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Investment Materials - Gypsum Bonded Investments- A Review

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Abstract- Dental casting investment material is undergoing a sea change in formulation due to the widespread advancements in technology at a rapid phase. The casting of metallic restorations and implant components in uncountable numbers continue to make this material an important component in dental technology. The demand for the requirement of high-quality customized dental casting materials in the past three decades has increased worldwide. The key to success is to attain highest form of accuracy in its physical properties like dimensional accuracy, surface hardness, etc. for dental casting alloys in order to perform well in innumerable conditions.

According to product type and application in dentistry there are three standards for casting investment materials namely-gypsum based investment materials, phosphate- and ethyl silicate-bonded products). The castability of an alloy also gets influenced by the type of investment material used during the process of casting process which is of great concern to many researchers. Hence, thorough knowledge of investment materials, applications and their properties is of utmost importance to clinicians as well as to technicians.

Keywords— investment, gypsum, expansion, ontraction, casting, shrinkage

INTRODUCTION

Dentists, researchers as well as patients share the common concern and demands for esthetics in the field of rapid advancing dentistry. Dental practitioners as well as researchers demand on good mechanical and physical properties of investment materials along with reasonable longevity of the restorations. They require techniques of preparing such a restoration to be relatively less technique sensitive and also affordable so that the cost does not exceed that of existing materials which is manufactured for the same purpose.¹

Most popularly used base metal alloy systems in dentistry comprises of stainless steels, cobalt-chromium, nickel-chromium, titanium, and nickel-titanium alloys.

Different techniques for casting should be employed in practice as the fusion and casting temperatures of the investing materials are considerably higher than those of their gold alloy counterparts. Thus, investment materials and casting process using the appropriate method is highly essential.⁴

An investment can be described as a ceramic material that is suitable for forming a mold into which a metal or alloy is cast. The operation of forming the mold is described as **investing** while **casting** is referred as the process by which a wax pattern of a prepared tooth is fabricated and converted to its metallic replica.⁵ The casting process is used to manufacture various dental restorations such as inlays, onlay crowns, bridges as well as removable and fixed partial dentures. The scope of prosthetic rehabilitation has undergone a dynamic change based on casting procedure in dentistry. Nickel based formulations are present in majority of all prosthetic restorations used clinically. The inherent cost of these materials is appreciably less as compared to that of gold-based systems as majority of the compositional elements are readily available.⁴ A series of steps along with basic fundamental principles and few modifications based on the type of restoration being cast are being employed to obtain the restoration from a wax pattern. In the year 1907, **Dr William Henry Taggart**, a Chicago dentist presented his

research on the production of a wax pattern, investing, burn-out and centrifugal casting to the New York Odontological Society.

Type I investments are those employed for the casting of inlays or crowns when the alloy casting shrinkage compensation is obtained principally by the process of **thermal expansion** of the investment material .

Type II major mode of compensation for alloy shrinkage during solidification for the investments used for casting inlays, onlays, or crowns is by the **hygroscopic expansion** which is obtained by immersing the invested ring in a water bath. Burnout of the investment is carried out at a lower temperature as compared to the one used for the high-heat burnout technique.

Type III investments are used in the manufacture of partial dentures with gold alloys.⁵

Generally, an investment is considered to be a mixture of three distinct types of materials mainly **refractory material, binder material, and other chemicals**. Refractory material is normally a form of silicon dioxide like quartz, tridymite, or cristobalite, or a mixture of these which are contained in all dental investment materials , whether for casting gold or high melting point alloys properties.⁵

REQUIREMENTS FOR AN IDEAL INVESTMENT

The ideal requirements of an investment material are as follows:

1) Manipulation should be easy¹¹

- The ability of reproducing the shape, size and details recorded in the wax pattern.
- The capability of maintaining its shape and integrity at elevated temperatures as the casting is carried out at very high temperature in excess of 1000°C.
- Easy manipulation with enough working time
- Smooth consistency and readily wet the surface of wax pattern.

