Today’s lecture will be about Gypsum (الجَبْصُ) \( \text{CaSO}_4 \cdot 2\text{H}_2\text{O} \), it’s a mineral widely found in nature, it has been used for dental casts since 1756.

• Gypsum products used in dentistry are based on calcium sulfate hemihydrate \( \text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} \).

Main uses: casts, models, dies and investment.

*Notice that the molecular formula at first contained dihydrate but in dentistry we use the mineral as a hemihydrate, the difference is 1.5 molecule of water.

- Manufacturing of dental gypsum:

We turn the gypsum found in nature into the gypsum used in dentistry by a process called ‘Calcination’, a heating process performed by the manufacturer to create the hemihydrate powder form of the product.
- Primary constituent = Calcium sulfate hemihydrate (powder)
- By-product = Water (H2O)
- Heat = 110-130°C

- Application of gypsum products involves the reverse reaction, where you add water:

\[
\text{CaSO}_4\cdot\frac{1}{2}\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{CaSO}_4\cdot2\text{H}_2\text{O} + \Lambda
\]

We mix water with the calcium sulfate hemihydrate powder converting it back into calcium sulfate dihydrate, heat is the by-product.

*Refer to the pictures in the slides 8-9, we have a picture of impressions from two patients, after getting these impressions in the clinic, we send them to the lab where they are poured with gypsum products making a cast, the casts are of different colors because different types of gypsum were used (will be explained later in this lecture).

*Revision from previous lectures: the impression material used for the impression on the left is ‘impression
compound’; the one on the right is an elastomeric impression material.

-TYPES OF DENTAL GYPSUM:

The various types of dental gypsum products are chemically identical; however they differ in their physical form depending on the method of manufacturing. We mentioned before that we do a calcination (heating) process to get gypsum, and depending on the heating procedure we get different types of gypsum:

- Type I: Plaster Impression
- Type II: Plaster Model
- Type III: Dental Stone
- Type IV: Dental Stone, high-strength or improved Stone (Die Stone)
- Type V: Dental Stone, high-strength, high expansion

1- Impression plaster (Type I):

• Rarely used in dentistry today because it has been replaced with other materials.

2- Plaster Model (Type II):
Other name: Plaster of Paris

**Refer to the slides, we have pictures of an impression and it’s cast.

Manufactured by grinding the gypsum rock to a fine powder and then heating the powder in **an open container** to eliminate water & shatter the crystal (normal calcination).

Also called *(Beta-hemihydrate particles)*; crystals are spongy and irregular in shape (porous particles).

**Notice the picture: Each crystal has a different size and shape, with many spaces between crystals.

**Pictures of the crystals are electron microscope pictures of the powder.

- Weakest and least expensive. Usually white in color (for differentiation).

- Used mainly where strength, is not a critical requirement. (We already can tell it’s not strong because we said the particles are irregular.)

- Used for:
  - Diagnostic casts (study models)
  - Articulation of stone casts (stone model bases)
  - And to fill a flask in denture construction.

** (The doctor said that we will understand the previous points later.)
3- Dental stone (Type III):

**Notice in the pictures that the color here is yellow. And the crystals here are more regular and homogenous, rod shaped or prismatic, less spaces between crystals.**

- Manufactured from gypsum by carefully controlled calcination **under steam pressure in a closed container**.

- Dental stone (alpha-hemihydrate); crystals are prismatic and more regular in shape than those of plaster.

- Comes in various colors.

- Used mainly for making casts for diagnostic purposes and casts used for complete and partial denture construction. (It is stronger than dental plaster so it’s used in cases where we need to deal with the cast more than just studying it)

4- Dental stone, high strength or improved stone {Die stone} (Type IV):

- Made from gypsum by calcining the gypsum in a calcium chloride solution. (The solution is added to the powder when heated)
**Notice in the picture: We get denser particles, more regular and homogenous, still rod-shaped/prismatic.**

Improved stone (modified alpha-hemihydrate); the cube-shaped particles have a reduced surface area that improves the flow of the mixture.

- Various colors present, it is 2.5 times stronger than plaster (white or yellow).

Referred to as die stone, because it is used in the production of die casts.

