CHAPTER 4: MATERIALS, TOOLS AND TECHNIQUES

The techniques described in this chapter are those taught in class at UCLA Prosthetics-Orthotics Education. It is recognized that there are other techniques that will accomplish the task as well.

Materials used in the fabrication of artificial arms have greatly improved as a result of prosthetic research programs initiated after World War II. Before this, prostheses were made primarily of wood, leather, and metal. Now plastics and synthetic fabrics are used; they provide better service, are lighter in weight, and are more hygienic. In this chapter, materials currently used for upper extremity prosthetics are described, special tools and their uses listed, and laboratory techniques outlined.

Materials

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.

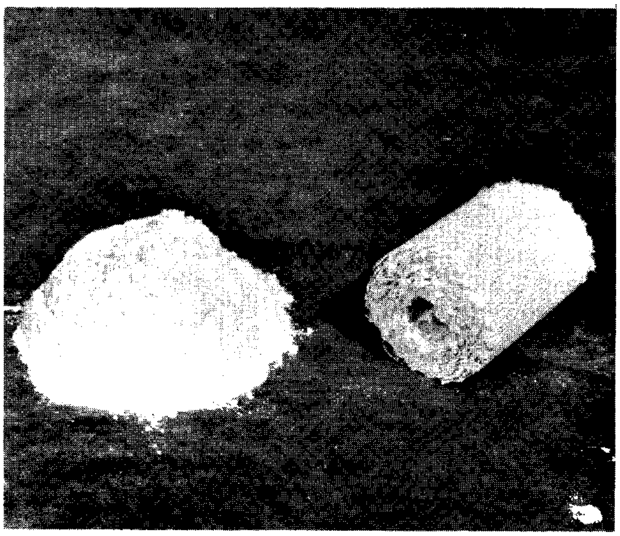
Setting time of plaster varies according to the quantity, temperature, and additives of the water. The powder requires a minimum amount of water to transform it into solid plaster; excess water slows the setting process because of the time required for the excess water to evaporate. Warm water hastens 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 woveninto 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 Plaster Bandage

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.)

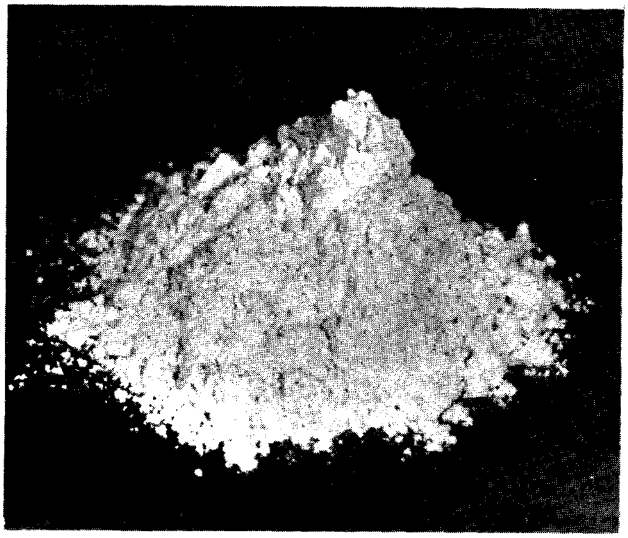
When the positive model is modified, the plaster can be wet or dry. It is a matter of personal choice. The model may be quickly dried in an oven up to 150° F.. Any excessive heat may cause the outside of the model to dry faster than the inside, resulting in cracks.

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.

Alginate

Alginate is used to take a cast or negative model of a bulbous end, a partial hand stump, or a stump with undercuts whereby a plaster wrap cast cannot be removed without distortion.

Alginate is white, light powder made from algenic acid, an extract from marine kelp. When mixed with water it sets into a flexible material which will not only form a cast but will allow undercut shapes to be removed without permanently distorting the cast.

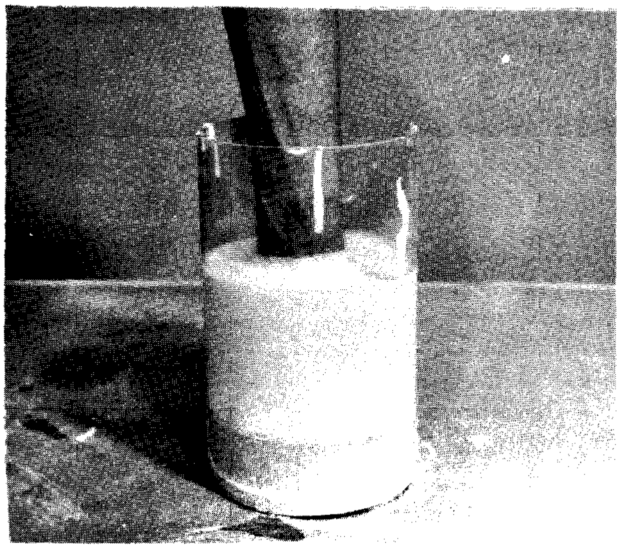


Alginate is used by dentists to obtain gum impressions for dentures; it may be obtained in a prosthetic grade at a lower cost than the dental grade. Like plaster, alginate should be stored in a dry place.

Alginate is mixed into water in a proportion of 40 percent alginate to 60 percent water by volume. The alginate is put into the water in a mixing container and stirred quickly because the setting time is approximately two minutes. When stirred, the alginate and water form a lumpy slurry mixture which should be quickly poured into a casting container. The patient? stump should then be put into the alginate slurry in the desired casting position. Shave any hair on the stump or use a parting agent before casting in alginate.

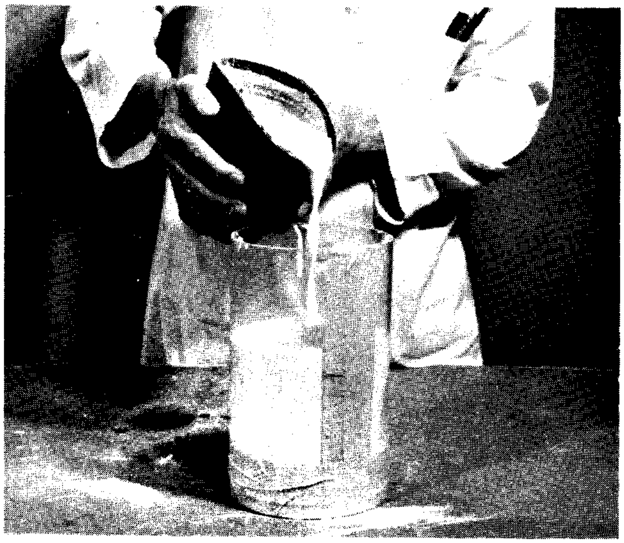
The alginate sets firmly in approximately five minutes; remove the stump gently with a freeing movement to allow air to enter and break the suction. The positive plaster model must be poured from the alginate cast as soon as possible because alginate will shrink and distort if it stands for a few hours.

The photographs on the following page illustrate the use of alginate.

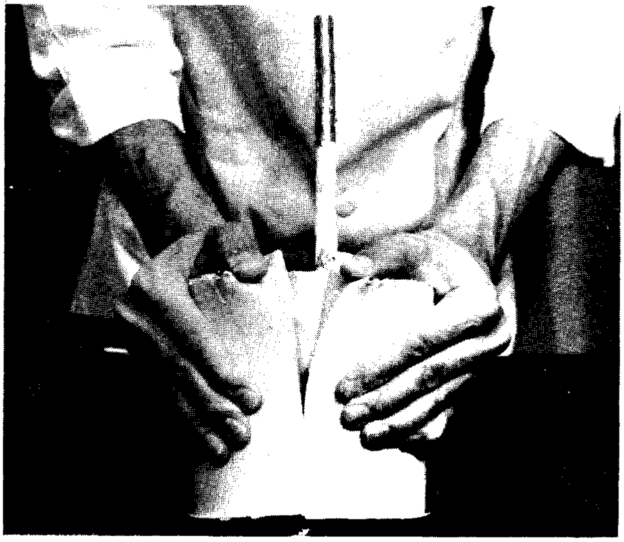


Stump Positioned in Casting Container

Stump Removed Showing Negative Model



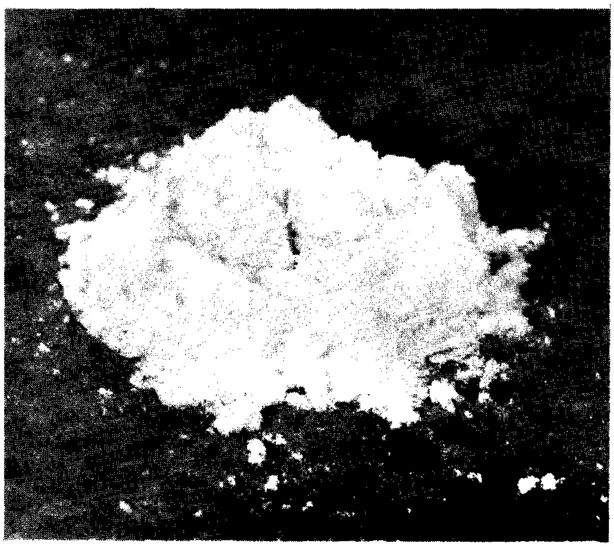
Plaster Model Being Poured



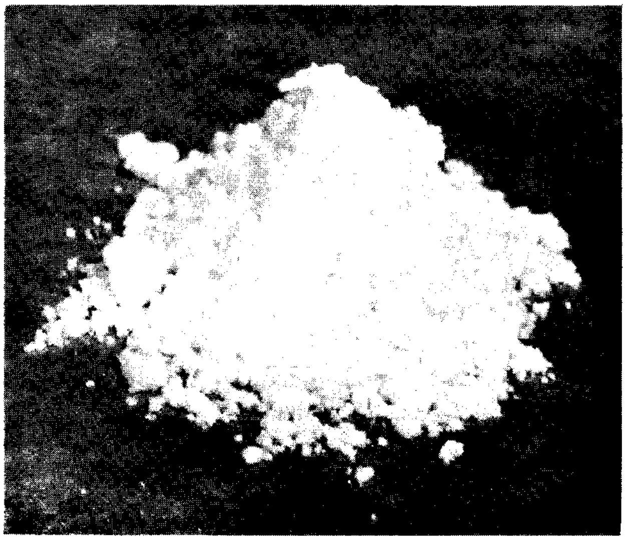
Plaster Model Being Removed From Alginate Cast

Fillers for Polyester Plastic

Fillers are used to lighten weight and prevent cracking of polyester plastic for buildups. The most commonly used fillers in upper extremity prosthetics are pyrogenic cilica, cellulosic fibers and phenolic micro-spheres



Under a microscope pyrogenic silica resemble tiny sponges.



Under a microscope cellulosic fibers look like tiny feathers.

Under a microscope phenolic micro-sphers resemble tiny balloons.

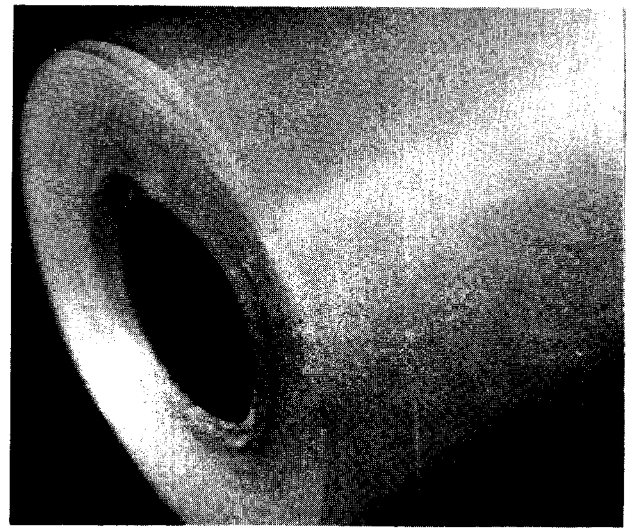
Any of the above fillers can be used for plastic buildups. They are lighter than pure resin.

The filler is stirred thoroughly with the resin until a homogeneous mixture of the desired consistency is attained. The more filler used, the thicker the mixture. Ordinarily, a paste is made that can be applied with a spatula.

Poly-Vinyl Alcohol (PVA)

PVA film is used as a parting agent between the laminating model and the plastic; it is also used as a pressure sleeve for control of the resin during lamination.

PVA film used in upper extremity prosthetics is clear, 0.003 inch thick, and ordinarily shiny on one side and dull on the other. It is available in rolls.



As a parting agent or pressure sleeve, PVA film is made into open-ended bags or used as a sheet and pulled down over the laminating model or the reinforcement layup. PVA is soluble in water; dampening, therefore, produces a pliable bag or sheet, convenient for stretching over the model or layup. Dampening helps control the thickness of lamination. A dry bag is strong and pulls tightly on the layup, resulting in a thin lamination. A wet bag is weaker and pulls less tightly, resulting in a thicker lamination.

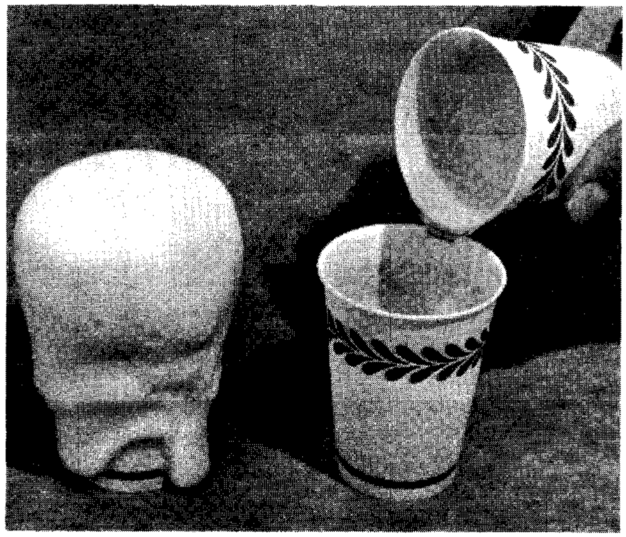
PVA glue, generally used on PVA bags, is made by dissolving PVA film in hot water. (Water with the application of heat is sometimes used instead of PVA glue.)

Polyurethane Foam

Rigid polyurethane foam is used to make forearm and humeral extensions and socket buildups. Flexible polyurethane foam is used to make cosmetic buildups, as for endoskeletal arms.

Polyurethane foam is made from a polyurethane plastic resin by adding to the resin catalyst a liquid with a low boiling point. Such liquids are usually halocarbons, such as Freon. When the mixture becomes warm from the exothermic reaction of the catalyst, the halocarbon turns into gas, forming small bubbles and greatly increasing the volume of the material. The result is a lightweight foam, which is flexible or rigid depending upon the type of resin used.

