MATERIALS AND EXTERNAL PROSTHESES

The typical artificial limb or brace of years ago was made of leather, wood, and high carbon steel. Each of these materials has its limitations, particularly in lack of durability. More importantly, they are difficult to protect against absorption of perspiration and other moisture which cause not only deterioration of the material but hygiene problems. As examples, Figure 1 shows a typical artificial arm of twenty years ago and Figure **2,** an artificial leg formerly constructed for amputations below the knee.

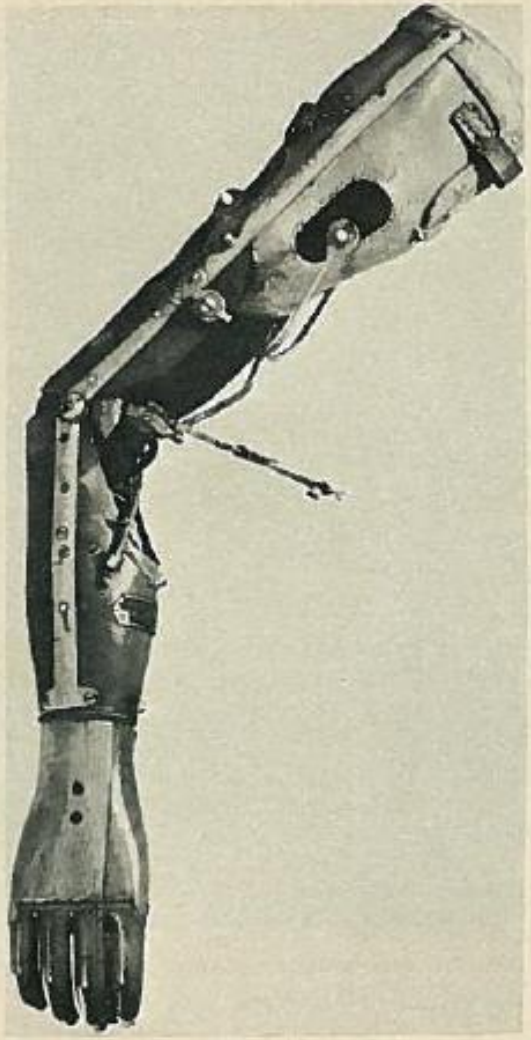

FIGURE 1.—A 1946 artificial arm made of leather, wood, and steel.

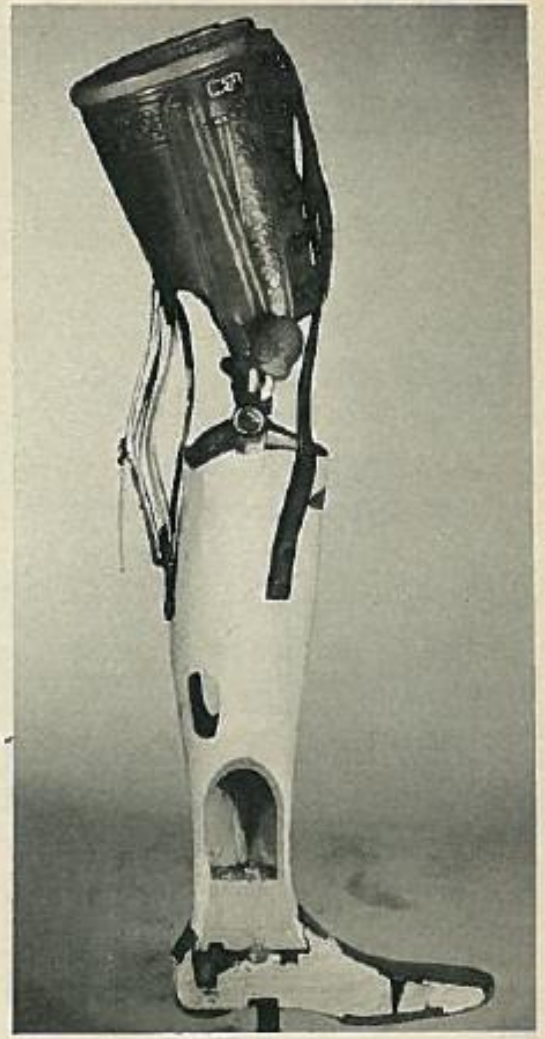

FIGURE 2.—Typical early post-World War II artificial leg for below-knee amputee. Wood, leather, and steel are used throughout. The foot and part of the shank have been sectioned to show the large amount of wood used.

Since World War **11,** laminates using polyesters or epoxies with fabrics made of synthetic or glass fibers have been increasingly used for limb sockets and for some prosthetic and orthotic structures. But a major effort **was** required to retrain artificial limb and orthopedic brace makers familiar only with wood and metal-working. Figure **3** shows the process that is now quite common in forming plastic laminate components over plasterof-paris molds. Also common presently is the **use** of such plastic laminates in combination with wood for the limb structure. As examples, Figure 4 shows the modern plastic-covered wood limb for a below-knee amputee and Figure 5, a different limb type made completely from plastic .

FIGURE 3.—Typical plastic lamination procedure using plaster-of-paris modified replica of the stump as the inner part of the mold to which a separator is applied and a polyvinyl alcohol sleeve as the outer portion of the mold. Stockinet has previously been pulled over the plaster-of-paris inner mold.

FIGURE 4.—Modern plastic artificial leg made for below-knee amputee.

