting expansion.

Regardless of the type of gypsum product used, an expansion of the mass can be detected during the change from the hemihydrate to the dihydrate.

As the amount of gypsum increases during setting period, the mass thickens because of the formation of needle-like crystals. The crystallization procedure is an outgrowth of crystals from nuclei of crystallization. Crystals growing from the nuclei can intermesh with and obstruct the growth of adjacent crystals.

If this process is repeated by thousands of the crystals during growth, an outward thrust or stress develops that produces an expansion of the entire mass. Thus, a setting expansion takes place, this crystal impingement and movement results in the production of **micropores**. The structure immediately **after setting** is composed of interlocking crystals, between which are micropores and pores containing the excess water required for mixing. **On drying**, the excess water is lost and the void space is increased.

- A mixture of silica and hemihydrate results in setting expansion greater than that of the gypsum product when it is used alone. The silica particles interfere with the intermeshing and interlocking of the crystals as they form. Thus, the thrust of crystals is outward during growth and they increase expansion.

- The purpose of the setting expansion is to aid in enlarging of the mold to compensate partially for the casting shrinkage of the mold.

Hygroscopic Setting Expansion (HSE)

If the setting process is allowed to occur under water, the setting expansion may be more than double in magnitude. The reason for the increase expansion when the hemihydrate is allowed to react under water is related to the additional crystal growth permitted.

The hygroscopic setting expansion differs from the normal setting expansion in that it occurs when the gypsum product is allowed to set under or in contact with water and that it is greater in magnitude than normal setting expansion. The hygroscopic setting expansion may be **6 or more times** the NSE of a dental investment.

Factors Controlling the Hygroscopic Expansion

1. *Effect of composition:* The finer the particle size of silica the greater is the expansion.
2. *Effect of w/p ratio:* The higher the w/p ratio of the investment the lesser is the expansion.
3. *Effect of spatulation:* as the mixing time is reduced, the hygroscopic expansion is decreased.
4. *Shelf-life of investment:* The older the investment, the lower the hygroscopic expansion.

Thermal Expansion

Thermal expansion is the increase in dimension of a set investment due to temperature increase during burnout.

The expansion of a gypsum-bonded investment is directly related to the amount of silica present and to the type of silica employed.

Thermal Contraction

On cooling from 700°C an investment can undergo contraction, which is less than its original dimension. This contraction results in contraction of gypsum and not related to the amount and any property of silica. On reheating it may expand, thermally to the same dimensions when it was first heated. But reheating of investment is not advisable as it develops internal cracks.

Strength

The strength of an investment increased rapidly as the material hardens after initial setting time. However, the free water content of the set product definitely affects its strength.

Hence two strengths of a gypsum product are recognized.

1. ***Wet or green strength:*** Strength obtained when the water in excess of that required for the hydration of the hemihydrate is left in the test specimen.
2. ***Dry strength:*** When the specimen has been dried of the excess water, the strength obtained is dry strength. The dry strength is 2 or more times the wet strength.

The strength of an investment must be adequate to prevent chipping of the mold during heating and casting of the alloy.

Factors Affecting Strength

1. *W/P ratio*: The greater the w/p ratio, the greater will be porosity. The more the water is employed in mixing; the lower is the strength because the greater is the porosity, fewer crystals are available per unit volume for a given weight of hemihydrate.
2. *Temperature:* Heating the investment to 700°C may increase or decrease the strength as much as 65%, depending on the composition, i.e. greatest reduction with NaCl containing investment.
3. After the investment has cooled to room temperature its strength decreases considerably mainly because of fine cracks that form during cooling.
4. The addition of an accelerator or retarder lowers both the wet and dry strength.

Manipulation

Clean rubber bowl, plaster spatula, required amount of investment material and distilled water (The water and powder should be measured by using an accurate graduated cylinder and scoop) then **Mixing** either by **Hand mixing or Mechanical mixing,** then after mixing the investment material poured around wax pattern and allow for setting.

Phosphate bonded investments

The rapid growth of the use of metal ceramic restorations and the increased use of higher melting alloys has resulted in an increased used of phosphate bonded investments.

Uses: to form mold for casting high temp. dental alloys like Co / Cr. Also use as fixture for holding dental appliance to be soldered or welded.

