Gypsum products serve the dental profession more adequately than any other materials

Dental Materials

Dr.Azhar Alawadi

Gypsum products propably serve dental profession more adequately than any other material.

Types of gypsum products:

1. Type I: Impression plaster.

2. Type II: Dental plaster.

3. Type III: Dental stone (medium strength stone).

4. Type IV: Improved stone (high strength stone) (die stone).

5. Type V: high strength/high expansion stone.

APPLICATION OF GYPSUM PRODUCTS IN DENTISTRY:

1- Impression plaster.

2- Mounting the casts to the articulation.

3- Form casts and dies.

4- Used as a binder for silica.

5- Used as a mold for processing dental polymers.

6- Used for bite registration (record centric jaw relation).

Properties of ideal model material (gypsum products):

1- Dimensional stability, no expansion or contraction during or after setting.

2- High compressive strength to withstand the force applied on it.

3- Surface Hardness, so surface details are not esily damaged.

4- Reproduce the fine details.

5- Produce smooth surface.

6- Reasonable setting time.

7- Compatible with the impression material.

8- Can be disinfected without damaging the surface.

Manufacturing gypsum products:

Gypsum products are produced by partial dehydration of mineral gypsum, which is calcium sulfate di-hydrate ($CaSO_4.2H_2O$) . They are supplied as powder when mixed with water they form slurry or paste, which set to form a rigid mass. Chemically speaking they are the same, but these products differ in their crystaline form.

Plaster:

When gypsum minral (Calcium Sulfate Dihydrate) is heated in open container to 110-120 ºC, it gives part of its water to form plaster which is (Calcium Sulfate Hemihydrate).

$$CaSO_4.2H_2O \xrightarrow{110\text{-}120\ ^\circ C} CaSO_4.\tfrac{1}{2}H_2O$$

The crystals of plaster are irregular in shape & porous. They're called Beta particles.

Stone:

Chemically, stone is the same as the plaster as mentioned before; it means that it is also CaSO4. ½ H2O but it is made by heating gypsum in wet condition under heat steam to 125ºC. The crystals are dense & regular and have prismatic shape. They're called alpha particles.

Die stone:

It is produced by boiling gypsum with 30% CaCl2 (calcium chloride). The crystals are also dense, regular & prismatic shaped & they're called alpha particles.

Setting reaction:

When mixing any type of gypsum product with water, they are converted back to gypsum & set to hard mass. The probable sequence is as follows:

- Plaster or stone or die stone (CaSO4. ½ H2O) dissolves in water.
- It reacts with water to form gypsum (CaSO4.2H2O)
- Gypsum is less soluble in water & the solution becomes super-saturated (unstable condition).
- Gypsum crystallizes allowing more particles to dissolve & form gypsum. This will continue until all particles have been converted to gypsum (CaSO4.2H2O). Each crystal when forms becomes nucleus for crystallization. Then the rigid mass is formed by the interlocking network formed by gypsum crystals.

$$CaSO_4.\tfrac{1}{2}H_2O + H_2O \xrightarrow{\text{Exothermic reaction}} CaSO_4.2H_2O + \text{HEAT}$$

Manipulation:

The powder is mixed with water at certain ratio according to the type of gypsum product.

W/P ratio for plaster is 0.5, this means 50 ml of water for each 100 gm of plaster powder.

W/P ratio for stone is 0.3

W/P ratio for die stone is 0.2

The difference in W/P ratio is due to the difference in the bulk volume of the powders. The water is measured & put in a clean rubber bowl then the powder is added to it gradually, allow the powder to settle then mix with clean spatula for 1 minute until creamy mix is obtained.

Setting time:

Setting time is the time from beginning of mixing the powder with water until the material hardens. This time may be measured by Gilmore Needle Apparatus (fig A) or by VICAT Apparatus (fig B), in which needle of different weight & thickness is used. Penetration of these needles being measured at various times during setting

A B

Fig 1. Vicat apparatus

Factors affecting the setting time:

1. **W/P ratio**: the more the water used for mixing, the fewer the nuclei per unit volume which will lead to increase in setting time.

2. **Fineness**: the finer the particle size of the hemihydrates, the faster the setting time. The gypsum nuclei will be more numerous & therefore more rapid rate of crystallization will occur (Decrease setting time).

3. **Mixing**: the longer & the more rapidly the gypsum products are mixed, the shorter is the setting time. When the powder is brought into contact with water, some gypsum crystals will be formed. As mixing begins, more particles will be exposed to water & thus form more crystals & with the continuous mixing, these newly formed crystals are broken up by the mixing & they are distributed throughout the mixture & result in the formation of more nuclei for crystallization, thus the setting time is decreased.

4. **Temperature**: there is little change in the setting time between 0-50 ºC but if

the temperature exceeds 50ºC, the setting time will be retarded (increased). As the temperature reaches 100 ºC, NO SETTING will take place.