The foam can be made in varying densities. The most commonly used rigid foam has a density of ten pounds/cubic foot; this is lightweight but strong enough to shape and laminate over, Flexible foam with a density of two pounds/cubic foot is commonly used for cosmetic buildups.



Foamed Polyurethane Resin   Liquid Polyurethane Resin

When the foam is hardening or being cured, the catalyst and resin release toxic vapors which cause eye irritation, headaches, or symptoms similar to asthma. Foaming should therefore be done in a well ventilated room. Exposure should be as brief as possible.

The resin and catalyst can cause dermatitis if they contact the skin. Methyl ethyl ketone solvent can be used to wash the resin and catalyst from the body or tools.

The resins and catalyst should be stored in cool places. The resin can be stored for approximately six months at 70° F. The catalyst should be stored at 55°F. because of its halogen with the low boiling point.

The resin and catalyst must be thoroughly mixed to produce a complete foaming. Each portion must be carefully weighted; incorrect proportions will produce a non-homogeneous and weak material. See the manufacturer% instructions for the correct proportions.

The amount of resin and catalyst needed to produce a foam to fill a specific volume can be obtained from the manufacturer% instructions. The resin and catalyst must not be shaken when the foaming action takes place because the cellular structure will collapse. (Foaming action moves upward; if this action is restrained, the foam will exert pressure on the container, resulting in a denser material.) If an insufficient amount of foam is prepared, more can be mixed and added; it will bond to itself.

Flexible and rigid foams have "skins" produced by pressure against the foaming container. Flexible foams may be shaped, but strength and appearance are affected; the skin, therefore, should remain intact. Rigid foams may be easily shaped using a rasp, wire screen, and sandpaper.

Parting Agents

Parting agents are used to prevent two surfaces from adhering. For example, oil is often applied to the boards of concrete forms to prevent the concrete from adhering to the boards; in this application, oil is the parting agent.

Many parting agents are used in upper extremity prosthetics: talcum powder, oil, silicone spray or grease, polyvinyl alcohol, polyvinyl chloride, vasoline, lacquer varnish, stockinette, wax, and soap.

The Cast

Cotton stockinette, less expensive than nylon stockinette, is usually put over a stump before taking a plaster wrap cast. The stockinette acts as the parting agent for the skin and plaster and also supports the subcutaneous tissue.

Master model: When the plaster master model is being made from the plaster cast, the stockinette may be removed or left in the cast. If left in the cast, it will partially serve as a parting agent. An additional parting agent is required, however. Talcum powder, oil, vasoline or soap are commonly used. The parting agent should not be applied excessively; if it is, the surface of the model will pit. A thin coating is all that is needed.

Check socket: When the wax check socket is being made from the plaster model, oil, lacquer, varnish, or vasoline are used as supplementary parting agents. The wax in the check socket serves as the parting agent. The additional parting agent seals the moisture in the model.

Breakout model: When the plaster, breakout or laminating model is being made from the wax check socket, a parting agent is not needed because wax in the check socket separates the plaster.

Plastic socket: When the plastic socket is being laminated over the breakout model, the parting agent, in addition to its primary function, provides a smooth surface on the socket and seals the moisture in the model. Polyvinyl alcohol bags, polyvinyl chloride bags, lacquer or varnish are commonly used. Several coats of lacquer or varnish are required. These coats should be applied over a dry model and allowed to thoroughly dry between coats.

Laboratory equipment: For protecting tools, work surfaces, and machines, oil, silicone, Vaseline and wax are commonly used. Silicone is an excellent parting agent but is expensive.

Protecting skin: Plaster absorbs the moisture in the skin; apply vasoline or oil to the skin to keep it from drying out. Toxic resins or other materials can cause dermatitis; use disposable plastic gloves. When hot wax is being used, put on heavy work gloves.

Solvents

Solvents are used in upper extremity prosthetics primarily for cleaning, such as dissolving spilled resin.

The most commonly used solvents are ethyl alcohol and methyl ethyl ketone.

Ethyl alcohol is a good solvent for lacquer, varnish, adhesives, inks and dyes. Methyl ethyl ketone or acetone is a highly active solvent for most plastic resins, synthetic and natural rubbers, gums, waxes, oils, lacquer, varnish, adhesives, inks and dyes.

Ethyl alcohol is used when a mild solvent is needed, for example, in cleaning used prostheses, equipment, tools, and skin. Methyl ethyl ketone is used when a strong solvent is needed. This includes cleaning spilled polyester or polyurethane resins, oils, waxes, or adhesives in general, whenever ethyl alcohol is not strong enough.

If methyl ethyl ketone is used to clean the skin, hands should be washed with powdered soap then a cream applied to the skin to avoid irritation or cracking.

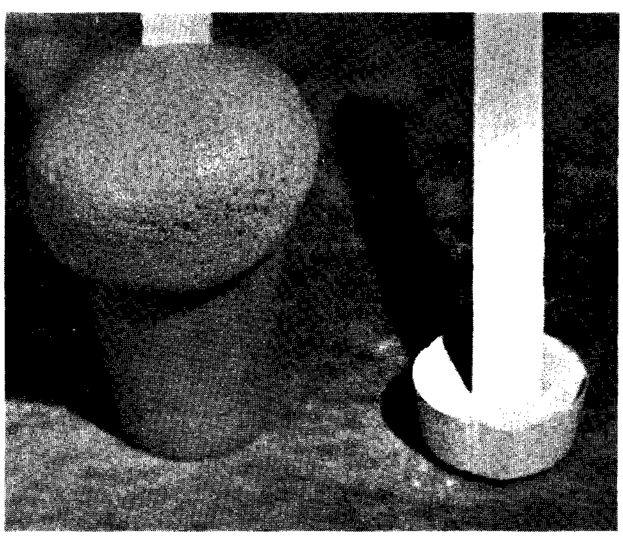
Special solvents are made by manufacturers of lacquers, varnishes and adhesives. When using thinners, consult the manufacturer's directions for the recommended solvent.

Elastomers

Elastomers in upper extremity prosthetics are used primarily for making cushions for the ends of sockets.

The elastomer most commonly used is silicone, a room-temperature-vulcanizing (RTV) synthetic rubber. It is made from a silicone resin mixed with a catalyst; it cures without additional heat or pressure.

There are resins which produce a solid rubber and resins which produce a foamed rubber. These resins can be mixed to provide a rubber of any hardness. Color pigment can be added to the resin.



Foamed Rubber　　　　Solid Rubber

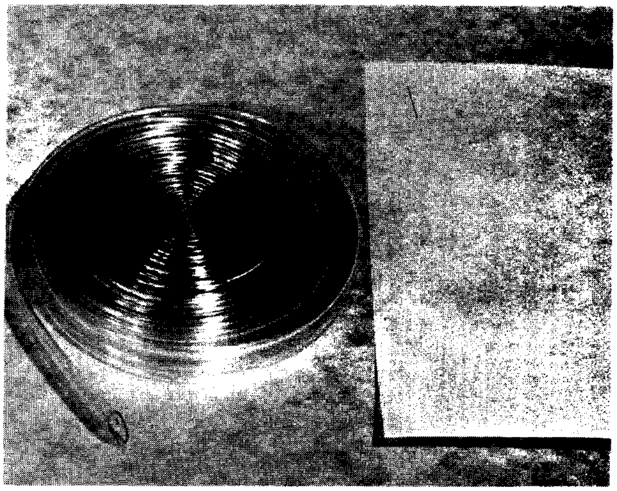
The silicone resin and catalyst may be stored in closed containers at temperatures below 70° F. for approximately six months. The silicone resin is not toxic. The catalyst, however, is irritating to the skin and eyes; it should be washed off the skin with soap and flushed out of the eye with water.

The proportions of resin and catalyst should be mixed carefully according to the manufacturer's directions.

The foam resin and catalyst produce a sponge-like material which is soft and comfortable to the touch; it is sometimes used as a cushion at the distal end of a socket. Only a small amount of resin is needed for this purpose. See the manufacturer's directions for a specific amount of foam.

Polyethylene

Polyethylene sheet is used to make triceps pads, half cuffs and shoulder saddles for harnessing. Polyethylene tubing is used to cover steel cable housing and axilla loop webbing.



Polyethylene Tubing   Polyethylene Sheet

Polyethylene is a thermoplastic which can be formed at relatively low temperatures. It is tough, from clear to translucent in color, and is subject to cold flow.

Polyethylene sheet approximately 1/8-inch thick is used to make triceps pads, half cuffs and shoulder saddles. The sheet is cut to the desired outline and heated. It is then formed to the body and allowed to cool in this form. The material is pleasing in appearance and is hygienic. When the fasteners are attached, however, they must be positioned securely; if not, they could pull out because of the cold flow action of the polyethylene. For this same reason the material has a tendency to return to its original sheet form. Polyethylene sheets are made in low, medium, and high densities. The low density polyethylene is flexible and therefore suitable for humeral cuffs or shoulder saddles.

Small size polyethylene tubing is slipped over steel cable housing to protect clothing and the prosthesis from dirt. The tubing is made in different sizes to fit the various housings.

Larger sized polyethylene tubing is put over axilla loop webbing to provide comfort in the axilla area, to protect the webbing from accumulating perspiration, and to prevent the webbing from folding. If the webbing is allowed to fold, the axilla loop will assume a cord-like shape and will cut into the axilla rather than distribute the forces over a larger area. The sensitive axilla cannot tolerate high forces.

Leather

Similar to polyethylene sheet, leather is used to make triceps pads, half cuffs and shoulder saddles. There are many kinds of leather. The most commonly used is the six-ounce cowhide strap. For upper extremity prostheses, the leather should be soft to touch, flexible enough to go around the arm or over the shoulder, light enough to mold to the arm, and heavy enough to hold fasteners. For light duty, four-ounce leather is adequate; for heavy duty, eight-ounce leather is better.

The leather is cut to a specific outline, fastened to the harness, and allowed to mold to the arm. With the advent of plastics, leather has been used less because plastics are cleaner. At present, however, leather is still functionally superior for triceps pads, half cuffs and shoulder saddles because it molds well to the body and is comfortable. Leather can be washed periodically with saddle soap; the surface should be sealed with a protective agent, such as lacquer or plastic coating.

Teflon Tubing

Teflon tubing is used on the inside of steel cable housings to reduce frictional losses on the steel cable.

Teflon, a tough, translucent white thermoplastic, has a low coefficient of friction.

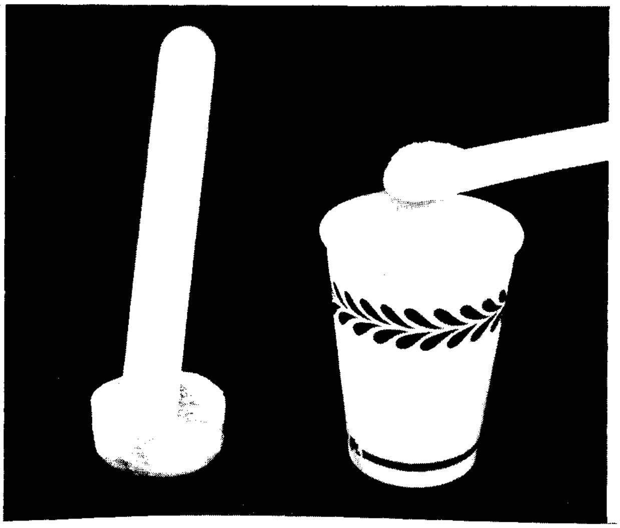
Teflon tubing is inserted into steel cable housing; the ends are flared with a tool to prevent the tubing from slipping out. The tubing can be purchased in different sizes to fit various housing sizes. In addition to reducing friction, it provides a smoother and quieter ride for the cable.

Acrylic Plastic

The bulkhead portion of a partial hand component is made of acrylic plastic; this same material is used to bond the bulkhead to the polyester plastic socket for a partial hand prosthesis, Acrylic is a thermosetting plastic. The type used in upper extremity prosthetics is made from a pink powder resin and a clear liquid hardener.

The powder resin may be stored indefinitely but should not be exposed to moisture. This will cause a marble-like appearance and will change physical properties of the cured acrylic plastic. The resin is not harmful to the skin and does not have toxic vapors.

The liquid hardener may be stored for a long time in a cool (70°F.), dark place. If it is exposed to high temperatures or sunlight, it will harden in the container. It has a strong, characteristic vapor. If the liquid is spilled on the skin, it dries the skin; it should be washed off with soap and water.



Solid Acrylic Powdered Acrylic

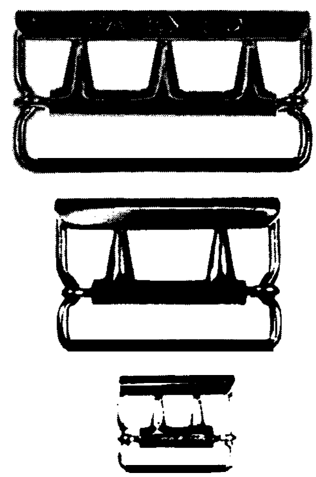
To make the acrylic plastic, measure three parts of powder resin to one part of liquid hardener by volume. Pour the powder into the liquid and mix. The resin sets in a few minutes and cures at room temperature in about a half hour.

Attachment Devices

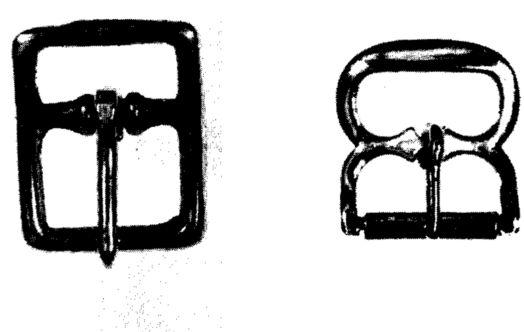
Attachment devices are used in upper extremity prosthetics primarily for connecting harness webbings together and for attachment to the prosthesis.

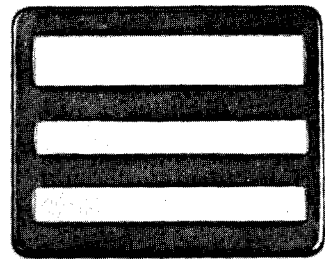
There are many types of fasteners. The most commonly used in upper extremity prosthetics are listed below.

Safety buckles have prongs which bite into the webbing to hold it after adjustment. A metal guard prevents the prongs from poking the patient, and protects clothing. Safety buckles of stainless steel are stronger and better suited for upper extremity prosthetics work than those of plated brass.