Definition of a die (from the internet): the positive reproduction of the form of a prepared tooth in any suitable hard substance, usually in metal or specially prepared artificial stone.

So it’s a single tooth cast…

Doctor’s explanation: We cut a prepared tooth from a cast and work on it with sharp tools/waxing/etc.., so we need this cast to be strong and resistant to abrasion.

From the slides: it is used during the fabrication of wax patterns of cast restorations.

- Used for making casts requiring higher strength and abrasion resistance.
5- High strength, high expansion dental stone (Type V):

- Higher compressive strength than type IV.

Here we mention a new concept; expansion, all gypsum products have expansion but it’s the highest in this type.

Type V stone is a newly developed high-strength stone with a higher compressive strength and higher setting expansion (0.3%). Why??

To compensate for the great casting shrinkage of some metal alloys (base Metal).

To understand:
These are wax patterns, crowns are made from wax in the beginning (to control the anatomy), then they are attached to plastic/wax screws, then we do ‘investment’ (we put the wax pattern and screw in some kind of box and pour an investment material which is also a type of gypsum product over them, so we’re using them as a mold), then we remove the pattern and screw, creating a space in the mold where we can pour a metal replacing the wax, then the technician removes the metal screw and finishes the crown.

The idea behind explaining all of the above; when metal is poured into the space it is in a molten state, when it cools down it shrinks significantly, especially in the case of base metal alloys, what compensates this huge shrinkage is an expansion of the surrounding environment, which is type V gypsum in our case.
As we said before, when we use gypsum in dental applications we mix it with water, so we need some specific ratios to work with; this is called the **W:P ratio**.

• It is clear that various gypsum products require different amounts of water. These differences are accounted for principally by the shape and compactness of the crystals.

More porous particles require more water because they do not pack together well, so the Beta-hemihydrates (very porous and irregular) need more water than the alpha-hemihydrates.
Here we can notice the difference in density.

<table>
<thead>
<tr>
<th>Material</th>
<th>Water (ml)</th>
<th>Powder (g)</th>
<th>ratio ml/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster Type II</td>
<td>45-50</td>
<td>100</td>
<td>0.45-0.50</td>
</tr>
<tr>
<td>Stone Type III</td>
<td>28-30</td>
<td>100</td>
<td>0.28-0.30</td>
</tr>
<tr>
<td>Improved Stone</td>
<td>22-24</td>
<td>100</td>
<td>0.22-0.24</td>
</tr>
<tr>
<td>Type IV</td>
<td>18-22</td>
<td>100</td>
<td>0.18-0.22</td>
</tr>
<tr>
<td>Type V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**This table should be memorized very well.**

These are the ideal ratios for each type, now we will discuss what would happen if we played around with these ratios:

- **Higher W:P ratio (Thinner mix):**
  - Longer setting time
  - Weaker product
  - Lower hardness
  - Lower Setting expansion

- **Lower W:P ratio (Thicker mix):**
  - Shorter setting time
  - Broader crystals, stronger and more solid mass
  - Higher setting expansion

These could be considered as advantages, a disadvantage is:

- Too low W:P ratio may be difficult to pour and may create some voids since the mass cannot flow well.

More about W:P ratios will be explained when talking about physical properties, but keep in mind we should always stick strictly to W:P ratios.
Physical properties

-Gypsum products vary in size, shape and porosity of powder.

-The larger, more irregular and porous the particles, the weaker and less resistant to abrasion the final product.

Physical properties we will be discussing:

A. **Strength and hardness:** controlled by shape of particles and porosity.

More Porosity = more water = weaker.
**Note that the least porous type (least W/P ratio) has the highest compressive strength (affected by the W:P ratio)

**B. Dimensional accuracy:** Difference of proportions between the cast and the real thing depending on setting expansion.

- Setting expansion occurs with all G.P as a result of crystal growth.
- Occurs only during hardening (setting), no more during storage.
- It's controlled by strict W:P proportioning and chemical additives.
**Note that expansion occurs to all types with different percentages. Also note the dramatic jump between type IV and type V.**

*Control of setting expansion:*

- Higher W:P ratio = less S.E … WHY?

  Fewer nuclei for crystallization, greater space between nuclei, less growth.