Ceramic materials in prosthesis

Plaster

Plaster in the form of bandages is used to take a wrap cast or negative model of the stump. Plaster in bulk form is used to make the positive model of the stump. Plaster is manufactured from gypsum, a solid crystalline material which is first pulverized and then subjected to intense heat to evaporate the water. The resulting powder is plaster. When water is added to plaster, the plaster recrystallizes or sets, forming a chalk-like solid. Heat of crystallization which is equal to the heat of decomposition is generated during the process of setting.

Gypsum plaster (plaster of Paris)

Gypsum plaster, also known as plaster of Paris, is a white powder consisting of calcium sulphate hemihydrate.

Calcium sulfate (or calcium sulphate) is the inorganic compound with the formula $CaSO_4$ and related hydrates. In the form of γ-anhydrite (the anhydrous form), it is used as a desiccant. One particular hydrate is better known as plaster of Paris, and another occurs naturally as the mineral gypsum. It has many uses in industry. All forms are white solids that are poorly soluble in water. Calcium sulfate causes permanent hardness in water.

The natural form of the compound is the mineral bassanite.

- Bassanite is a calcium sulfate mineral with formula $CaSO_4 \cdot 1/2H_2O$ or $2CaSO_4 \cdot H_2O$. In other words it has half a water molecule per $CaSO_4$ unit, hence its synonym calcium sulfate hemihydrate.

Plaster of Paris is stored in moisture-proof containers, because the presence of moisture can cause slow setting of plaster of Paris by bringing about its hydration, which will make it useless after some time.

When the dry plaster powder is mixed with water, it rehydrates over time into gypsum. The setting of plaster slurry starts about 10 minutes after mixing and is complete in about 45 minutes. The setting of plaster of Paris is accompanied by a slight expansion of volume. It is used in making casts for statues, toys, and more.

Setting time of plaster varies according to the quantity, temperature, and additives of the water. The powder requires a minimum amount of water to transform it into solid plaster; excess water slows the setting process because of the time required for the excess water to evaporate. Warm water hastens setting because it promotes the heat of crystallization; conversely, cool water delays hardening. Various accelerators (such as potassium sulphate or common salt) or decelerators (such as sodium citrate or borax) also influence the setting time

Plaster is similar to concrete during the initial set; hardening occurs relatively quickly, but water continues to evaporate for days resulting in a drier plaster. To hasten the evaporation process, plaster can be put in a warm oven to “cure? The plaster will shrink slightly as it dries. Maximum shrinkage for a wrap cast is approximately five percent, for a solid model approximately two percent, Shrinkage is not significant, however, because the wrap cast and models are ordinarily used before complete drying takes place.

If bulk plaster and plaster bandages are exposed to too much moisture in the air, the setting process partially occurs; they are then too hard to use. Plaster should therefore be stored in a dry place; the oldest stock should be used first.

- Plaster Bandages: There are two types of plaster bandage, **plain and elastic**. The plain type consists of an open mesh cotton fabric impregnated with plaster. The elastic type is similar to the plain type except that fine strands of rubber are woven into the fabric for a lengthwise stretch. Both types are made in rolls for convenient application.
- Most plaster bandages used in upper extremity prosthetics are fast setting (5-8 minutes) or extra-fast setting (2-4 minutes). This time is measured from the moment the plaster is soaked to the moment the plaster starts to set.

- **Bulk Plaster**: Bulk plaster is a fine, white powder. Orthopedic plaster, a grade of bulk plaster most useful for upper extremity prosthetics, is more refined than the commercial grades of plaster used in building construction.

- **Plaster Bandage**: Plaster bandage is soaked in tepid water just before application. If the water is too cool, it will chill the patient; if it is too warm, it may loosen the adhesive agents which bond the plaster to the fabric. The bandage should remain in the water until bubbling stops. When the bubbling stops, the bandage should be squeezed to remove excess water and then applied. Squeezing minimizes plaster loss. If the bandage is squeezed too much, however, it will set too quickly and will not be smooth. Some bandages have loose plaster; if this is the case, squeeze the bandage carefully to avoid the loss of the plaster.

- The wrap cast should be thick enough to provide strength. Three layers are usually sufficient. If the wrap cast is thicker than this, it is often difficult to remove and requires a longer period to dry. If more than one wrap cast is taken, the soaking water should be changed. The plaster residue from the previous bandage can act as an accelerator and shorten the setting time.

- Bulk Plaster: In preparing bulk plaster for the positive model, fill the wrap cast or negative model with water and pour it into a plaster mixing container. Sprinkle but do not mix bulk plaster into the water in the mixing container until a small amount of plaster remains above the surface. Stir the contents slowly and thoroughly to form a smooth, creamy, lump-free mixture and pour this into the negative model containing a parting agent. Avoid air bubbles by pouring the mixture slowly and tapping the negative model. (The plaster mixing container should be made of flexible rubber or plastic for easy cleaning; after the plaster sets, flex the sides and bottom of the container and the plaster will pop loose.)

- When the positive model is modified, the plaster can be wet or dry- It is a matter of personal choice. The model may be quickly dried in an oven up to 150’ F.. Any excessive heat may cause the outside of the model to dry faster than the inside, resulting in cracks.

- The positive plaster model can be shaped with a knife or a rasp and smoothed with wire screen, a fabric cutter, or even sandpaper on a dry model. For making plaster buildups on a model, mix a small amount of plaster with water to form a thick slurry. When the slurry is put on the model, water will be absorbed quickly. The plaster buildup can be molded in its putty-like state before it completely sets