2) Setting time

- Adequate setting time to allow the investing procedure and at same time it should harden within a relative short period of time.
- Sufficient time available for mixing of the material and investing the wax pattern before the investment material sets.
- According to ADA specification no. 2, investments should have setting time of not less than 5 minutes or not more than 25 minutes.
- The initial setting time of the modern gypsum-bonded investment is 9–18 minutes.

3) Sufficient strength at room temperature

- Ability to withstand the high temperatures when subjected during the process of burnout of the wax and casting of the alloy metal, without decomposing the investment material .
- Chemical stability at room temperature as well as at high temperature during casting procedures .
- It should not decompose and release gases that could cause damage to the surface of casting metal.

4) Dimensional stability- Dimensional accuracy and stability are of significant importance in ensuring that the device will fit. Setting and removal of impression material along with cooling from mouth to room temperature are essential elements. Cooling as well as heating of wax pattern during fabrication is important too for dimensional stability .⁶

5) Stability at higher temperatures

- No reaction with the alloy or with any of the oxides that may form on the surface of cast metal as high temperatures are essential for casting procedure .
- In order to allow the escape of gases from all parts of the mould so that it fills quickly and completely the investment material must be porous , and possess sufficient strength to withstand any forces casting. Accurate reproduction of the surface , the unset material

must easily adapt to the shape of the pattern without applying any excessive force, the material should be compatible with the wax patterns and easily be removed from the casting at the end of the procedure.

6) **Sufficient expansion:**

- It is essential to compensate for casting shrinkage of the wax pattern and metal that occurs place during the casting procedure.
- The dimensional changes of materials on heating is majorly due to the increase in the amplitude of thermal vibration – the stretching and bending of bonds due to more energy is supplied. This is called as **thermal expansion**.
- The strength of the bonds between atoms and molecules along with type of structure **principal factors to be considered**.
- The net expansion of the investment material is obtained by a combination of various expansions such as normal setting expansion, hygroscopic expansion, and thermal expansion.

7) **Beneficial casting temperatures:**

- Following the investing procedure, the invested casting ring is placed in an oven to burnout the wax pattern in order to create a mold space for the molten metal to accommodate.
- The temperature is gradually increased till 700°C for gypsum-bonded investments no longer than 20–30 minutes.
- For phosphate-bonded investments, the temperature is elevated till 1050°C for the same time period. During this process some amount of expansion also occurs.
- Many changes are observed in the refractory material of the investment undergoes leading referred to as thermal expansion procedure.

8) Porosity:

- It should be porous enough to allow the air or presence of any other gases in the mold cavity to escape easily during the process of casting.
- The location of the sprue attachment to that of the wax pattern is of utmost importance for proper casting procedure . The sprue should be fixed to the bulkiest portion of the wax pattern.
- To minimize distortion of the delicate area place the sprue away from the fine margins of the wax pattern. Always flare the point of contact when attaching the sprue which permits more-even flow of the metal into the mold and produces less porosity.
- The rate of flow of the molten metal into the mold cavity is controlled by the diameter of the sprue, in relation with the pressure of the casting machine and density of the molten metal.
- The high density of the molten metal as well as large diameter of the sprue helps in faster flow of molten metal into the mold cavity.
- The mold cavity cannot be completely filled until all gases are driven out through the pores of the investment material.
- Improper sprue design can also lead to suck back porosity.⁷

9) Smooth surface:

- Fine detail and margins should be on the casting.

11) Inexpensive

- It should be cost effective and technique sensitive. No single material is known that completely fulfils all of these requirements. By blending different ingredients an investment can be developed that possesses most of the required qualities. These ideal qualities are the basis for considering the behaviour and characteristics of casting investments.⁹

BASIC CONSTITUENTS

The investment material consists of mixture of three distinct type of materials⁹:

1. Refractory Material
2. Binder
3. Modifiers

Refractory Material:

The investment mould used to cast metal alloys with high melting temperatures, the first demand is that it survives those temperatures without mechanical or chemical breakdown. In other words, the investment must be refractory, which means resistant to change at high temperature.⁶

A **refractory** is a material that will withstand high temperatures without decomposing or disintegrating, e.g. silica.

