**Investment materials**

**Introduction**

Following the production of a wax pattern by either the direct or indirect method , the next stage in many dental procedures involves the investment of the pattern to form a mould. A sprue is attached to the pattern and the assemblage is located in a casting ring. Investment material is poured around the wax pattern whilst still in a ﬂuid state. When the investment sets hard, the wax and sprue former are removed by softening and/or burning out to leave a mould which can be ﬁlled with an alloy or ceramic using a casting technique.

The investment mould used for casting alloys and some castable ceramics needs to be constructed from a material which retains its integrity at the casting temperature. Unmodiﬁed dental plasters or stones are not suitable for this purpose.

**Requirements of investments for alloy casting procedures:**

1. The investment should be capable of reproducing the shape, size and detail recorded in the wax pattern.
2. the investment should have a sufﬁciently high value of compressive strength at the casting temperature so that it can withstand the stresses set up when the molten metal enters the mould.
3. One function of the investment mould is to compensate for this casting shrinkage. This is generally achieved by a combination of

setting expansion during the hardening of the investment mould and thermal expansion during the heating of the mould to the casting temperature.

1. The main factors involved in the selection of investment material are the casting temperature to be used and the type of alloy to be cast. Some gold alloys are cast at relatively low casting temperatures of around 900ºC whilst some chromium alloys require casting temperatures of around 1450ºC. The investment which is best able to retain its integrity at the casting temperature and able to provide the necessary compensation for casting shrinkage is chosen.

**Available materials**

Investment materials consist of a mixture of a refractory material, normally silica, which is capable of withstanding very high temperatures without degradation, and a binder which binds the refractory particles together. The nature of the binder characterizes the material.There are three main groups of investment material in common use. They are referred to as gypsum-bonded, silica-bonded or phosphate-bonded.

**Gypsum-bonded materials**

These materials are supplied as powders which are mixed with water and are composed of a mixture of silica (SiO2) and calcium sulphate hemihydrate )gypsum product) together with other minor components including powdered graphite or powdered copper and various modiﬁers to control setting time.

Silica is a refractory material which adequately withstands the temperatures used during casting. It is available in three allotropic forms – quartz, cristobalite and tridymite – which are all chemically identical but differ slightly in crystalline form. Quartz and cristobalite are used extensively in investments. In addition to imparting the necessary refractory properties to the investment, the

silica is responsible for producing much of the expansion which is necessary to compensate for the casting shrinkage of the alloy. The expansion is accomplished by a combination of simple thermal expansion coupled with a crystalline inversion which results in a signiﬁcant expansion. Quartz undergoes inversion at a temperature of 575ºC from the so-called ‘low’ form or α-quartz

to the so-called ‘high’ form or β-quartz. For cristobalite ,conversion from the low to the high form occurs at a lower temperature of around 210ºC. The expansion is probably due to a straightening of chemical bonds to form a less dense crystal structure. The change is reversible and both quartz and cristobalite revert back to the low form on cooling. The overall thermal expansion and inversion expansion of materials containing cristobalite is greater than those containing quartz.

The calcium sulphate hemihydrate is an essential component since it reacts with water to form calcium sulphate dihydrate (gypsum) which effectively binds together the refractory silica. The setting expansion of the calcium sulphate dihydrate, when mixed with water, is used to partially compensate for the shrinkage of the alloy which occurs on casting. Further compensation can be achieved by employing the hygroscopic setting expansion which occurs if the investment mould is placed into water at the initial set stage. The latter method is known as the water immersion hygroscopic expansion technique and can result in an expansion of ﬁve times the normal setting expansion. Another method is the water added technique in which a measured volume of water is placed on the upper surface of the investment material within the casting ring. This produces a more readily controlled expansion. Hygroscopic expansion is further encouraged by lining the casting ring with a layer of damp asbestos which is able to feed water to a large surface area of the investment mould. The latter technique is routinely employed even when no attempt is made to maximize hygroscopic expansion by immersing in water or adding water.