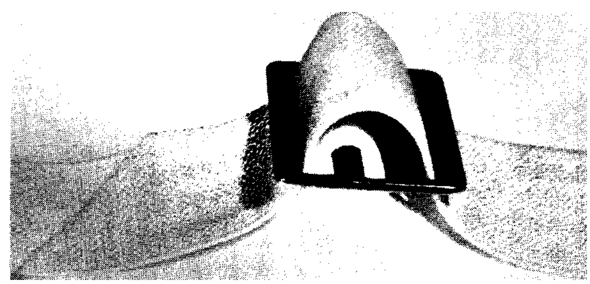


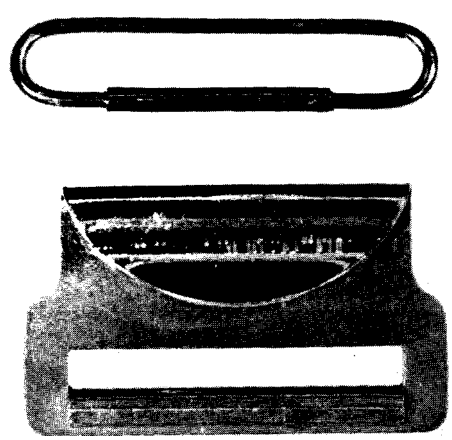
Shoe buckles have prongs which fit into holes made in the webbing to hold it after adjustment.





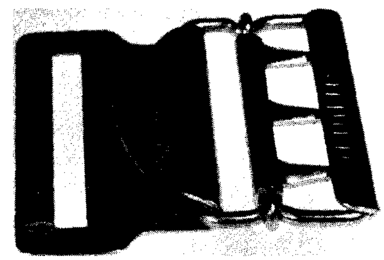
Four-bar buckles developed by Northwestern University have no prongs; they resist greater forces than most buckles. Webbing is threaded through the buckle as shown, providing a strong friction grip. This buckle is not as easy to adjust as the previously listed buckles; however, it has no prongs that require holes in the webbing, and it lies flat on the body.



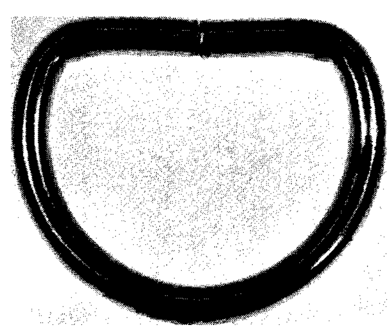


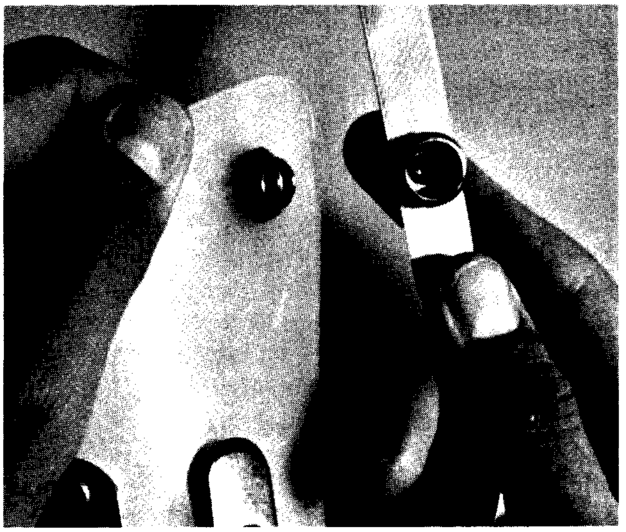
Truss hooks and links are used for quick disconnecting; adjustment is made by using Velcro, a four-bar buckle, or a shoe buckle.

Truss hooks and safety buckles can be combined to provide quick disconnecting; adjustment is made at the area of connection



"D" rings are used when webbing movement is desired. The webbing is threaded through the ring and folded back on itself; it is then able to ride around the half circle of the "D" with body movement.

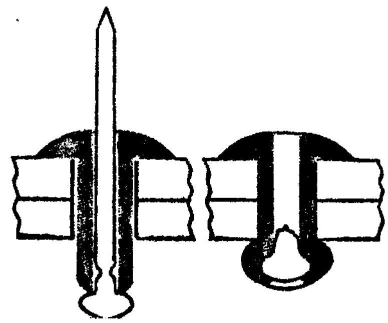




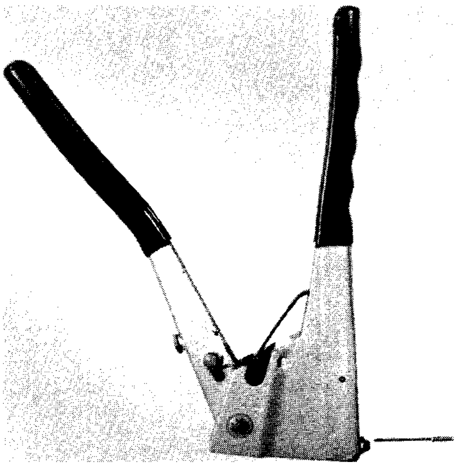
Snap fasteners are used for quick dis-connecting. They are usually used with narrow webbing; truss hooks are used with wide webbing. One type of snap fastener can be unsnapped from one direction only; this is a desirable safety feature. Punch and dyes are used for installation.

There are rivets of many different types; they can be used for such things as attaching webbing to the prosthesis or half cuffs to elbow hinges. The two types of rivets listed below are relatively new and popular in use.

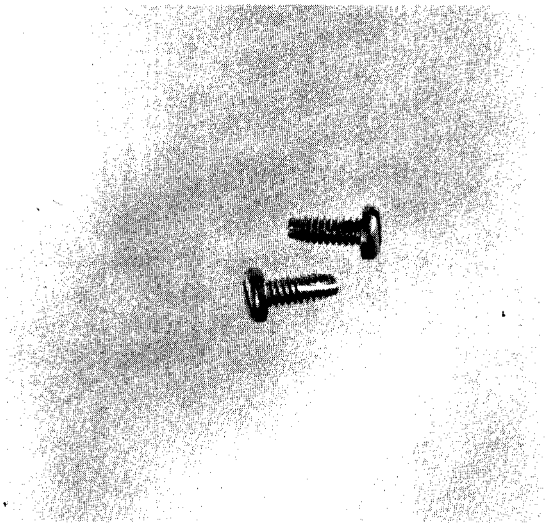
"Speedy" rivets are easily and quickly installed by hammering the two parts together. They can not withstand high axial loads, however. A bucking bar and hammer are used for installation.



"Pop" rivets can be installed from one side without a bucking bar. The pop rivet is installed from the outside with a special gun. A pop rivet and the pop rivet gun are shown. The rivets are available in aluminum, steel and stainless steel available in various diameters and lengths. Stainless steel is preferred when strength and corrosion resistance is desired. Pop rivets are not recommended for flexible plastic because they have a small shoulder and can be pulled out.



Self-taping screws can be used in polyester plastic; a tape hole is drilled and then the screw installed. The screws tap their own holes, hold securely, and can be used in thin cross sections.



Webbing

Webbing is used in making shoulder harnesses.

Webbing is a tape-like fabric. It lies flat on the body and is easily concealed by a shirt or blouse. It is made in many widths and in elastic and non-elastic fabrics.

The three common types of webbing are dacron, cotton, and Velcro.

Dacron: The most commonly used dacron webbing is non-elastic and 1/2-, 1-, and 1-1/2-inches wide. Dacron is very strong and is used when strength and non-stretchability are desired in the harness. The 1/2-inch wide webbing is used primarily for the elbow lock control strap. The l-inch wide webbing is used for support, control and anchor straps. The 1-1/2-inch wide webbing is used for chest straps to comfortably distribute forces around the chest. (Since dacron is a plastic, the ends of dacron webbing can be heated or burned to prevent unravelling.)

Cotton: The most commonly used cotton webbing is l-inch wide elastic. It is used when stretch is primarily desired, such as an anterior suspension strap or a cross-back strap.

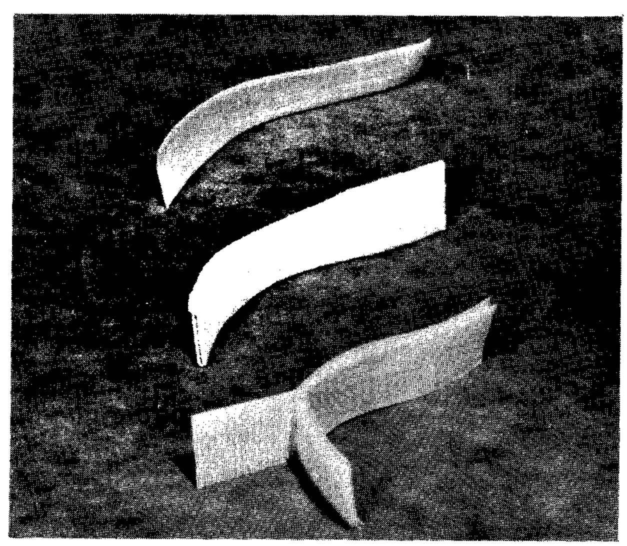
Velcro: This self-fastening webbing is used when adjustability is desired. One surface of Velcro has minute nylon loops, and the other surface has minute nylon hooks. When the two surfaces are pressed together, they adhere; they can resist forces parallel to each other but not forces which pull' them directly apart. Velcro surfaces are usually sewed onto dacron tape for backing.

All three webbings can be machine washed and dried.

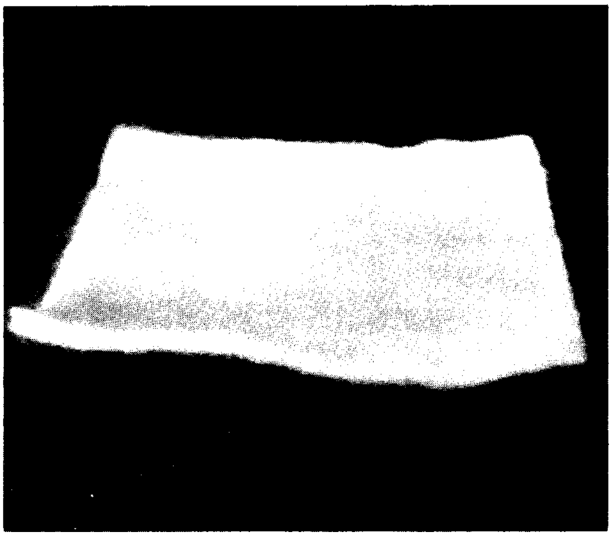
dacron

cotton

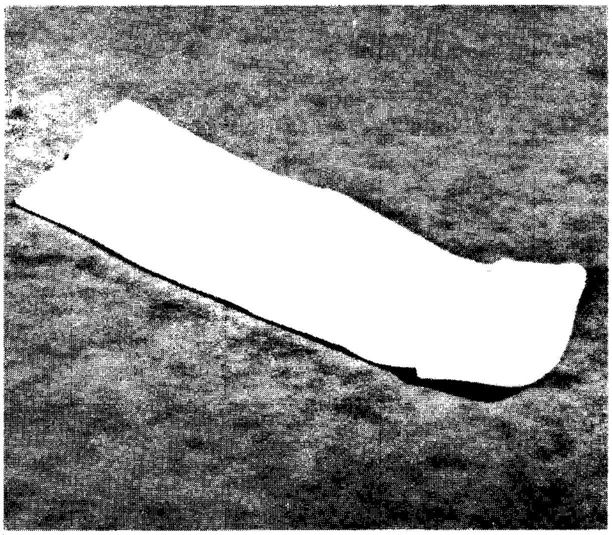
Velcro



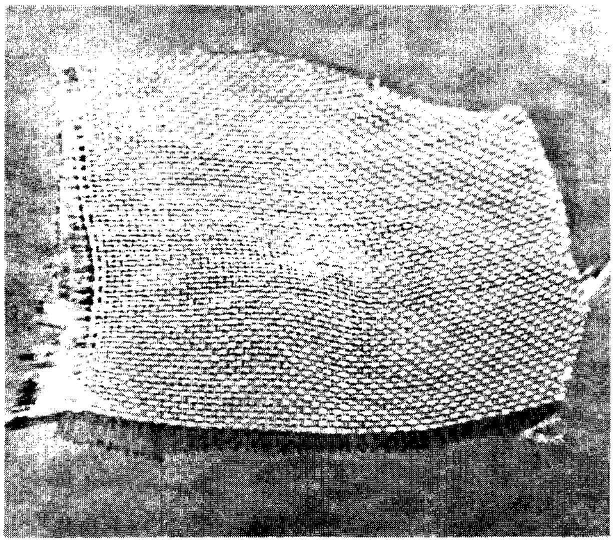
Dacron felt is used as an inner reinforcement layer on the socket. Nylon stockinette is then put over the dacron felt on the model, and both impregnated with resin. One layer of dacron felt and three layers of nylon stockinette provide enough strength for upper extremity socket lamination. Dacron felt is a fabric noted for its smoothness when laminated and its reinforcement value.



Nylon stockinette is a seamless, tubular, elastic fabric made of nylon fibers. When laminated, it is stronger than dacron felt.



If additional strength is needed, fiberglass cloth--a fabric woven from glass fibers--can be added to reinforce selected areas. It is stronger but more brittle than nylon. The strength-to-weight ratio of a fiberglass reinforced plastic is as high as many lightweight metals.



Stump Socks

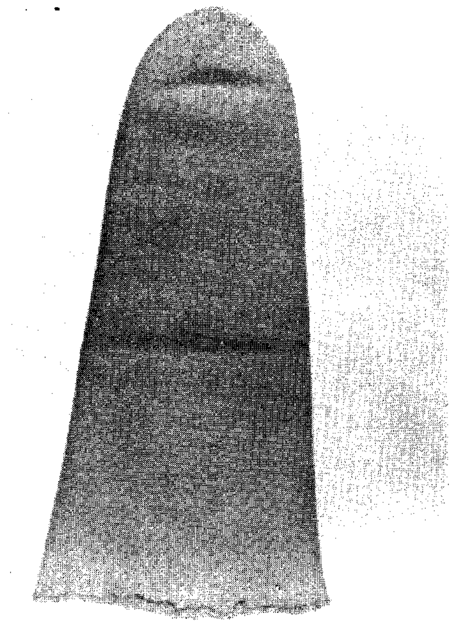
Stump socks are worn to protect the skin, to absorb perspiration, and to provide warmth for the stump. Both cotton and wool stump socks are available in various thicknesses. The socks come in different lengths and widths and are measured as shown below.

Not all upper extremity amputees wear stump socks; of those that do, some wear wool and some wear cotton. It is a matter of personal preference.