They mainly serve two functions⁹

1. Act as a material that can withstand high temperatures.
2. Regulate the thermal expansion.

Refractory material is usually a form of silicon dioxide such as -

- I. Quartz
- II. Tridymite
- III. Cristobalite

Silica (silicon dioxide) is one of the most abundant constituents of the earth's crust. There are several crystalline forms of silica, which have different temperature ranges of stability. These are called quartz, tridymite, cristobalite and fused silica. Inversion from one of these forms to another takes place slowly.

QUARTZ

Quartz is the second most abundant mineral in earth's continental crust, behind feldspar. Quartz is a hard, crystalline mineral composed of silica-silicon dioxide. The atoms are linked in a continuous framework of SiO₄ (silicon-oxygen tetrahedra), with each oxygen being shared between two tetrahedra, giving an overall chemical formula of SiO₂.¹²

Quartz exists in two forms, the normal α -quartz and the high-temperature β -quartz, both of which are chiral. The transformation from α -quartz to β -quartz takes place abruptly at 573 °C.

TRIDYMITE- Tridymite is a high-temperature polymorph of silica and usually occurs as minute tabular white or colourless pseudo-hexagonal crystals, or scales, in cavities of felsic volcanic rocks. Its chemical formula is SiO₂. Tridymite consists of an alternating sequence of layers, each plane being the mirror image of the one above and below, opposing apices of course corresponding to shared oxygens. The mirror plane then passes through those shared oxygen atoms (Fi

Cristobalite-Cristobalite is mineral polymorph of silica that is formed at very high temperatures. It is used in dentistry as a component of alginate impression materials as well as for making models of teeth. It has the same chemical formula as quartz, SiO₂, but a distinct crystal structure. Both quartz and cristobalite are polymorphs with all the members of the quartz group, which also include coesite, tridymite and stishovite.

Binder Material:

A material which will set and bind together the particles of refractory substance, e.g. gypsum, phosphate and silicate is known as **Binder** material. The common binder used for gold alloys is dental stone (alpha-hemihydrate). The investments for casting cobalt chromium alloys use ethyl silicate, ammonium sulphate or sodium phosphate.¹¹

Modifiers

Chemicals such as sodium chloride, boric acid, potassium sulfate, graphite, copper powder or magnesium oxide are added in small quantities to modify various physical properties.

These agents may be accelerators or retarders to control the rate of setting, reducing agents such as powdered graphite or copper to protect embedded gold-alloy components in “casting-on” techniques, or additives to increase the thermal expansion of the investment. Typical additives are boric acid and soluble halide salts, particularly those of alkali or alkaline earth metals. Non-oxidizing agents, retarders, accelerators, and colouring agents are added to the refractory and binder materials to enhance their physical properties. Some chemicals added to investment materials include sodium chloride, boric acid, potassium sulfate, graphite, magnesium oxide, etc.⁹

CLASSIFICATION OF INVESTMENT MATERIAL

According to Phillips

Three types on the Basis of binder used in the investment materials

- Gypsum bonded investment
- Phosphate bonded investment
- Silica bonded investment

According to Anusavise

Based on silica/Refractory Material

- Quartz investment
- Cristobalite investment
- Tridymite investment

According to ANSI/ADA specification No.2

(Based on casting investment for dental gold alloys)

Type 1-Used for casting of inlays or crowns when the alloy casting shrinkage compensation is accomplished principally by thermal expansion of the alloy.

Type 2-used for casting inlays, onlays or crowns and major mode of compensation for alloy shrinkage during solidification is by hygroscopic expansion of the investment.

Type 3-used for the construction of partial dentures with base metal alloy.