Composition

It composed from *Powder* (Table) and *liquid.*

Liquid (Colloidal silica liquid suspensions): Colloidal silica suspensions are used with the phosphate investments in place of water as it requires greater expansion. Some phosphate investments are made to be used with water for the casting of many alloys.

Ingredient of the powder	Wt %	Functions
Refractory materials E.g. Quartz or cristobalite or mixture of both	80	•Withstand higher temperatures. • Give large setting expansions.
Binder E.g. Mixture of basic MgO and acidic ($NH_4H_2PO_4$)	20	Increases strength, setting and thermal expansions.
Carbon	Trace	Acts as reducing agent.

Working and Setting Time

- Phosphate investments are affected by temperature. The warmer the mix, the faster it sets. The setting reaction itself is exothermic, and this further accelerates the rate of setting.
- Increased mixing time and mixing efficiency, results in a faster set and a greater rise in temperature.

- In general, the more efficient the mixing, the better the casting in terms of smoothness and accuracy.
- Mechanical mixing under vacuum is preferred.

Setting and Thermal Expansion

In practice, setting reaction shows slight expansion, and this expansion can be increased by the use of a colloidal silica solution instead of water. When phosphate investments are mixed with water, they exhibit shrinkage between the temperatures of (200-400) °C. This contraction is practically eliminated by replacing the water with colloidal silica solution.

Manipulation

Required amount of powder and liquid are dispensed in vacuum mixer bowl and hand spatulated for 30 seconds until the powder is wetted by the liquid. Then the mixing bowl is attached to the vacuum mixer and mechanically spatulated according to manufacturer's recommended mixing time. Then the mix is poured in the casting ring (poured around wax pattern and allow for setting).

Advantages

- They have the ability to withstand high temperatures.
- They have sufficient strength.
- They can withstand the impact forces and pressure of centrifugally cast molten alloy.
- They provide setting and thermal expansion high enough to compensate for the thermal contraction of cast metal prosthesis during cooling.

Disadvantages

- Using the casting temperature greater than 1375°C, results in mold breakdown and rougher surfaces of the castings.
- The high strength of these investments makes removal of the casting from the investment a difficult task.

Ethyl Silicate Bonded Investments

The ethyl silicate bonded investments require more complicated and time-consuming procedures. It is used in the construction of the high fusing base metal partial denture alloys.

It is supplied as a powder that requires mixing with a liquid to bind the mixed mass via setting reaction at room temperature.

- The powder consists of refractory particles of silica and glasses in various forms along with MgO and some other oxides in minor amount.
- The liquid that is used for the setting reaction may be supplied as a stabilized alcohol solution of silica gel or it may form from two liquids that are supplied. When the system uses two liquids then one is ethyl silicate and the other may be an acidified solution of denatured ethyl alcohol.

Advantages

- These investments offer the ability to cast high temperature Co / Cr and Ni /Cr alloys.
- Good surface finish (thin sections with fine detail can be reproduced).
- Low distortion and high thermal expansion.
- They are less dense (i.e. more permeable) than phosphate bonded investments.
- The low-fired strength makes removal of casting from investment easier than with phosphate bonded investment.

Disadvantages

- Added processing attention and extra precaution needed in handling the low strength fired molds.
- The low strength and high thermal expansion requires a more precise burn out process and firing schedule to avoid cracking.
- The silica-bonded investments undergo slight contraction during setting and the early stages of heating. This is due to the nature of

the setting reaction and subsequent loss of water and alcohol from the material.

- Of the three main types of investment–the phosphate bonded products are becoming popular. Silica bonded materials are rarely used nowadays due to the fact that they are less convenient to use than the other products and that ethanol produced in the liquid can spontaneously burn at elevated temperature.

Soldering investment:

It is composed of quartz and calcium sulphate hemihydrates binder for low melting point alloys. For high melting point alloys phosphate bonded investment should be used. Soldering investment should have lower setting and thermal expansion than casting investment. They are made of ingredients that do not have as fine particles size as casting investment

All ceramic crown investment:

This investment must accurately reproduce the fine details; remain undamaged during firing of ceramic. And have thermal expansion compatible with that of ceramic. They are also phosphate bonded and contained fine grained refractory fillers to allow accurate reproduction of details.