Stump socks should be changed daily and washed after each change. Manufacturers furnish detailed instructions for the care of stump socks; amputees should be given these instructions and should follow them carefully.

Top Width
(1/2 of circumference at top)

Length
(Distance top to end)

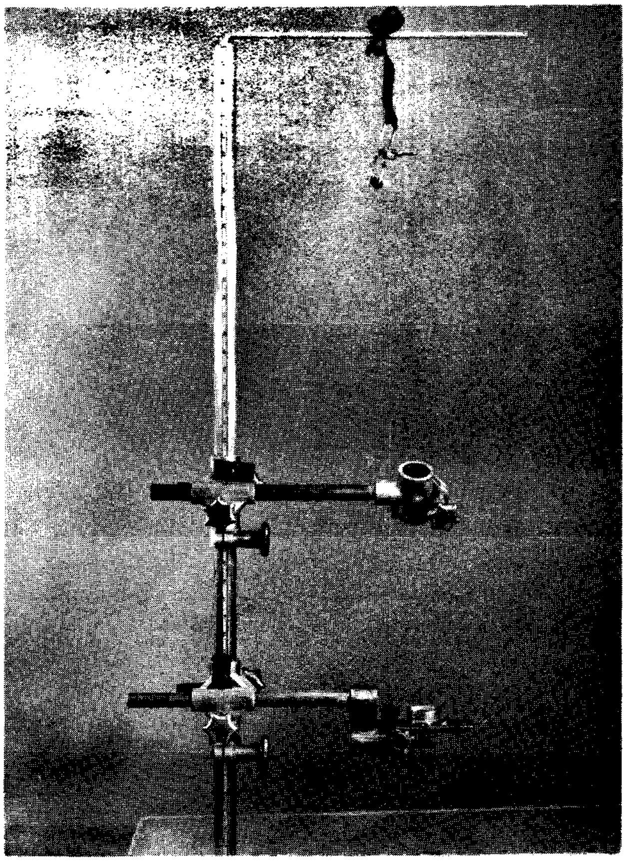


Bottom Width
(1/2 of circumference at end of seam)

Tools

Vertical Fabricating Jig

The vertical fabricating jig is used to hold models and to hold sockets and wrist units or elbow unit turntables during alignment procedures.



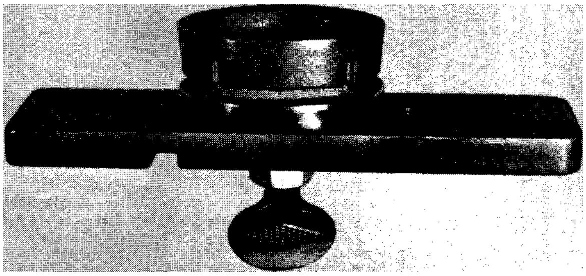
The jig consists of a vertical shaft with three holding devices. Only the two holding devices illustrated are used for upper extremity prosthetics; the third is used for lower extremity prosthetics. In the illustration, the upper device holds the mandrel, the lower, the wrist unit or elbow unit turntable. The rod at the top is used to suspend the PVA bag during lamination. The j ig is commercially available.

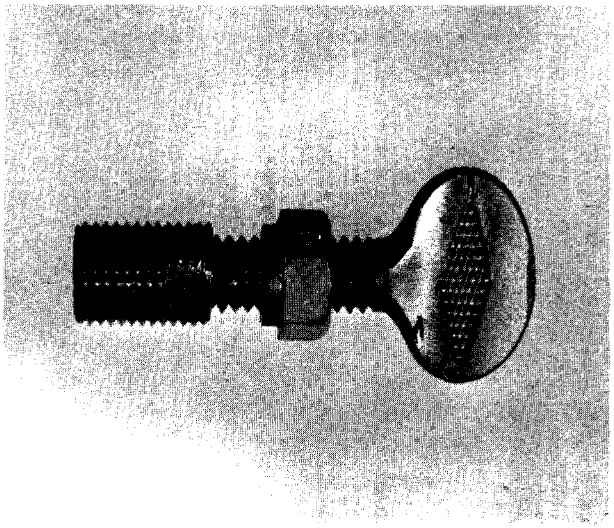
The vertical fabricating jig is not the only device which can be used to hold models. A variety of other jigs or a vice may be used. Many facilities, however, already have a vertical fabricating jig in the laboratory for lower extremity prosthetics use. For this reason and because it does provide accurate alignment, the vertical fabricating jig is recommended.

Wrist Unit Adaptor

The wrist unit adaptor fits into the foot plate of the vertical fabricating jig and allows the wrist unit to be positioned and held while the forearm section is being aligned and made.

As shown below the large-threaded portion fits into the wrist unit, and the small-threaded portion with the shoulder nut and wing nut fits into the large section from the opposite side of the foot plate.

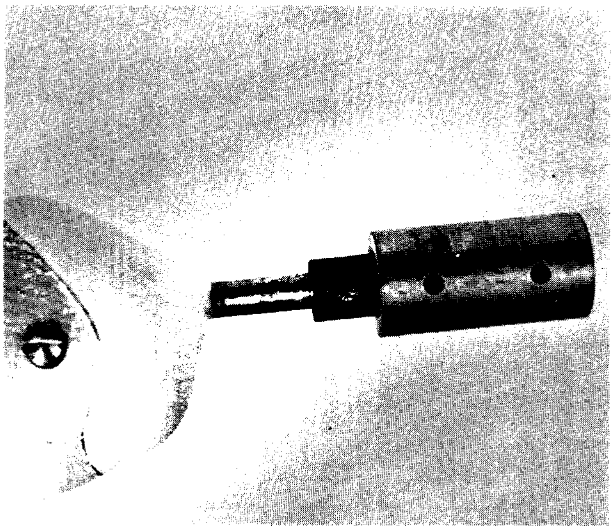




Bushings

Bushings are used to fit mandrels into the vertical fabricating jig.

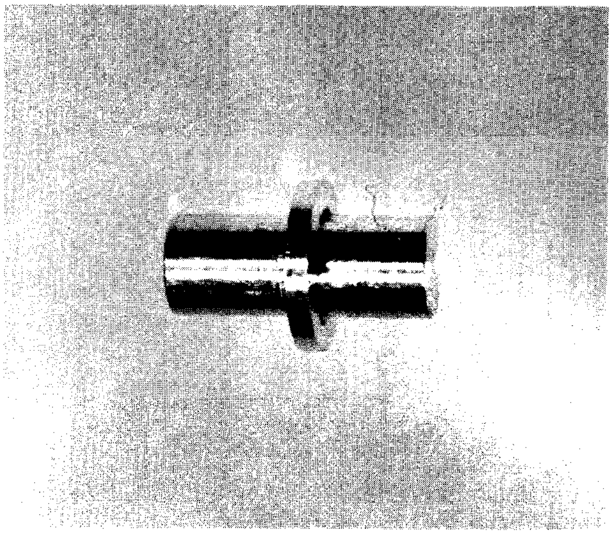
Two sizes of bushings are commonly used. The 1-1/2-inch OD, 3/4-inch ID bushing fits the 1/2-inch ID steel pipe mandrel. The 3/4-inch OD, 1/2-inch ID bushing fits the 1/2-inch OD aluminum mandrel. For small mandrels to be put into the vertical fabricating jig, both bushings are used as shown. The bushings are commonly available.



Elbow Unit Turntable Adaptor

This adaptor fits into the foot plate of the vertical fabricating jig and allows the elbow unit turntable to be positioned and held while the humeral section is being aligned and made.

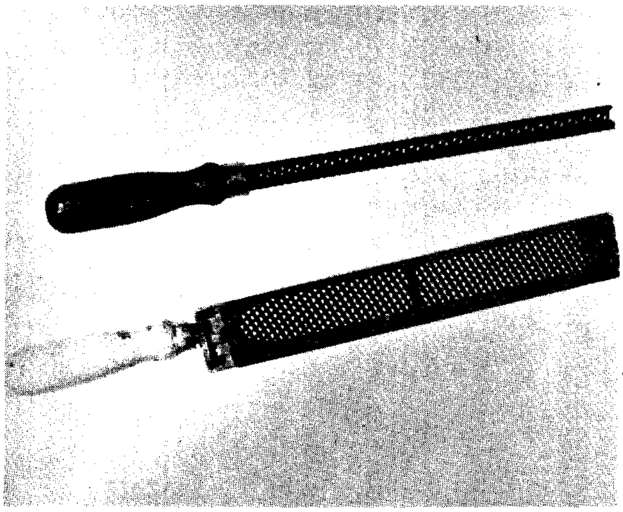
As shown below the adaptor has a shoulder with shaft on both sides. One side fits into the foot plate, and the other side goes into the turntable the adaptor is not commercially available at this writing.



Perforated Metal Rasps

Perforated metal rasps are used to shape plaster models and foam or wax extensions.

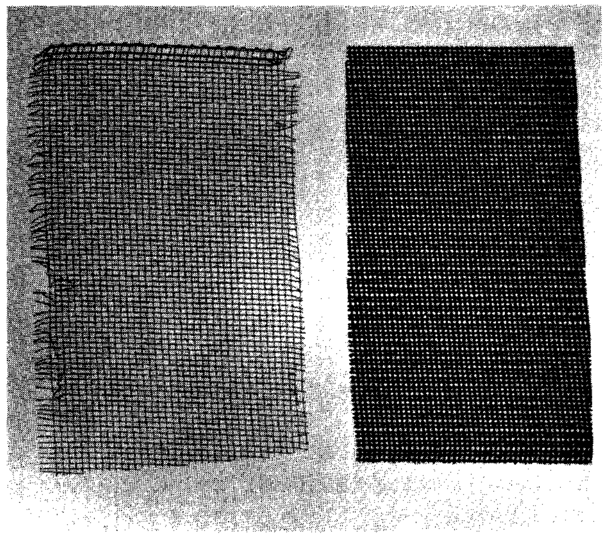
Three shapes of rasps are commonly used: round, half-round and flat. The round and flat are shown. In all three the shavings pass through the rasps to prevent clogging. The rasps are commercially available.



Screen

Screen is used to smooth plaster models and foam or wax extensions.

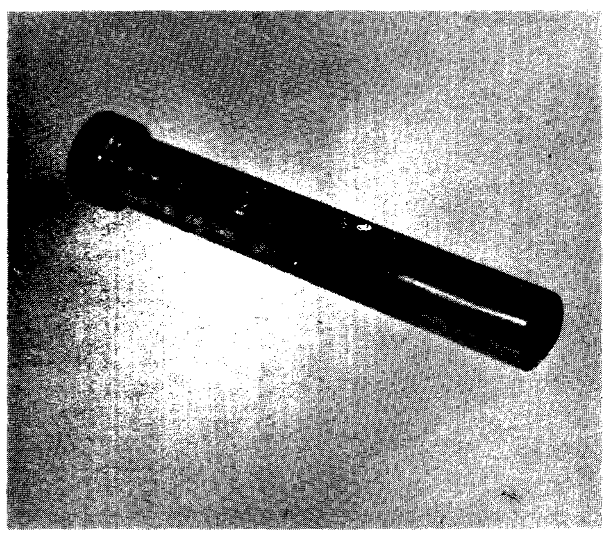
Two commonly used types of screen are shown. Metal wire screen (left) is used for rough smoothing, and the abrasive coated fabric screen (right) is used for fine smoothing.



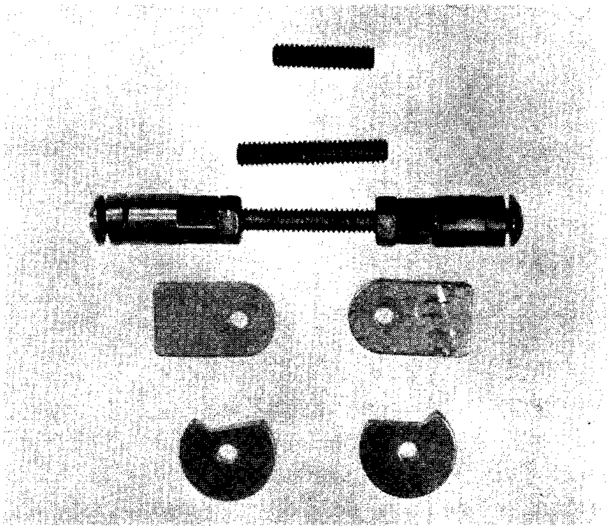
Bag Punch

A bag punch is used to make holes in the wax check socket for placing joint spacers.

A standard bag punch makes tapered holes; it should not be used for joint spacer holes. To make a 1/2-inch bag punch for straight holes, cut off the taper of a 3/8-inch bag punch and bevel the edge from the inside. A modified punch is illustrated.



Joint Spacers



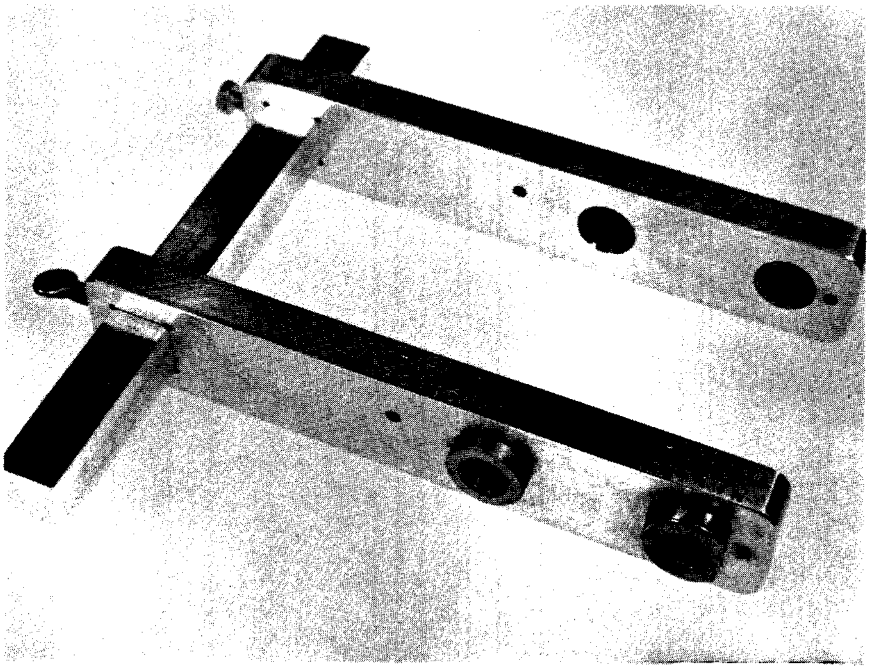
Joint spacers are used to provide an accurate alignment of the hinges for below elbow and elbow disarticulation sockets.