GYP SUM BONDED INVESTMENT

Gypsum bonded products are used for casting conventional gold alloys have served the dental profession more selflessly than any other materials. These investments have calcium sulfate hemihydrate as binder and are relatively easy to manipulate.⁵. Dental plaster, stone, high-strength/ high-expansion stone, and casting investment materials constitute this group of closely related products. With slight modification, gypsum products are used for several different purposes. They are also used as a binder for silica, gold alloy casting investment, soldering investment, and investment for low-melting-point nickel-chromium alloys. The main reason for such diversified use is that gypsum materials are unique in nature and their properties can be easily modified by physical and chemical means.⁷

COMPOSITION

All gypsum-bonded investment powders consist basically of:

- a) Refractory filler
- b) Binder.
- c) modifying agents present (less than 5%)

TABLE 1 shows the Composition Of Gypsum Bonded Investment Material

TABLE 1- COMPOSITION OF GYP SUM BONDED INVESTMENT MATERIAL

INGREDIENT	WT %	FUNCTIONS
Calcium sulfate α -hemihydrate	25-45	<ul style="list-style-type: none">● Act as a binder● Improves strength

Silica	55-75	<ul style="list-style-type: none"> ● Refractory material and can withstand high temperatures ● Regulates the thermal expansion
Modifiers	Trace	<ul style="list-style-type: none"> ● Regulates the setting expansion and setting time ● Also prevents most of the shrinkage of gypsum when it is heated above 300°C
Reducing agents E.g. Carbon, powdered graphite or powdered copper	Trace	<ul style="list-style-type: none"> ● To provide a nonoxidizing atmosphere in the mold when gold alloy is cast
Colouring agents	Trace	<ul style="list-style-type: none"> ● Provides characteristic colour

MANIPULATION

- **Selection of Materials** ¹⁶

Clean rubber bowl, plaster spatula, required amount of investment material and distilled water.

- **Proportioning**

The water and powder should be measured by using an accurate graduated cylinder for the water volume (i.e. by use of scoop). If the container is shaken, the volume will increase as a result of entrapment of air. Preweighed envelopes are better as they promote accuracy, reduce waste and save time.

- **Mixing**

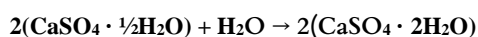
Hand mixing: A measured amount of water is placed in the bowl and the weighed powder is shifted in and the mixture is then vigorously stirred with the periodic wiping of the inside of the bowl with the spatula to ensure the wetting of all of the powder and breaking up any agglomerates or lumps. Entrapment of air in the mix must be avoided to avoid porosity leading to weak spots and surface inaccuracies. The use of an automatic vibrator of high frequency and of low amplitude can reduce the air entrapment. The mixing should continue until a smooth mix is obtained usually, within a minute.

- **Mechanical mixing**

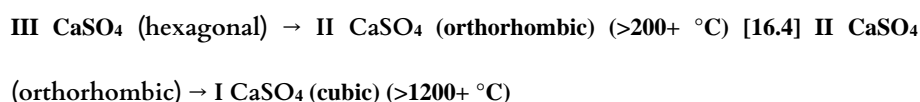
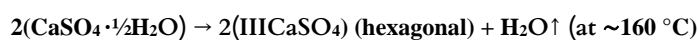
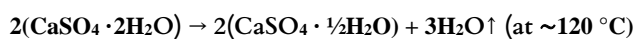
The preferred method of mixing is to add the measured water first, followed by gradual addition of the preweighed powder. The powder is incorporated during approximate –15 seconds of mixing with a hand spatula, followed by 20–30 seconds of mechanical mixing under vacuum by a mixture. The strength and hardness achieved by such mechanical mixing exceeds that obtained by one minute of hand mixing.¹⁶

SETTING REACTION

The chemistry of this material was investigated several decades ago. It sets by crystallisation¹⁸:



When heated, evaporation of the excess water required for mixing takes place between 60 and 100 °C, followed by the loss of water of crystallisation. With further heating, the structure of the anhydrite changes from hexagonal to orthorhombic.