- Longer mixing time = more S.E

  More nuclei for crystallization, more growth.

*Chemicals that affect S.E:*

- Potassium sulfate, sodium chloride and borax give less S.E.

*What will happen if the setting process occurs under water?*

- S.E will increase because additional crystal growth is permitted, this is called Hygroscopic setting expansion.
Hygroscopic setting expansion: is a physical process, occurs by allowing the crystals to grow freely without surface tension as compared to crystals formed in air.

C. Reproduction of details

® Greater porosity leads to less surface detail (Because it affects attraction between the particles and the surface).

® Reproduction of detail of an impression depends on the compatibility and interactions between the model material and the impression material.

® The ability of the material to flow into and register finer detail and finer lines is used to rate its detail of reproduction.

D. Solubility

-Set gypsum products are not highly set.

-Solubility directly related to porosity, so plaster is much more soluble than stone.

(The doctor just read them without explaining)
E. Setting time: The setting process occurs in more than one stage, we start by mixing powder and water (0.5-1 min), then move to ‘working time/initial setting time’ (pouring the material into the impression, then chemical changes happen and the material sticks to the impression but it’s not ready yet) (8-16 mins), lastly ‘final setting time’ (the material is set and ready to be separated from the impression).

- Initial setting time-working time: After 1 min of mixing, WT begins. As viscosity increases, the material no longer flows and loses its glossy appearance; this indicates initial set which takes 8-10 min.

**Numbers aren’t very important.

- Final setting: Represents the time until the setting mass becomes rigid and can be separated from the mold. Indicates the major completion of the hydration reaction. Marked by failure of penetration of a fingernail or knife or dissipation of the heat of reaction (the by-product, exothermic rxn (يعني بنستناها لحد ما تبرد) (30 to 45 minutes).

- How to control the setting time? Three methods:
  - Control solubility of the hemihydrate: more soluble = less S.T
  - Control number of nuclei for crystallization: more nuclei= less S.T
  - Control rate of crystal growth: Accelerators or retarders.
We can control the previous methods by **impurities** such as:

- Gypsum particles remain after calcination (not all of them turn into hemihydrates), so they will act as nuclei for dihydrate to precipitate = shorter S.T.

We also can control them by **fineness**: Finer particle size of the hemihydrate = shorter S. T

*Plaster, stone, improved stone (from longer S.T to shorter).

**W:P ratio**: higher W:P ratio = prolonged S.T.

**Mixing**: Longer and more rapid spatulation = shorter S.T.

**Temperature**: erratic, no direct effect/relationship (25°C-37°C may accelerate, 50°C - retardation, 100°C - no reaction).

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**Retarders and Accelerators (chemicals)**

The most effective method to control S.T.

- **Accelerators**
  - Increase potential nuclei of crystallization
  - Gypsum, potassium sulphate, sodium chloride <28%

- **Retarders**
  - Form adsorbed layer on the crystals and inhibit growth
  - Glue, gelatin, gums

- Salts that form a layer of a salt that is less soluble than sulphate
  - Borax, potassium citrate, sodium chloride

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F. **Manipulation:** the doctor skipped the slides and said we already talked about mixing; refer to the slides to be sure.

G. **Disinfection:** disinfection should be done to the impression not the model, but in case you missed it at the clinic you can do it to the model by:

- A spray of iodophor.
- Or by immersion in 1:10 dilution of a 5% sodium hypochlorite solution.

**Special products**

Some products designed to have better features, such as:

1- Mounting stones or piasters:
- Fast setting and have low setting expansion.
- Low strength.

2- Modified stone

-Add a small amount of plastic or resin to reduce the brittleness and improves the resistance to scratching.

**Advantages and disadvantages**

Advantages:

1- Inexpensive and easy to use.
2- Good accuracy and dimensional stability.
3- Reproduction of fine details.

Disadvantages:

1- Mechanical properties are not ideal, brittle nature.
2- When used with alginate, the model surface remains relatively soft due to retarding effect of hydrocolloids (Because alginate contains borax and we mentioned before that it’s a retarder).

**End of notes**

(Everyone will probably study from the book so this was a complete waste of time :D )