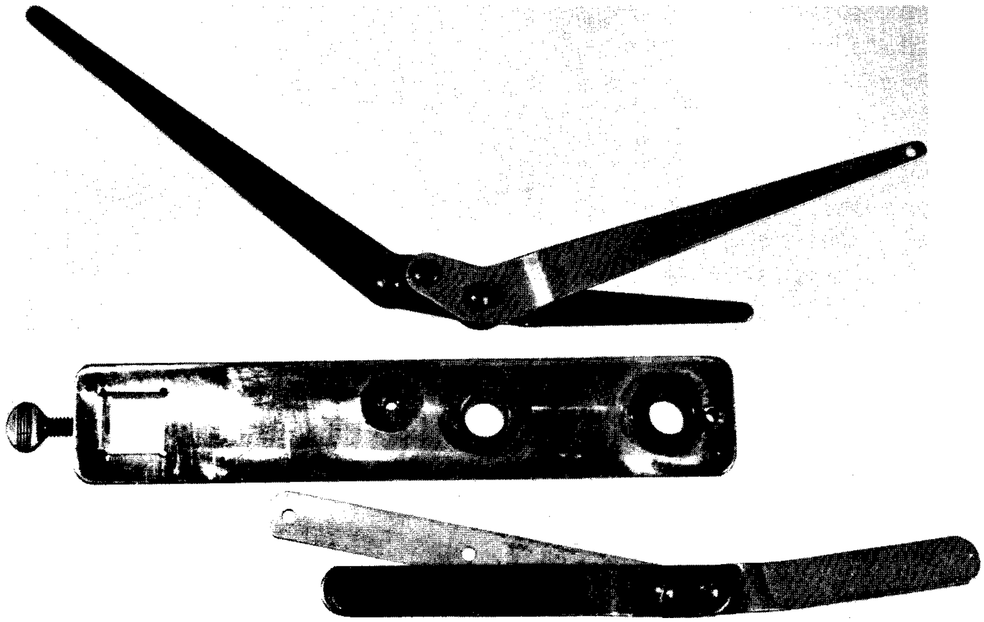
Joint spacers consist of an assembly of pieces, as shown, that are commercially available. Use of the spacers depends upon the type hinge to be aligned.

Joint Alignment Jig

The joint alignment jig is used for the two types of below elbow step-up hinges. The two joint axes must be aligned very carefully to avoid binding of the hinges.

In the fabrication procedure one of the two joint spacers is put into the elbow joint axis of the wax check socket and embedded in the breakout model. The model is then put into the joint alignment jig; the hole for the second joint spacer is drilled after the model has been aligned with the jig.





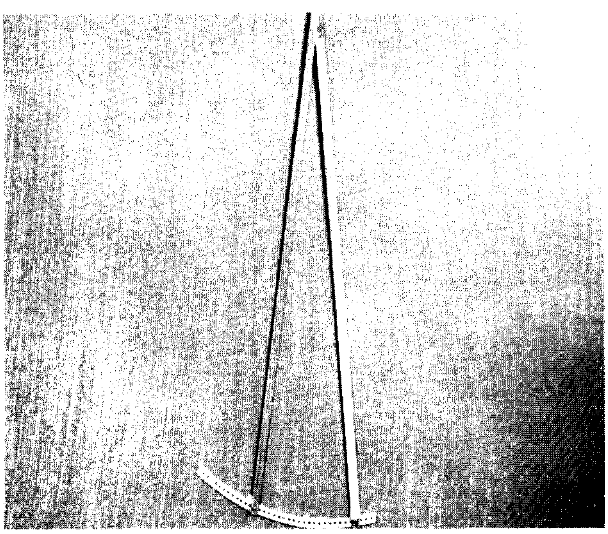
Multiple-action and variable-ratio step-up hinges are spaced differently; hence, there are separate sets of holes for each.

PVA Form

A form is commonly used in making PVA bags.

One type consists of a conically shaped Masonite board with a l-inch wide felt strip on one edge. The size of the board shown is adequate for most applications. It is not commercially available at this writing.

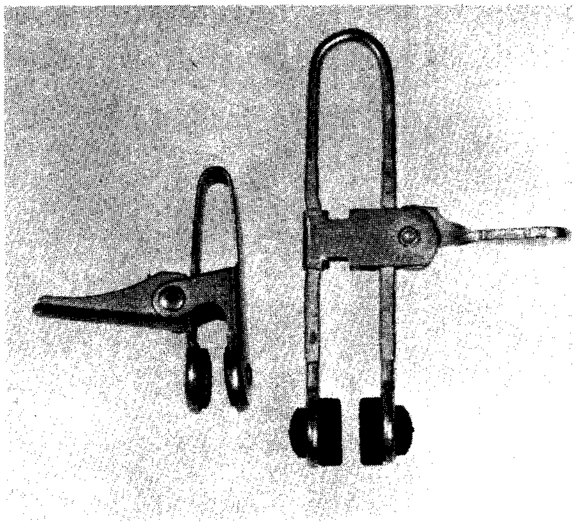
Another type of form is made of aluminum with a felt strip; it is adjustable at the lower end in l--inch increments up to 13 inches. It is commercially available*



Harness Clamps

Clamps are used to temporarily attach the harness during fitting. The clamps allow adjustment to be made before the final stitching of the harness for the finished prosthesis

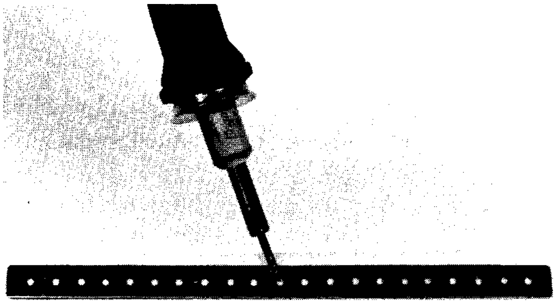
The two most commonly used types of harness clamps, illustrated, are both commercially available.



Webbing Templates

Templates are a convenient way to make holes in dacron webbing.

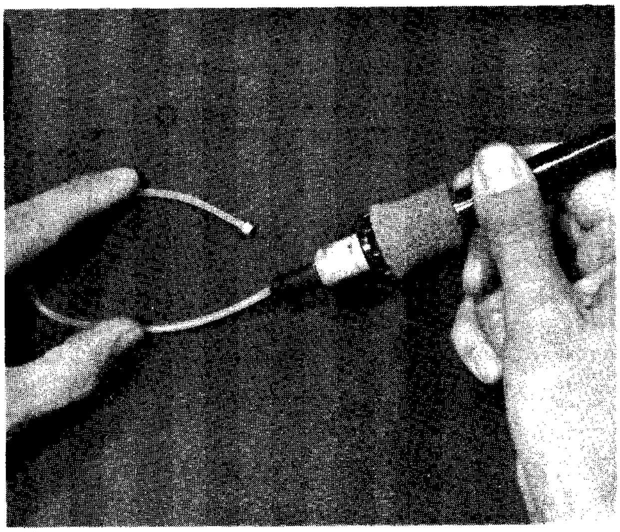
A template and soldering gun, illustrated, make evenly spaced holes with sealed edges in dacron webbing. Templates of various widths with a variety of hole spaces can be used on webbings of different widths. The templates are not commercially available at this writing: The webbing width is not important



Flaring Tool

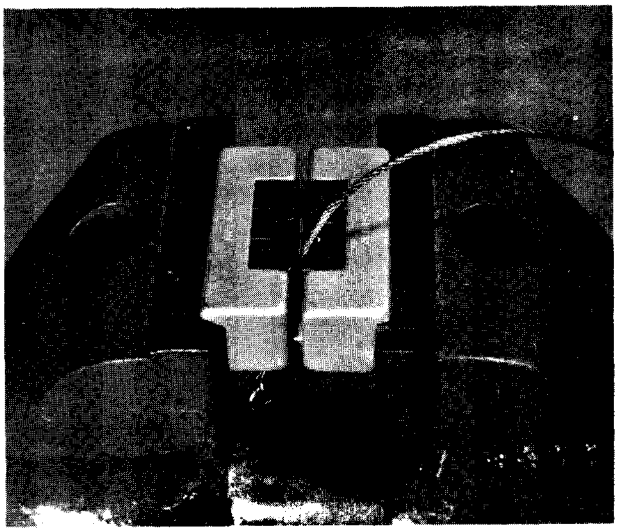
This tool is used to flare the ends of teflon tubing to prevent it from slipping into the cable housing.

The flaring tool is a standard wood burning tool with a modified tip that heats and curls the ends of the teflon tubing. The tool is commercially available.

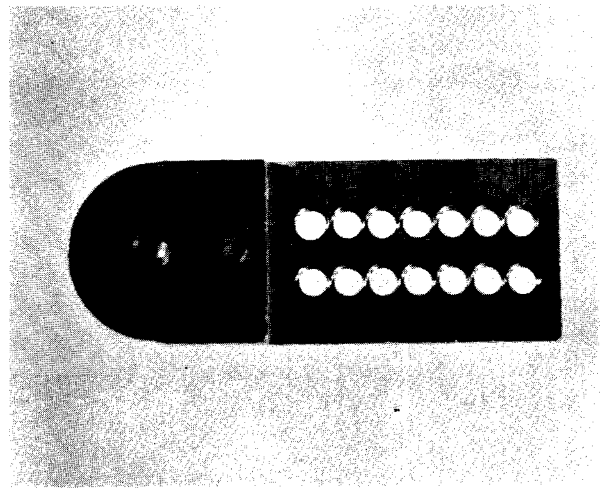


Swaging Tool

The swaging tool is used to crimp attachments, such as hangers and ball swivel terminals, for cable control. There are three sizes of crimping holes. The tool is used in a vice and is commercially available.



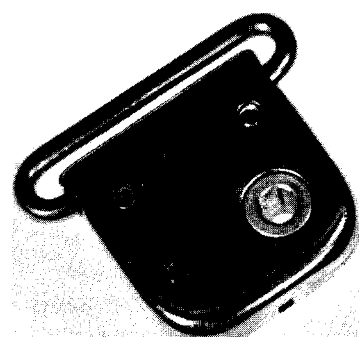
Adjustable Elbow Flexion Attachment



This device is used to temporarily attach the elbow flexion attachment whereby optimum placement for permanent attachment on the forearm can be determined.

The attachment fits onto a standard prosthetic elbow unit by a peg and screw. It is adaptable to right or left forearms.

Adjustable Hanger



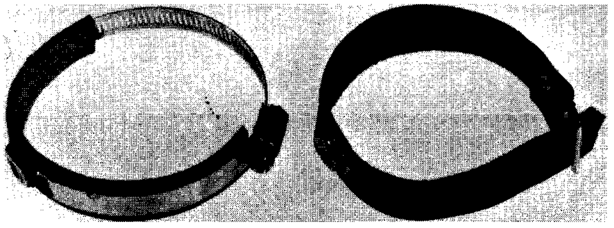
This device is used to temporarily attach the hanger to the control cable whereby its optimum placement for permanent attachment can be determined.

The adjustable hanger has a hole through which the cable is put. The allen-screw is turned and the cable is then clamped in place by a cam action. The hanger is commercially available.

Adjustable Base Plate

This device is used to temporarily attach the base plate to the humeral section of an above elbow prosthesis whereby its optimum placement for permanent attachment can be determined.

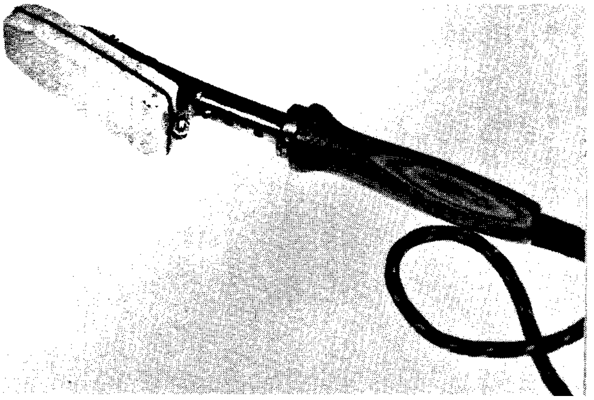
Two types are commonly used: an adjustable hose clamp with the base plate silver soldered to it, and a leather strap with a buckle with the base plate riveted. to the strap. Neither is commercially available.



PVA Sealing Iron

The sealing iron is used on a PVA bag to make an airtight seam.

The iron is composed of an adjustable heating element which is covered with a teflon coated fabric. It is commercially available.



Techniques

How to Make PVA Bags

PVA bags are used to put over plaster models as a parting agent and to put over lamination layups as a pressure sleeve during laminating. The PVA separates the plastic from the model and provides a smooth finish. A parting agent must be used between the model and the PVA bag to seal the moisture in the model. In the second, the PVA bag contains the plastic resin, controls the thickness of the lamination and provides a smooth finish.

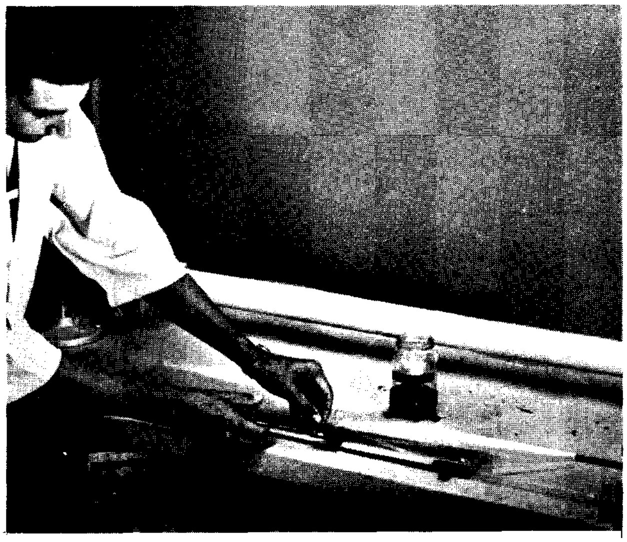
PVA bags are commercially available in standard sizes. The following procedure may be used for non standard PVA bags or self-made bags.