Higher setting and thermal expansions are recorded when stone replaces plaster. Stone produces a workable mix at a lower water–powder ratio, hence a denser set structure. Although the mould is heated in air, a localised wet environment is created in the initial stage of burn-out, more so if the mould still contains a significant part of the excess water required for effective mixing. A dense set structure and wet environment favours the formation of stone when the mould is heated. After the remaining water of crystallisation has been lost, the transformation of the anhydrite from III CaSO₄ to II CaSO₄ takes place more rapidly and at a lower temperature when stone has formed during heating (of the mould). The matrix contracts less as a result of the denser structure and rapid transformation (Mori et al., 2003). Empiric development led to small additions of boric acid and sodium chloride to reduce shrinkage resulting from the loss of water of crystallisation during heating. In the localised wet environment in the first stage of dehydration, the presence of sodium chloride favours the formation of stone. This accelerates the transformation of the anhydrite from III CaSO₄ to II CaSO₄, which is completed 200 °C lower than normal. The denser structure resulting from stone formation and rapid transformation lead to less contraction in the matrix during heating. Unfortunately, most of the gain appears transient.

SETTING TIME

The chemical reaction is initiated at the moment the powder is mixed with water, but at the early stage only a small portion of the hemihydrate is converted to gypsum. The freshly mixed mass has a semifluid consistency and can be poured into a mold of any shape. As the reaction proceeds, however, more and more calcium sulfate dihydrate crystals are produced. The viscosity of the mixed mass increases, and the mass can no longer flow easily into the fine details of the mold. This time is called the **working time**.⁵

The **initial setting time** is the time required for gypsum products to reach a certain arbitrary stage of firmness in their setting process. In the normal case, this arbitrary stage is represented by a semi hard mass that has passed the working stage but is not yet completely set.

The time required for the reaction to be completed is called the **final setting time**. The final setting time is defined as the time at which the material can be separated from the impression without distortion or fracture. If the rate of the reaction is too fast or the material has a short setting time, the mixed mass may harden before the operator can manipulate it properly. On the other hand, if the rate of reaction is too slow, an excessively long time is required to complete the operation. Therefore, a proper setting time is one of the most important properties of gypsum materials. Even at final setting, however, the conversion of calcium sulfate hemihydrate to calcium sulfate dihydrate is only partially completed. In high-strength stones, the conversion to dihydrate is never complete. The presence of residual hemihydrate in the set gypsum increases the final strength of the set mass.⁵

➤ **Setting time of an investment**

It can be measured in the same manner as plaster. Furthermore, it can be controlled in the same manner. According to ANSI/ADA Specification No. 2 for dental inlay casting investment, the setting time should not be shorter than 5 min or longer than 25 min. Usually, the modern inlay investments set initially in 9 to 18 min. Sufficient time should be allowed for mixing and investing the pattern before the investment sets.⁷

RATE OF SETTING

The same physical changes that occur during the setting of gypsum plasters can also be recognized when gypsum-bonded investments set.

A. Manipulation time. Investing the wax pattern or pouring the investment cast must be completed while the mix is still fluid. As with gypsum plasters, loss of fluidity is indicated by the disappearance of the glossy surface.

B. Setting time. The initial setting time is usually determined using a Gillmore or Vicat needle. These measures indicate when the investment is strong enough for the sprue base and sprue former to be removed. Mold heating should be delayed until setting expansion is complete (usually between 1 and 2 hours from the start of mixing).

C. Particle size of the powder

The particle size affects the smoothness of the mold cavity surface (and thus of the casting) and also the inherent porosity of the mold (and thus the venting of the mold cavity). Only the particle size of the refractory filler is of practical importance, as it is the major constituent and remains unchanged in the set investment. The gypsum crystals formed during setting of the binder are much smaller than the silica particles.

EXPANSION

The total expansion is the sum of the: Setting Expansion + Hygroscopic Expansion + Thermal Expansion. |

Commented [1]: Please add the equation in an editable format.

The actual amounts of expansion involved can be balanced directly by different manufacturers but are designed to compensate for the average contraction of the metal alloy being cast.⁹

NORMAL SETTING EXPANSION

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**.¹⁶ A mixture of silica and calcinated gypsum (calcium sulfate hemihydrate) results in setting expansion greater than that of the gypsum product used alone. The silica particles probably interfere with the intermeshing and interlocking of the crystals as they form. Thus, the thrust of the crystals is outward during growth, and they increase expansion. Generally, the resulting setting expansion in such a case is high. ANSI/ADA Specification No. 2 for Type I investment

permits a maximum setting expansion in air of only 0.6%. The setting expansion of such modern investments is approximately 0.4%. It can be regulated by retarders and accelerators.