The mechanism of hygroscopic expansion is not fully understood. However, it may be envisaged that water is attracted between crystals by capillary action and that the extra separation of parti-

cles causes an expansion. The magnitude of the hygroscopic setting expansion which occurs with gypsum bonded investments is greater than that which occurs with gypsum model and die materials.Gypsum alone is not satisfactory as an investment for alloy casting since it contracts on heating as water is lost and fractures before reaching the casting temperature. The magnitude of the contraction, which occurs rapidly above 320ºC, is signiﬁcantly reduced in investment materials by the incorporation of sodium chloride and boric acid.

Three types of gypsum bonded investments can be identiﬁed as follows:

Type 1 thermal expansion type; for casting inlays and crowns.

Type 2 hygroscopic expansion type; for casting inlays and crowns.

Type 3 for casting complete and partial dentures.

**Silica-bonded materials**

These materials consist of powdered quartz or cristobalite which is bonded together with silica gel. On heating, the silica gel turns into silica so that the completed mould is a tightly packed mass of silica particles.The binder solution is generally prepared by mixing ethyl silicate or one of its oligomers with a mixture of dilute hydrochloric acid and industrial spirit. The industrial spirit improves the mixing of ethyl silicate and water which are otherwise immiscible. A slow hydrolysis of ethyl silicate occurs producing a sol of silicic acid with the liberation of ethyl alcohol as a byproduct.

The silicic acid sol forms silica gel on mixing with quartz or cristobalite powder under alkaline conditions. The necessary pH is achieved by the presence of magnesium oxide in the powder.

In order that the material should have sufﬁcient strength at the casting temperature it is necessary to incorporate as much powder as possible into the binder solution. This process is aided by a

gradation of particle sizes such that small grains fill in the spaces between the larger grains. A very thick, almost dry mix of investment is used and it is vibrated in order to encourage close packing and produce as strong an investment as possible.

A small shrinkage occurs during the early stages of the heating of the investment prior to casting. This is due to loss of water and alcohol from the gel. The contraction is followed by a more sub-

stantial thermal expansion and inversion expansion of the silica similar to that for gypsum-bonded investments. Ethyl-silicate bonded investments do not expand on setting in the same way that gypsum-bonded and phosphate-bonded materials do. The total

linear expansion is therefore identical with the linear thermal expansion.

**Phosphate-bonded materials**

These materials consist of a powder containing silica, magnesium oxide and ammonium phosphate. On mixing with water or a colloidal silica solution, a reaction between the phosphate and

oxide occurs to form magnesium ammonium phosphate.

This binds the silica together to form the set investment mould. The formation of the magnesium ammonium phosphate involves a hydration reaction followed by crystallization similar to that for the formation of gypsum. As in the case of gypsum, a small expansion results from the outward thrust of growing crystals. The material is also able to undergo hygroscopic expansion if placed in contact with moisture during setting. Moisture adversely affects the unmixed material and the container should always be kept closed when not in use.

On heating the investment prior to casting, mould enlargement occurs by both thermal expansion and inversion of the silica. Thermal expansion is greater for the colloidal silica-mixed materials than for the water-mixed materials.

Two types of phosphate-bonded investment can be identiﬁed as follows:

Type 1 for inlays, crowns and other ﬁxed restorations.

Type 2 for partial dentures and other cast removable restorations.

**Properties of investment materials**

**Thermal stability**: One of the primary requirements of an investment is that it should retain its integrity at the casting temperature and have sufﬁcient strength to withstand the stresses set up when the molten alloy enters the investment mould.

**Porosity:** The gypsum-bonded and phosphate-bonded materials are sufﬁciently porous to allow escape of air and other gases from the mould during casting. The silica-bonded materials, on the other hand, are so closely packed that they are virtually porosity-free and there is a danger of back pressure’ building up which will cause the mould to be incompletely ﬁlled or the castings to be porous. These problems can be overcome by making vents in the investment which prevent the pressure from increasing.

**Compensating expansion**: The accuracy of ﬁt of a casting depends primarily on the ability of the investment material to compensate for the shrinkage of the alloy which occurs on casting. The magnitude of the shrinkage varies widely but is of the order of 1.4% for most gold alloys, 2.0% for Ni/Cr alloys and 2.3% for Co/Cr alloys.