Materials :

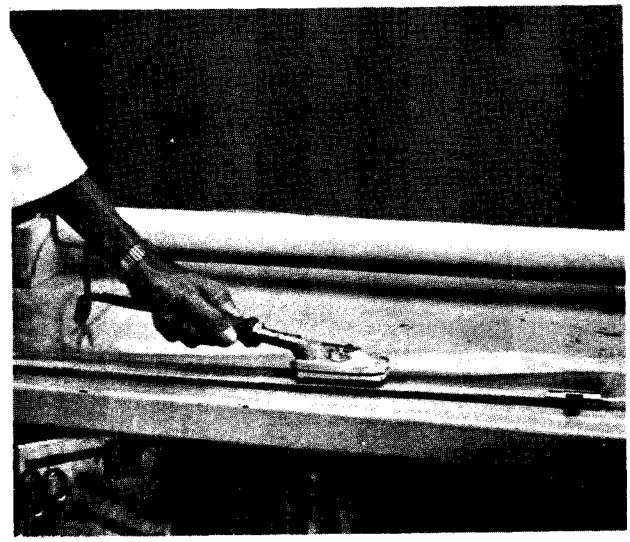
- roll of PVA sheet
- tape measure
- PVA form
- scissors
- PVA glue
- sealing iron

Cut a conically shaped sheet of PVA with the upper width matching the top circumference of the model and the lower width matching the bottom circumference of the model, plus approximately 3 inches overlap for the seam. The length of the PVA should be at least 18 inches longer than the model to allow for the tie at the bottom and pouring of the resin at the top. A PVA form may be used to hold the PVA when it is being measured and cut.

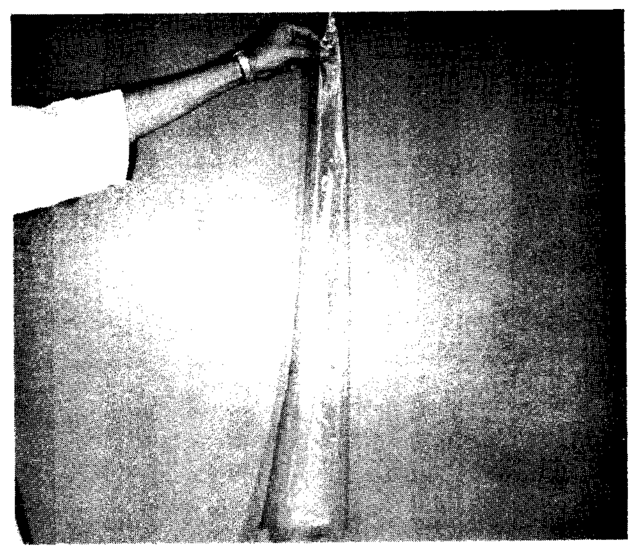
Using a jig as shown, overlap the edges of the PVA. Temporarily fasten the edges to the jig, and put the PVA glue between the surfaces of the two edges smoothing out all wrinkles.



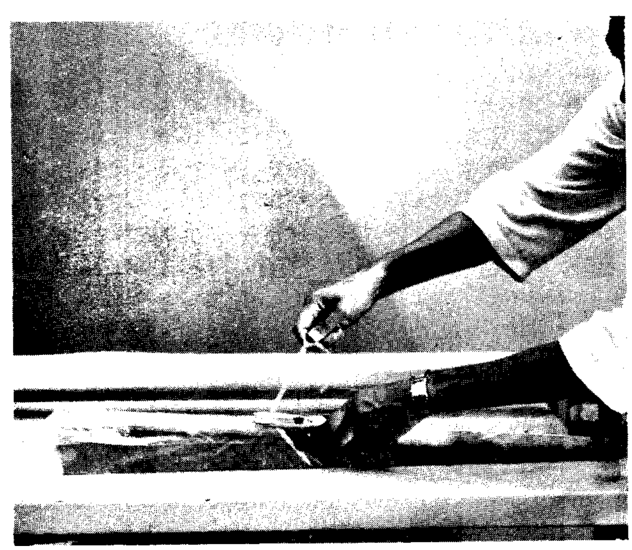
With a sealing iron at approximately 150° F, apply slight pressure to the seam. Again, eliminate all wrinkles. The pressure, heat and PVA glue will provide a seal along the edges.



Visually inspect the seam for defects. Holding the ends tightly, fill the bag with air. It must be air tight for laminating. Al-low some leakage of air to keep it from exploding.



Trim the skirt or flag from the seam making one thickness of PVA on either side of the seam.



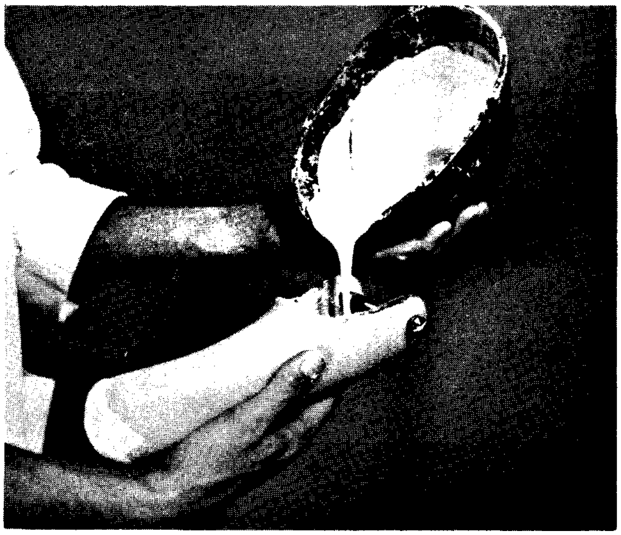
How to Make a Breakout Model

A breakout model permits plaster to be easily removed from socket shapes difficult to remove plaster from when the model is solid. Most below and above elbow socket breakout models should be made from the wax check sockets. Although a breakout model requires more time, the ease with which the plaster is removed is well worth the additional effort.

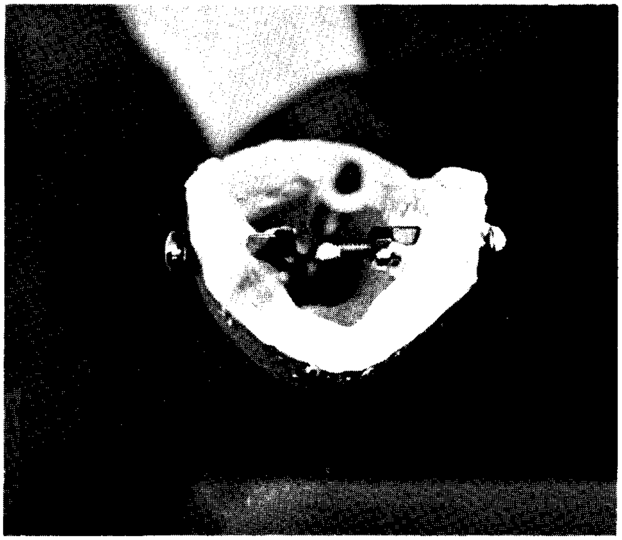
Materials:

- plaster
- mixing container
- mandrel

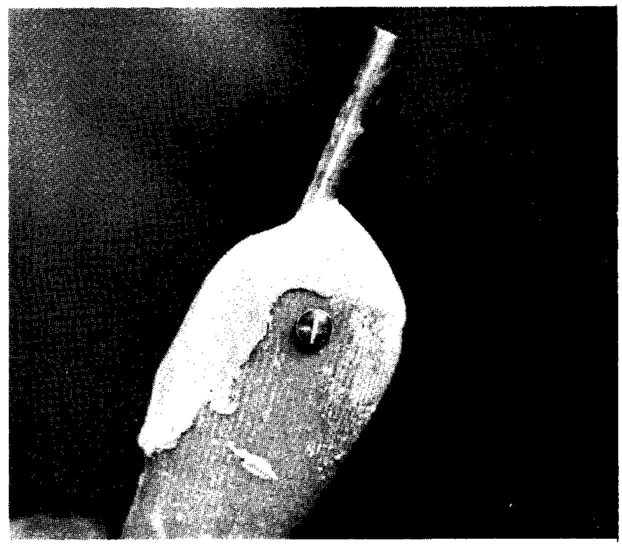
Pour a smooth creamy mixture of plaster and water into the wax check socket. Roll the plaster inside the socket to cover all the surface. Let it set.



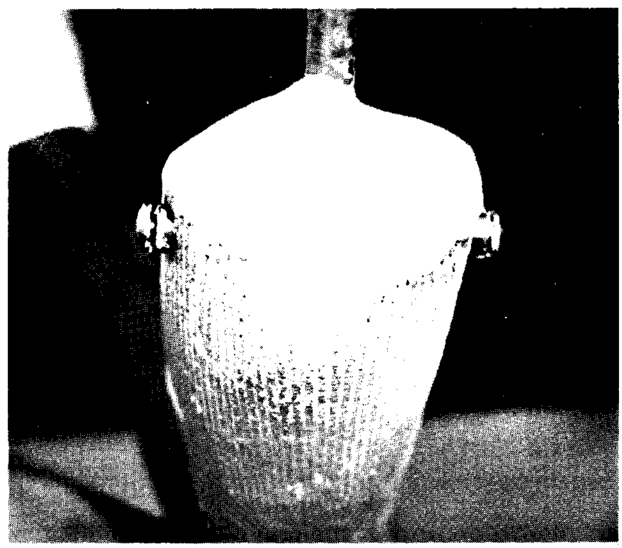
Pour another mixture of plaster in the socket, roll it on the inside, and again let it set. Continue this procedure until the plaster is 3/8-1/2 inch thick. Four or five coats of plaster are ordinarily required. If -joint spacers are present, apply a parting agent. Before each layer is applied, wait until the surface of the preceding layer is dull; this will make the layers easier to break out.



Place a mandrel in the socket surrounded by newspaper or any lightweight filler material. Cap the model with a thick plaster mixture making sure the mandrel is conveniently placed and secured in the plaster.



If joint spacers are in the wax check socket, thoroughly enclose the spacers in the cap to hold them securely in place.



How to Make a Hollow Model

A hollow model is used on many shoulder socket shapes for lighter weight and faster drying. Most shoulder models are large; if they are made of solid plaster, they
1 are heavy to work with and require a long time to dry.

In order to reduce weight a technique similar to that used on the breakout mold is utilized. The inner surface of the check socket is built up with successive layers of a plaster slurry until it is about 1/2-inch thick. Wadded newspaper or other lightweight filler is used in the hollow area. The mandrel is held in place and a thick plaster cap formed over the filler and bonded to the previously applied plaster at the borders.

How to Make a Plastic Laminate

Laminating consists of impregnating the layers of reinforcement material with plastic resin to produce a laminated socket, a socket extension, or a forearm. The following laminating procedure is commonly used in upper extremity prosthetics.

Materials:

reinforcement material

string

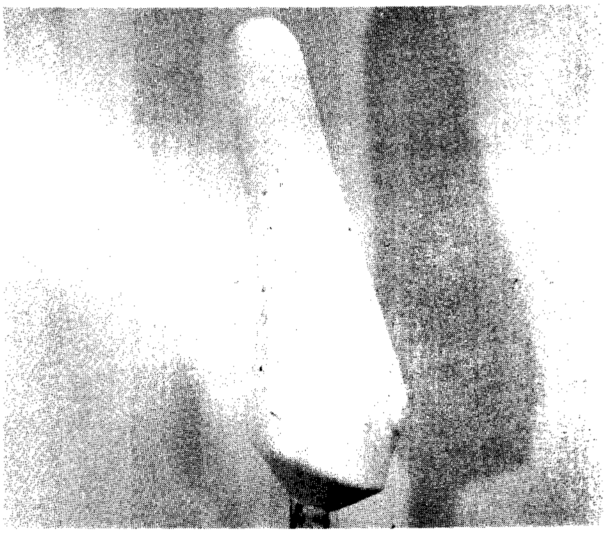
PVA bags

wet towel

resin, catalyst, promoter and pigment

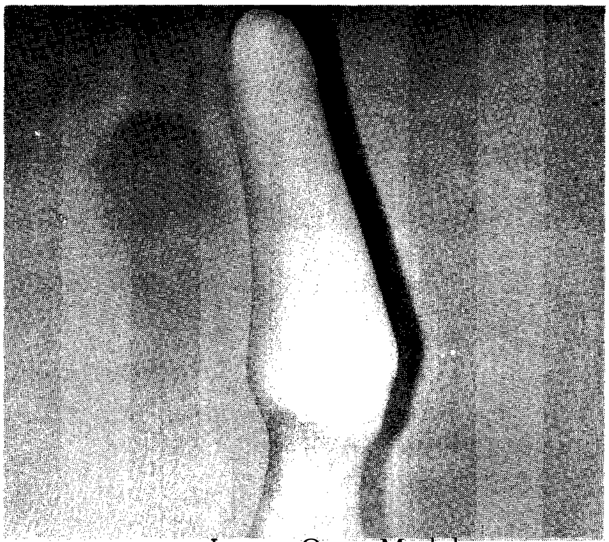
cord

Apply a parting agent to the laminating model. Put the reinforcement material or "layup" over the model. For sockets, apply one layer of dacron felt first; the felt provides a smooth inner finish on the socket and allows for some modification without disturbing the outside layers of stockinette. Next, for sockets or socket extensions, apply two or three layers of nylon stockinette; the nylon stockinette adds strength to the laminate. For heavy duty, apply additional layers of nylon stockinette. If reinforcement is needed, apply fiberglass cloth'over the specific areas between the layers of nylon stockinette.

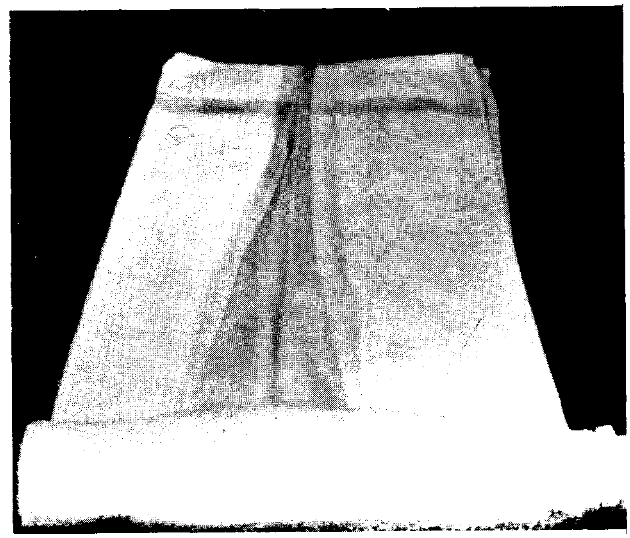


Model With Parting Agent

Pull the layup down tightly over the model. Tie the layup at the bottom with string to hold it in place during lamination.