The purpose of the setting expansion is to aid in enlarging the mold to compensate partially for the casting shrinkage of the gold. There is some doubt as to whether all of the setting expansion is effective in expanding the mold cavity formed by the wax pattern.

As the investment sets, it eventually gains sufficient strength to produce a dimensional change in the wax pattern and mold cavity as setting expansion occurs. The inner core of the investment adjacent to a mesial-occlusal-distal (MOD) wax pattern can actually force the proximal walls outward to a certain extent. If the pattern has a thin wall, the effective setting expansion is somewhat greater than for a pattern with thicker walls, because the investment can move the thinner wall more readily.

HYGROSCOPIC SETTING EXPANSION (LOW HEAT TECHNIQUE)

Hygroscopic expansion is the continuation of setting expansion when it is allowed to set in the presence of water. The water has to be incorporated before setting of the investment takes place. This water then replaces the water of hydration, thus preventing confinement of crystal growth. Hence the crystals continue to grow outward in the presence of water, resulting in more expansion.¹¹

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 in 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.

FACTORS CONTROLLING THE HYGROSCOPIC EXPANSION

- **Effect of composition:** The magnitude of the hygroscopic setting expansion of a dental investment is generally proportional to the silica, finer the particle size of silica the greater is the expansion.
- **Effect of water/powder ratio:** The higher the w/p ratio of the investment the lesser is the expansion.
- **Effect of spatulation:** With most investments, as the mixing time is reduced, the hygroscopic expansion is decreased.
- **Shelf-life of investment:** The older the investment, the lower the hygroscopic expansion.¹⁶
- **Effect of confinement:** Both the normal and the hygroscopic setting expansions are confined by opposing forces, such as the walls of the container in which the investment is poured or the walls of a wax pattern.

- **Effect of the amount of added water:**

The magnitude of the hygroscopic setting expansion can be controlled by the amount of water that is added to the setting investment. It has been proved that the magnitude of the hygroscopic expansion is in direct proportion to the amount of water added during the setting period until a maximum expansion occurs. No further expansion is evident regardless of any amount of water added.

The hygroscopic setting expansion is a continuation of the ordinary setting expansion, because the immersion of water replaces the water of hydration, thus preventing the confinement of the growing crystals by the surface tension of the excess water.

Because of the dilution effect of the quartz particles, the hygroscopic setting expansion in these investments is greater than that of the gypsum binder when used alone.

The phenomenon is purely physical. The hemihydrate binder is not necessary for the hygroscopic expansion, because investments with other binders exhibit a similar expansion

when they are allowed to set under water. As a matter of fact, expansion can be detected when water is poured into a vessel containing only small smooth quartz particles.

The water is drawn between the particles by capillary action and thus causes the particles to separate, creating an expansion. The effect is not permanent after the water is evaporated, unless a binder is present. Any water-insoluble powder that is wettable can be mixed with the gypsum hemihydrate, and hygroscopic expansion results. Consequently, the quartz is not a factor. The influence of all the factors previously described can be related to the theory presented.

The greater the amount of the silica or the inert filler, the more easily the added water can diffuse through the setting material and the greater the expansion, for the same reason as described for the normal setting expansion of investment.

The water/powder ratio affects the hygroscopic expansion for the same reason that it affects the normal setting expansion. Once setting starts, the later water is added to the investment, the less is the hygroscopic setting expansion, because part of the crystallization has already started in a "normal" fashion.

Some of the crystals have intermeshed, inhibiting further crystal growth after the water is added. On the same basis, the less water added, the lower the expansion; that is, there is less counteraction of the surface tension. Finally, the term hygroscopic in a strict sense is a misnomer. Although the added water may be drawn into the setting material by capillary action, the effect is not related to hygroscopic .