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

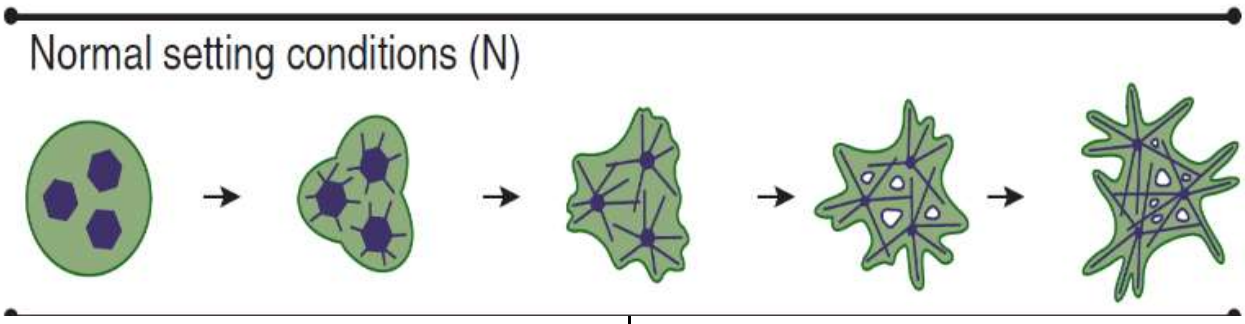
6. **Retarders & accelerators**: the addition of accelerators & retarders is the most effective & practical way to control the setting time. Retarders are chemical materials added to gypsum products to increase the setting time, ex. Glue borax & gum Arabic. It will reduce the dissolution of the hemihydrates & might deposit on the nuclei of crystallization & effectively reduce the rate of crystallization which means retard the setting time.

Accelerators are chemical materials added to gypsum product powder to decrease setting time, ex. Sodium chloride in certain concentration. This salt increases the rate of dissolution of the hemihydrates & thus the saturation of the solution occurs more rapidly.

Dimensional changes on setting (Setting expansion):

Regardless the type of gypsum product, the expansion of the mass can be detected during the change from hemihydrates to the dihydrate after mixing with water. This expansion could be explained on the basis of mechanism crystallization.

There is an outward growth of crystals from nuclei of crystallization, as a result of the growth, there is an entanglement & interception (pushing) between the crystals. If one crystal intercepts another crystal, there will be stress at the point of the interception in the direction of the growth. If this process repeated by thousands of the crystals during growth, it is possible that the outward stress or thrust could produce an expansion of the mass. The final structure immediately after setting is composed of interlocking crystals & many micro pores containing excess water. On drying, the excess water is lost. Figure A shows the nuclei of the hemihydrates when mixed in water while figure B shows the outward growth of these nuclei due to crystallization & figure C shows the interception of the growing crystals that leads to outgrowth of the whole setting mass of gypsum products.



Factors affecting the setting expansion:

1. **W/P ratio**: the higher the W/P ratio, the less the expansion because fewer nuclei of crystallization per unit volume are present than the thicker mixes & since it can be assumed that the space between the nuclei will be greater in such case, it follows that there will be less growth interaction of the dehydrate crystals with less outward thrust resulting.

2. **Addition of chemicals (accelerators & retarders)**: both will reduce the setting expansion. The accelerators will make the crystallization very rapid that the growth is resisted with the accelerators. When using the retarders, the crystals will be shorter & thicker so the thrust between the crystals is reduced which means the expansion is reduced.

Hygroscopic expansion:

Refers to the expansion of gypsum products when it is allowed to set immersed in water. It might be more than doubled. This increased expansion is due to additional growth of the crystals permitted & not to any difference in the chemical reaction.

Factors affecting the strength:

1. W/P ratio: the greater the W/P ratio (more water) the greater the porosity & the fewer the crystals.

2. Mixing time: increase mixing time will increase the strength but over mixing will reduce strength because it will break up the crystals which are formed & will result in less crystal interlocking.

3. Drying: drying will remove the excess water & the cohesion between crystals will increase which will increase the strength as explained earlier.

4. Chemicals: addition of accelerators & retarders will lower both wet & dry strength. This is due to the reduction in the cohesion between crystals.

5. Porosity; the greater the W/P ratio the greater the porosity & the less the compressive strength

Note:

- Die stone is the hardest among the stone & plaster, the stone is harder than the plaster (die stone strength > stone > plaster).
- Setting expansion of the plaster is more than that of the stone & the die stone. Die stone has the least setting expansion. (setting expansion of plaster > stone > die stone)
- W/P ratio of plaster 0.5 > W/P ratio of stone 0.3 > W/P ratio of die stone 0.2

Storage:

Plaster, stone & die stone powder absorb moisture from the atmosphere which causes gradual deterioration of the powder. The hemihydrates particles will absorb water from the atmosphere & reaction will occur; the hemihydrates will be transformed to dehydrate & these crystals of set material will act as nuclei for crystallization & this will shorten the setting time. To avoid this, the plaster & stone powder should be stored in airtight waterproof containers in a dry region in the laboratory.