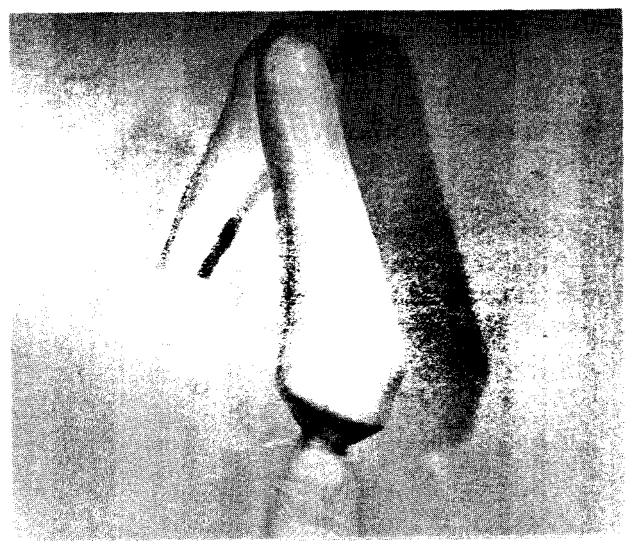


Layup Over Model

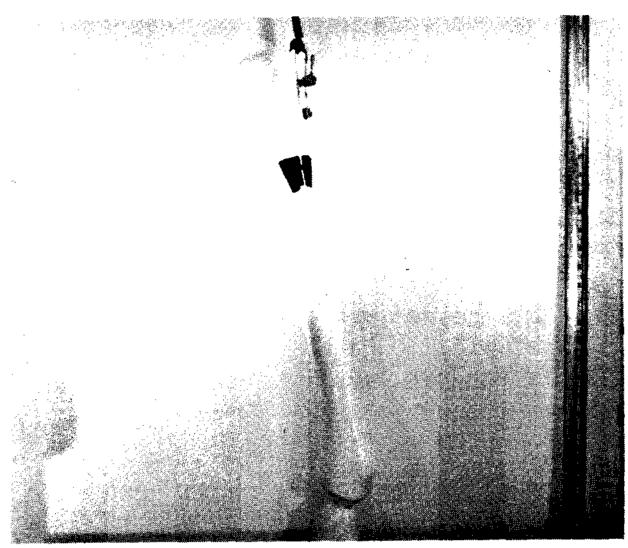


Dampen a towel with water and wring it out; roll up the PVA bag in the towel. Leave the PVA bag in the towel for two or three minutes to moisten the bag. It will now stretch tightly over the layup, providing the pressure sleeve for the lamination

If a thin lamination is desired, a drier bag should be used; it will not stretch as easily and will pull more tightly over the layup.



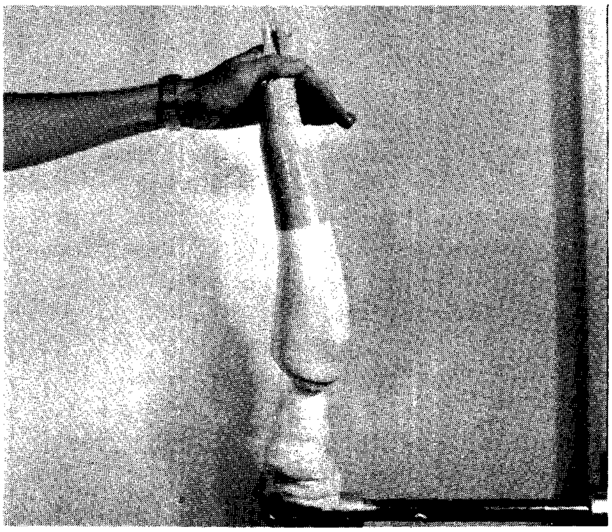
Pull the bag down over the layup so it fits tightly without wrinkles. Enough PVA should remain above the layup to form a reservoir for the amount of resin needed to complete the lamination. Tie the bag at the bottom to prevent it from slipping up.



Insert a funnel or cup into the top of the PVA bag and suspend it overhead; this is for pouring the resin.

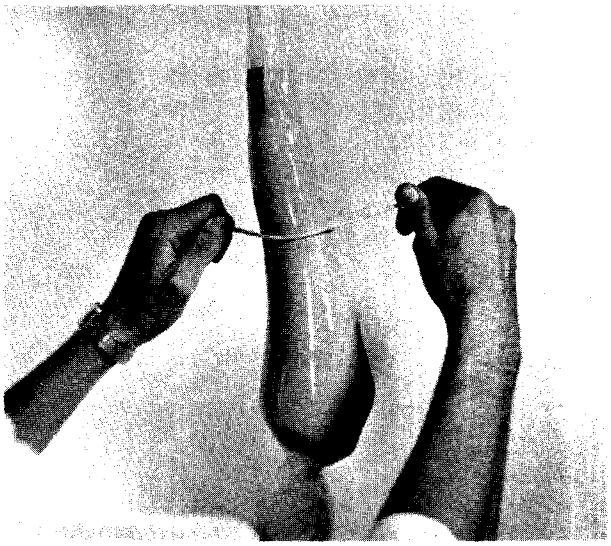
Mix the resin with its catalyst, promoter and pigment according to the manufacturers instructions. Pour it into the top of the PVA bag.

Force the resin to saturate the layup. Do not flood resin into the bottom of the layup; it will only be excess resin and trimmed off later. Punch a small hole in the bottom of the PVA bag to allow air to escape.



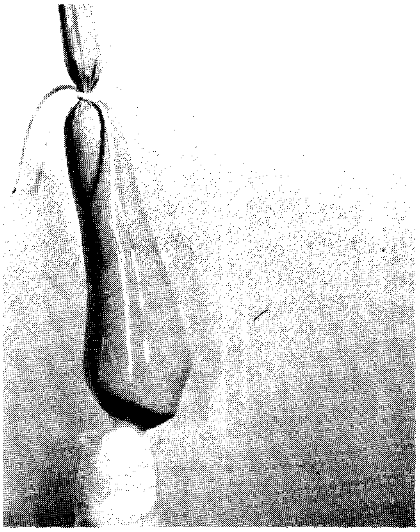
Using a cord, move the resin completely over the layup as shown to thoroughly saturate the entire layup. Then bring the excess resin and any air bubbles up to the top.

Pinholes occasionally exist in the PVA causing the resin to leak out. These holes can be easily sealed with a piece of adhesive tape.



After all excess resin has been brought to the top with a string, tie the top of the PVA bag just above the layup to isolate the excess resin. Allow the resin to set. While the resin is setting, watch for any air bubbles that may appear. Remove the air bubbles by moving them into the reservoir.

When the resin has set, the lamination is complete. If more than 15 percent flexible resin has been used, the laminate must be oven cured.

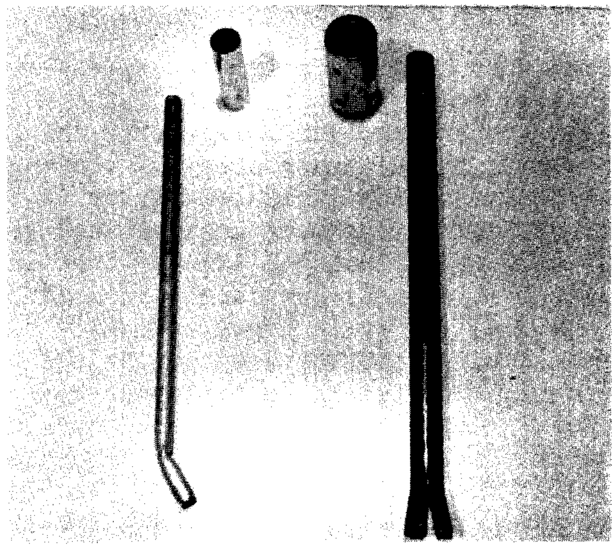


Tools

Mandrels

A mandrel inserted into a plaster model serves as a handle by which to hold the model.

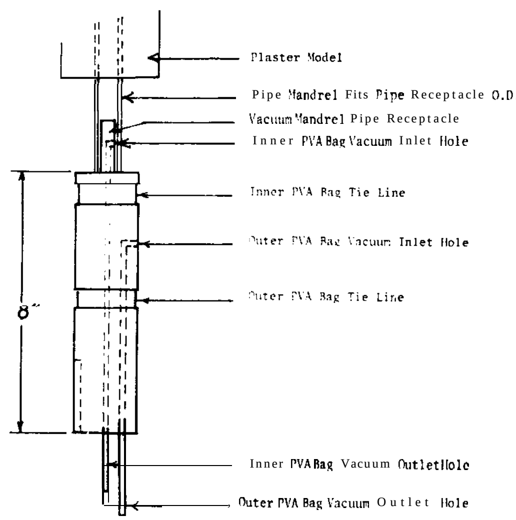
Two sizes of mandrels are commonly used. For large models, 1/2-inch ID steel pipe is used, and for small models, 1/2-inch OD aluminum tubing.



Tubing Pipe

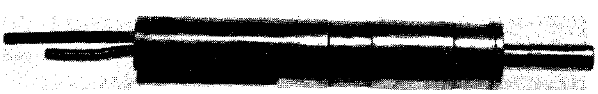
Vacuum Mandre 1

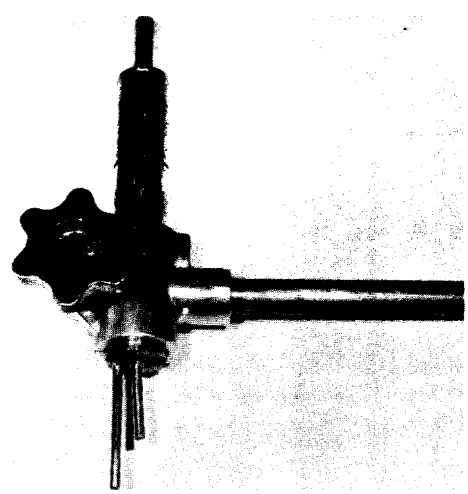
The vacuum mandrel is designed for use with the Milmo duplicating jig. It is used during lamination to draw the plastic resin over concave shapes for a thin, strong lamination.



The vacuum mandrel shown below is used at UCLA. It has a 1-1/2-inch OD and a groove in the side so it will fit into the mandrel holding device on the vertical fabricating jig.

When a small mandrel is used in the model, a small bushing must be used for placing the model on the vacuum mandrel.





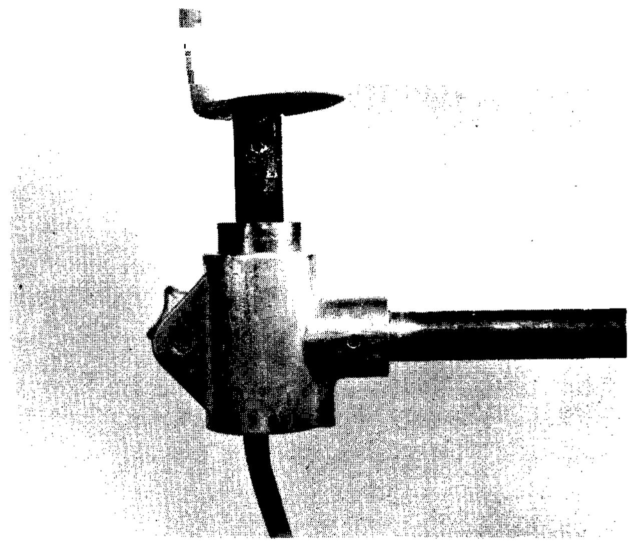
How To Laminate With Vacuum

Vacuum is used in laminating to achieve a thin, lightweight and strong lamination. This is done by compression of the multiple layers of the layup over the model. When laminating over irregularly shaped models, vacuum will form the layup and PVA bags to the exact shape of the model. Vacuum assists in maintaining uniform thickness of the laminate. Prior to the use of vacuum in upper extremity prosthetics, laminations were accomplished successfully by the process of drying the plaster model, using a lacquer-type parting agent and a dry PVA bag pulled tightly over the layup as previously described. Widespread use of vacuum indicates there is a need for it in upper extremity prosthetics. The need is related to the materials used as parting agents. At the present time, PVA is the best parting agent available for use on wet plaster models. Dual source vacuum is the technique of choice when the PVA bag is used over a wet model, especially one of irregular shape. Its availability speeds up the process by not having to wait for oven or drying out time of the model. The plaster model can be used to laminate immediately after removal from the check socket. This insures that the usual plaster shrinkage of up to 5 percent will not occur and thus hamper the socket fit.

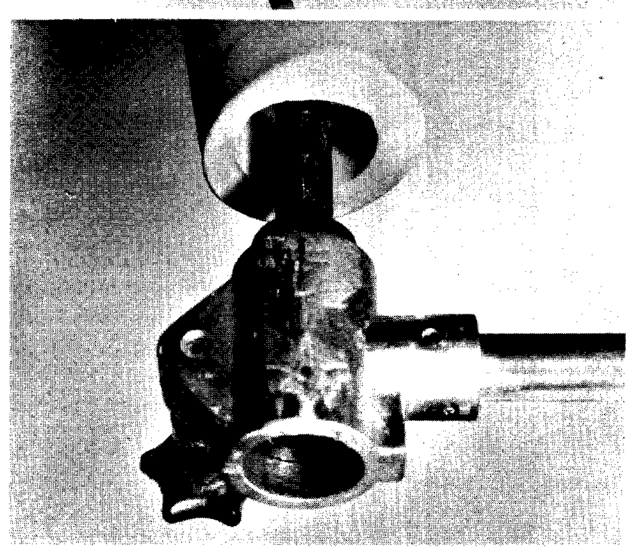
A Simple Vacuum Mandrel for a Single Source Vacuum Lamination

A pipe mandrel with a hole drilled as shown below can be used for a single source vacuum lamination.

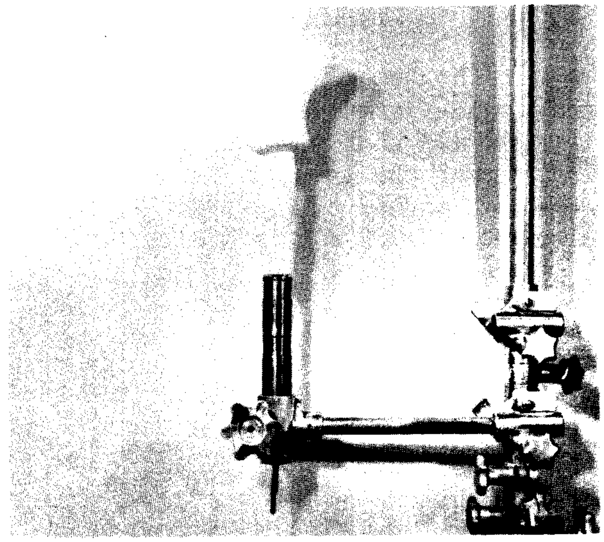
One way is to locate the hole just below the model. Place cloth or paper around the hole so it can "breathe? Place vacuum hose inside on mandrel and tape in place.