THERMAL EXPANSION (HIGH HEAT TECHNIQUE)

Thermal expansion is the increase in dimension of a set investment due to temperature increase during burnout.¹⁶ The expansion of a gypsum-bonded investment is directly related to the amount of silica present and to the type of silica employed. A considerable amount of quartz is

necessary to counterbalance the contraction of the gypsum during heating. The contraction is entirely balanced when the quartz content is increased to 75%.⁷

If a sufficient amount of setting expansion had been present, a casting made at 700 °C would probably

fit the die reasonably well.

The thermal expansion of quartz investment is influenced by¹⁶:

- The particle size of the quartz
- Type of gypsum binder
- Water Powder ratio

According to ADA specification no.2 for type-I investment, which rely principally on the thermal expansion for compensation, the thermal expansion must be 1–1.6%.

For type-II investment, which relies on hygroscopic expansion for compensation of the contraction of the gold alloy, the thermal expansion is 0%–0.6% at 500°C.

An inlay investment undergoes maximum thermal expansion at a temperature not higher than 700°C. Hence when a thermal expansion technique is

employed, the maximum mold temperature for the casting of gold alloy should be less than 700°C because gold alloy can become contaminated at a mold temperature higher than this..

THERMAL CONTRACTION

When an investment material is cooled from 700 °C, the contraction curve follows the expansion curve . There is an the inversion of the β quartz or β cristobalite to a more stable α form at room temperature as the investment contracts to less extent than its original dimension which is not due to the presence of silica. This phenomenon occurs due to the shrinkage of gypsum when it is first heated. On reheating the investment is , it expands thermally to the same peak value reached when it was first heated. It should be taken care to not hear investment a second time due to the development of internal cracks.

PROPERTIES

❖ **Silica/Binder Ratio**

Investments usually contain 65% to 75% silica, 25% to 35% calcium sulfate hemihydrate, and about 2% to 3% of some additive chemicals to control the different physical properties and to color the investments. If the silica/stone ratio is increased, the hygroscopic expansion of the investment also increases, but the strength of the investment decreases.

❖ **Water/Powder Ratio**

As with the setting expansion of gypsum products, the more water in the mix (the thinner the mix or the higher the W/P ratio), the less the setting and hygroscopic expansions. Less thermal expansion is also obtained with a thinner mix.⁸

❖ **Role of Water**

During the setting process, dental casting investments actually absorb water from their surroundings and expand. It also has been observed that, during setting, the more water an investment is permitted to take up from any source, the higher its hygroscopic expansion. The hygroscopic expansion of an investment during setting versus the amount of water added to its surface. As indicated, the more water added to the surface of the mixed investment, the higher the hygroscopic expansion, up to a point beyond which further additions of water do not create any additional expansion. This degree of expansion and its corresponding quantity of water called the critical point. Note that for an investment to reach its maximum hygroscopic expansion, sufficient water should be available to it. If hygroscopically expanding investments are in contact with less water than they are able to absorb, they will not exhibit their maximum hygroscopic expansion.

❖ **Spatulation**

The effect of spatulation on the setting and hygroscopic expansion of the investment is similar to that on the setting expansion of all gypsum products. The curve C, less spatulation produces lower expansion with hygroscopic investment

❖ **Delay Before Immersion**

After the wax pattern is invested, the investment mass may be immersed in a water bath to obtain a better fit of the casting. The time between mixing and immersion has an effect on the total amount of expansion. In general, the hygroscopic expansion decreases with increased time between mixing and immersion. However, some investigators claim that if the investment is immersed at about the initial setting time, it expands more than if it is immersed earlier. However, more reproducible results are obtained from one test to another if the immersion is made before the gloss of the investment is lost.

❖ **Water-Bath-Temperature**

The temperature of the water bath has a measurable effect on the wax pattern. At higher water-bath temperatures, the wax pattern expands, requiring less expansion of the investment to compensate for the total casting shrinkage. In addition, higher water-bath temperatures soften the wax. The softened wax then gives less resistance to the expansion of the investment, thus making the setting and hygroscopic expansions more effective. The net effect is higher expansion of the mold with higher water-bath temperatures.

❖ **Particle Size of Silica**

The particle size of calcium sulfate hemihydrate has little effect on hygroscopic expansion, whereas the particle size of silica has a significant effect. Finer silica produces higher setting and hygroscopic expansions.

❖ **Fineness**

The fineness of the investment may affect its setting time, the surface roughness of the casting, and other properties. It was previously noted that a fine silica results in a higher hygroscopic expansion than does a coarser silica. A fine particle size is preferable to a coarse one, because the finer the investment, the smaller the surface irregularities on the casting

❖ **Porosity**

During the casting process, the molten metal is forced into the mold under pressure. As the molten metal enters the mold, the air must be forced out ahead of it. If the air is not completely eliminated, a backpressure builds up to prevent the gold alloy from completely filling the mold. The common method for venting the mold is through the pores of the investment. Thus, it is important that the extremity of a wax pattern not be covered by more than approximately 6 mm of investment to allow sufficient interconnectivity of the porous network, which will permit gas within the mold cavity to escape during filling of the mold with molten metal. Generally, the more gypsum crystals that are present in the set investment, the less its porosity. It follows, therefore, that the lower the hemihydrate content and the greater the amount of gauging water used to mix the investment, the more porous it becomes. Gypsum-bonded investment, which is commonly used in gold casting, can cause several defects such as gas porosity from the decomposition of gypsum. Thus, the insight study in the behaviour of gypsum-bonded investment can lead to resolve the problem in casting process.⁵⁴

STORAGE

The same precautions for storage of plaster or dental stone apply to the storage of an investment. Under conditions of high relative humidity, the setting time may change. Under such conditions, the setting expansion and the hygroscopic expansion may be altered so that the entire casting procedure may be adversely affected.

Therefore, the investments should be stored in airtight and moisture-proof containers. During use, the containers should be opened for as short a time as possible. All investments are composed of a number of ingredients, each of which possesses a different specific gravity. There is a tendency for these components to separate as they settle, according to their specific gravity, under the normal vibration that occurs in the dental laboratory.

Under certain conditions this separation may influence the setting time and other properties of the investment. For this reason, and because of the danger of accidental moisture contamination, it is advisable to purchase pre-packaged investments in relatively small quantities.

The selection of an investment is largely a matter of preference. Some investments are formulated for casting inlays and crowns employing thermal expansion as the main factor for casting shrinkage compensation, and some are designed for use with hygroscopic setting expansion. Consequently, the choice is dependent partly on the specific techniques for which the investment is designed.

Age of Investment

Investments that are 2 or 3 years old do not expand as much as freshly prepared investments. For this reason, the containers of investment must be kept closed as much as possible, especially if the investment is stored in a humid atmosphere⁷.

STRENGTH

Adequate strength of the investment material is significantly important to prevent any unforeseen fracture or chipping of the mold during eating and casting of the gold alloy although compressive strength should not be unduly high. The strength of an investment material is measured in the form of compressive stress and is increased according to the amount and the type of the gypsum binder present in the material. The use of chemical modifiers also helps in increasing the strength as maximum binder can be used without any significant reduction in

the thermal expansion. On the basis of composition , Heating the investment to 700° C (1292° F) either increase or decrease the strength upto 65%.In the presence of sodium chloride greatest reduction in compressive strength on heating is noted in investment material s. As the investment has cools down to room temperature, the strength decreases considerably, due to the presence of fine cracks that are formed during cooling. Also the presence free water content affects the strength of material.

Two strengths of a gypsum product are addressed

1. Wet or green strength: Strength obtained due to the presence of excess water required for the hydration of the hemihydrate.
2. Dry strength: When the specimen has been dried of the excess water, the strength obtained is dry strength which is 2 or more times the wet strength.

Factors Affecting Strength

W/P ratio: The greater the w/p ratio, the greater will be porosity. The more the water is incorporated in mixing it lowers is the compressive strength due to the presence of the greater is the porosity, fewer crystals are available per unit volume for a given weight of hemihydrate.

Temperature:

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.

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