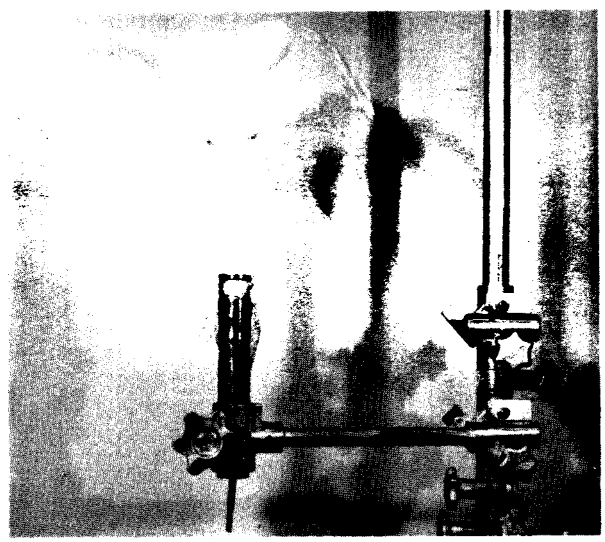
As an alternate method, make a hole in the bottom of a paper cup and place the pipe through it. Place the cup and pipe in the model before the plaster sets. The cup must extend above the edge of the model. Locate the hole inside the space and pull vacuum on the pipe. If the model has deep undercuts, drill holes from the outside of the model into the space. This will help hold the inner PVA bag to the model without gapping.



Single Vacuum Using Mandrel and Single Vacuum Source

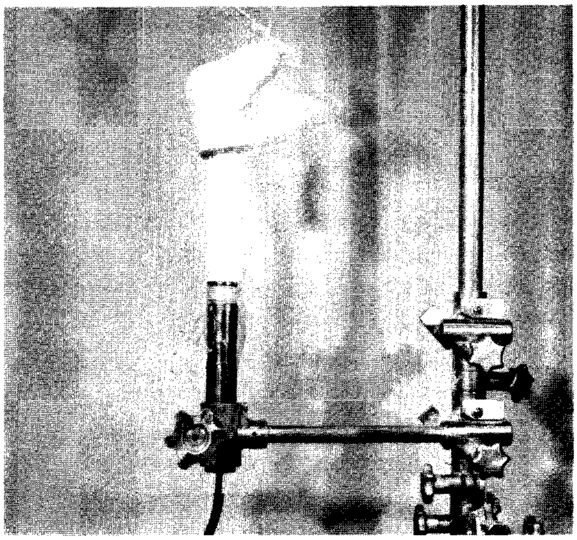


Put the model mandrel over the vacuum mandrel as shown. Apply the layup over the model (with parting agent applied), and tie off the layup at the bottom.



Dampen the PVA bag. Pull it over the layup, and tie it at the upper tie off point on the vacuum mandrel. The PVA bag should be damper for vacuum than without vacuum; with a damper bag the vacuum can pull the bag against the layup over irregular and concave shapes.

Insert a funnel or cup into the top of the PVA bag and suspend it overhead. This is to receive the resin.

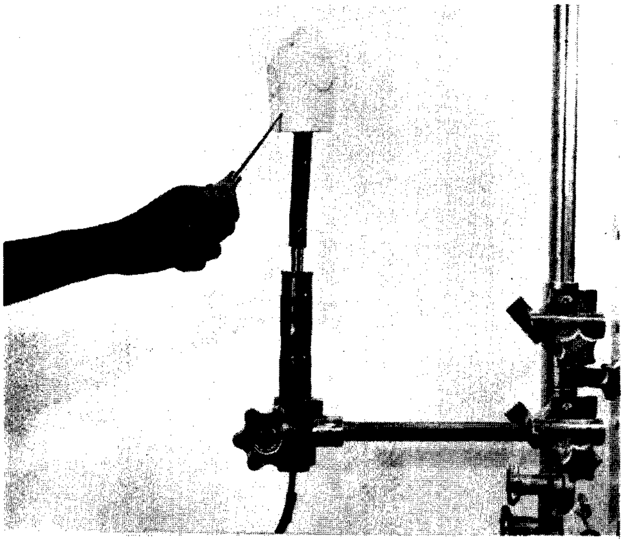


Tie off the top of the PVA bag. Test the vacuum system to see that it is airtight and that the bag pulls entirely over the layup. Only a few inches of mercury vacuum are usually needed.

Mix the resin, pour it into the PVA bag, and work it well into the layup. With a string, move excess resin to the top. While working the resin, leave some in the top of the bag to seal the lamination from outside air.

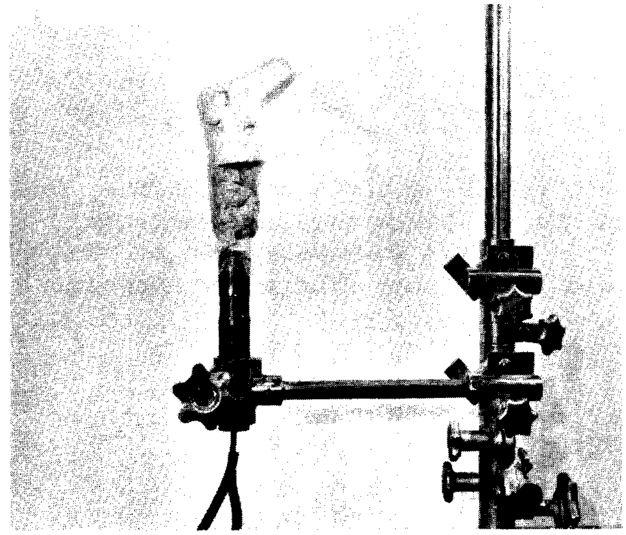
When all excess resin is at the top, remove it by tying the top of the bag just above the layup. Allow the resin to set. Leave the vacuum on until the resin is set so the PVA bag will not pull away from the model.

Double Vacuum Using Double Source

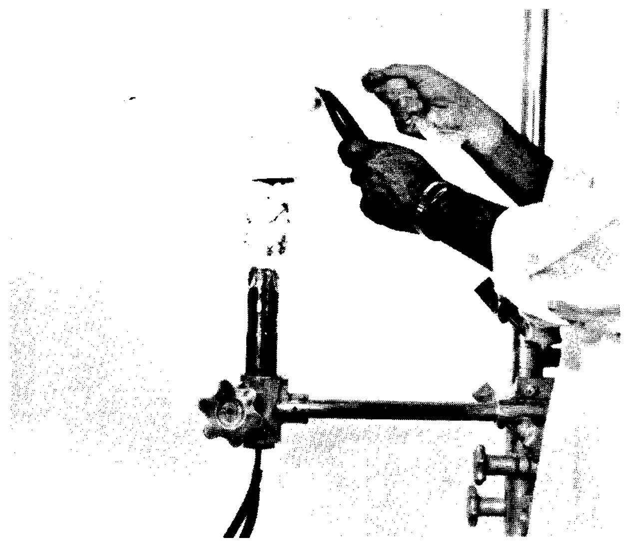


Put the model mandrel over the vacuum mandrel. Scribe lines or drill holes in the bottom part of the model to allow air to escape to the inner vacuum source.

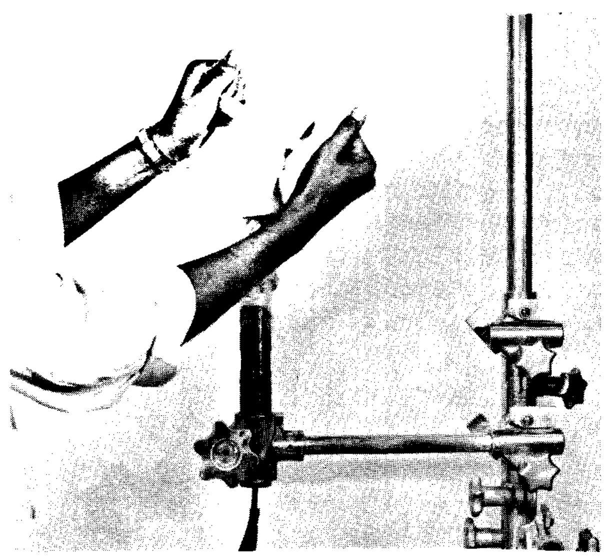
Put vasoline or oil on the model and pull the inner PVA bag over the model. Put paper or cloth around the model mandrel to prevent the PVA from sealing the mandrel and cutting off the vacuum supply. Tie off the bottom of the bag at the upper tie off point on the vacuum mandrel.



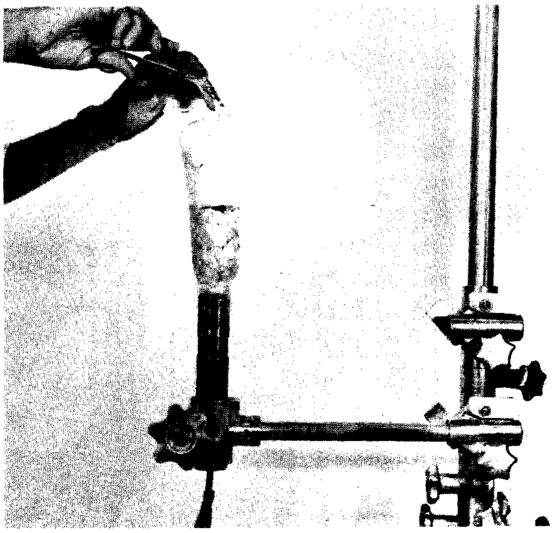
Cap the inner PVA bag by first trimming the bag around the top of the model as shown.



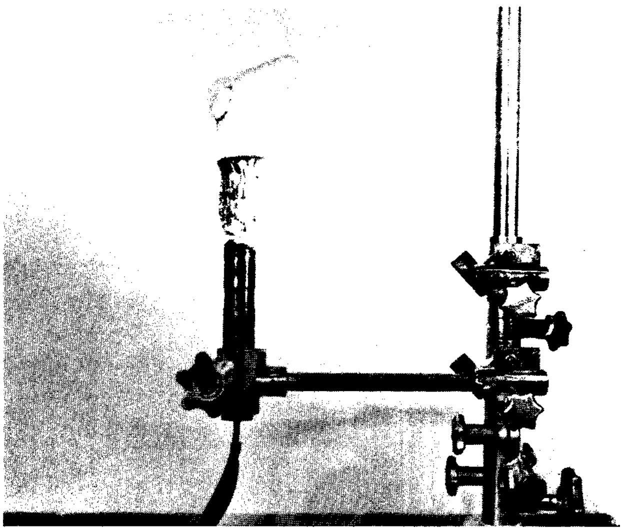
Put PVA glue around the edge of the bag. Pull a sheet of PVA over the top of the model as shown. The sheet should overlap the bag with as few wrinkles as possible.



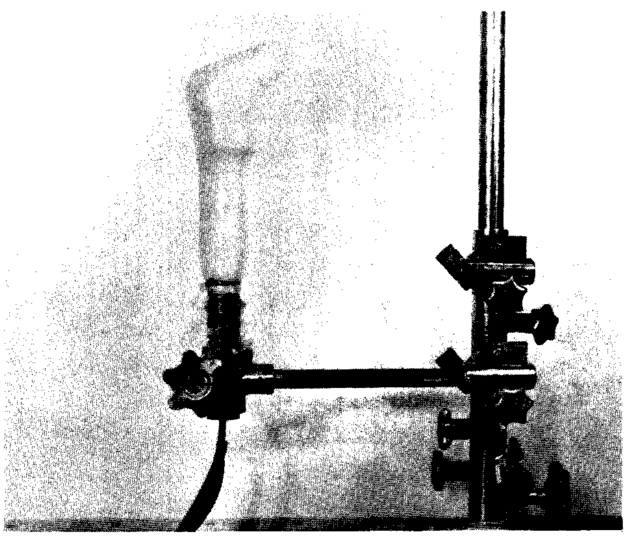
While holding the sheet in place, seal it to the bag with a sealing iron. Trim the PVA seam as smooth as possible. The inner PVA is now capped.



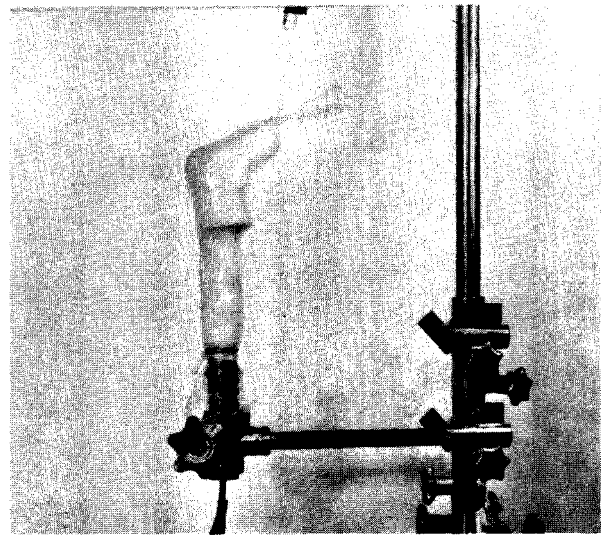
Test the inner vacuum system for air tightness; the PVA bag should also pull entirely over the model. Only a few inches of mercury vacuum are generally needed.



Make the layup and pull the outer PVA bag over the layup. Tie the bottom of the outer bag at the lower tie off point on the vacuum mandrel. Put paper or cloth over the vacuum mandrel hole to prevent the PVA from sealing the outer vacuum supply.



Put a funnel or cup into the top of the outer PVA bag and suspend it overhead for receiving the resin.



Tie off the top of the bag. Test the outer vacuum system for airtightness; the bag should also pull entirely over the layup. Only a few inches of mercury vacuum are usually needed.

Mix the resin. Pour it into outer PVA bag, and work it well into the layup. With a string, move excess resin to the top. While working on the resin, leave some in the top of the bag to seal the lamination from the outside air. When all excess resin is at the top, remove it by tying the top of the outer bag just above the layup. Allow the resin to set. Leave both vacuums on until the resin sets so the PVA bags will not pull away.

Double Vacuum Using Single Source

This method is similar to the method of using a double source for a double vacuum with one exception: the outer PVA bag vacuum is achieved by poking a hole in the bottom of the inner PVA bag in order that the same vacuum pulls on both PVA bags. With this method the thickness of the plastic lamination can be controlled (if the inner bag requires more vacuum than outer bag, the lamination will be too thin) and the inner bag cannot pull away from the model. (If the outer bag requires less vacuum than the inner bag, the inner bag may pull away from the model.)

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