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Sheet Plastics and Their Applications in Orthotics and Prosthetics

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INTRODUCTION

Around 1970, a flexible plastic shell type orthosis was introduced to provide dorsiflexion assist during the swing phase of gait. Since then, polypropylene has become the most widely used and accepted material for this application.

However, many other types of sheet plastics are being used by orthotists and prosthetists today. Some plastics have more applications than others, but many types of plastics seem to have a particular characteristic which lends itself well to certain disabilities or even to certain body segments.

The decision to use one type of plastic over another, or to use plastic at all, is being determined more frequently by the orthotist and prosthetist. This decision has been placed in the hands of these practitioners by physicians and other health professionals, because it is felt that this could best be decided by the practitioners who work most closely with these materials.

It is important to remember that in many situations, when treating a disability orthotically, any one of several different types of plastic may be utilized. The particular plastic chosen may be a subjective decision based on prior experiences. However, in any event, the responsibility of this decision is one that most orthotists and prosthetists have willingly accepted.

In order to communicate some basic knowledge of sheet plastic technology to orthotists, prosthetists, physicians, therapists, and other professionals, this article is presented as a guide to the variety of sheet plastics now available. This list may serve as an accurate reference for those sheet plastics most widely used in orthotics and prosthetics.

TERMINOLOGY

At the Physical Medicine and Rehabilitation Department at the Hospital of the University of Pennsylvania, orthotics has advanced to incorporate the vast utilization of thermo-plastics. The techniques applied to fabricate an orthosis require that a negative impression of the body segment be taken. After specific laboratory assembly procedures, a custom molded orthotic device is created for the patient's disability. The terminology used to refer to these orthotic devices includes:

- FO—Foot Orthosis
- AFO—Ankle Foot Orthosis

- KAFO—Knee Ankle Foot Orthosis
- HKAFO—Hip Knee Ankle Foot Orthosis
- KO—Knee Orthosis
- HO—Hip Orthosis
- WHO—Wrist Hand Orthosis
- EWHO—Elbow Wrist Hand Orthosis
- SEWHO—Shoulder Elbow Wrist Hand Orthosis
- SO—Sacral Orthosis
- LSO—Lumbar Sacral Orthosis
- TLSO—Thoraco Lumbar Sacral Orthosis
- CTLSO—Cervical Thoraco Lumbar Sacral Orthosis

Prosthetics differs in the terminology used, but the techniques performed in developing a functional prosthesis are similar to those as practiced in orthotics.

A negative impression is taken of the residual limb and, from that mold, a socket is fabricated to fit the residual limb intimately. The goals achieved by a proper socket fit are maximum function and comfort for the amputee.

The type of prosthesis is referred to as either an endoskeletal or an exoskeletal. The terminology commonly used today includes:

- TM—Transmetatarsal amputation
- AD—Ankle Disarticulation
- BK—Below Knee
- AK—Above Knee
- HD—Hip Disarticulation
- HP—Hemipelvectomy
- WD—Wrist Disarticulation
- BE—Below Elbow
- ED—Elbow Disarticulation
- AE—Above Elbow
- SD—Shoulder Disarticulation
- IT—Interscapulo Thoracic

A GUIDE TO ORTHOTIC AND PROSTHETIC USES OF SHEET PLASTICS

Low Temperature Plastics:

Orthoplast

Orthoplast is possibly used in orthotics more frequently than any other sheet plastic. Occupational therapists, orthopedic technicians, and physicians like this material because it can be applied directly to the patient, thereby making a negative impression on the patient unnecessary. Orthotists will use this material often when asked to fabricate orthoses used in the treatment of fractures.

Orthoplast may also be incorporated in a device which may need to be flexible and custom molded over two positive models for an improved fit. However, it is usually not the preferred material because of its shorter life expectancy when compared to the other, more durable flexible sheet plastics. Even so, many orthotists will choose to use orthoplast in the orthotic treatment of scoliosis with a Milwaukee style orthosis

Low Temperature Plastic	Most common applications	Properties	Forming temperature	Time Required to Heat	Forming Process	Available thickness, density, color
Orthoplast	Splint designs, Milwaukee pelvic girdles, fx. orthoses, T.L.S.O.'s	Thermoplastic, low heat forming, durable, cohesive, comfortable, self-adhering, can be riveted, strapped, bonded or hinged, one year life expectancy	160°–170°F	Dry heat or hot water until flexible	Applied over positive cast or over protective sleeve on limb	1/8″ Plain or perforated White

Figure 1.

or a T.L.S.O. "body jacket" because the material can be easily adjusted with a heat gun even after the finished orthosis has been worn by the patient.

High Temperature Plastics:

Kydex

A rigid plastic, Kydex is an excellent reinforcing material over soft plastic foam. It is also used as the supporting material in Philadelphia collars. Some orthotists prefer its use in upper extremity applications such as the wrist-hand-orthosis with or without articulation at the wrist. In many locales, it is popular for use in spinal orthotic prescriptions. Kydex can be reheated and changed repeatedly over its long life.

Nyloplex

Nyloplex is routinely used in upper extremity orthoses. Its use, however, often depends on the practitioner's past training. For example, Nyloplex is popular with practitioners graduated from New York University, while those trained at Rancho Los Amigos might prefer aluminum, which is most frequently used there. Nyloplex is cosmetic and can be reheated repeatedly like Kydex. It is also transparent and durable. Moreover, it has been used for spiral and hemispiral AFO's, but durability is still a problem in these applications.

Polypropylene-Standard Grade

Standard Grade Polypropylene is the most widely used sheet plastic in orthotics and prosthetics. In most cases, the nonarticulated AFO is fabricated from polypropylene and is referred to locally in Philadelphia as a "MAFO" (molded AFO). It must be remembered, however, that not all MAFO's are solid ankle designs, nor are all nonarticulated MAFO's flexible at the ankle trim. Since metal joints are frequently used when treating certain disabilities, I would emphasize that the metal hinge be attached to the more rigid polypropylene sections as opposed to, for example, the flexible polyethylene anterior shell.

Polypropylene is the strongest sheet plastic available which can be formed over a positive model. Common orthotic uses include upper extremity devices designed for long term use, MAFO's, KAFO's, CTLSO's, TLSO's, pelvic bands and joints, pelvic girdles, and other innovative devices where rigidity and durability are essential.

Co-Polymer

Co-polymer is more rigid after the forming process than orthopedic grade polypropylene, but is slightly more flexible than standard grade polypropylene. Many practitioners appreciate the choice between the slightly different characteristics of these three materials, while others will routinely choose only one type.

Co-polymer would be the plastic of choice when custom molded orthoses are prescribed for permanent orthosis wearers such as post-poliomyelitis patients. In this situation, co-polymer meets the critical needs of durability, cosmesis, light weight design, and intimate fit. I emphasize that the decision to use co-polymer or to use polypropylene may not always be an obvious one for the orthotist formulating the orthotic design.

Polypropylene-Orthopedic Grade

Orthopedic grade polypropylene is standard grade polypropylene with an additive which makes it more flexible and, therefore, more durable under stress. However, this additional flexibility can be undesirable when maximum rigidity is required. A careful evaluation at the initiation of orthotic treatment is essential to determine the most appropriate material and design. When a custom molded fracture orthosis is prescribed for an active patient, orthopedic grade polypropylene is an excellent choice, which will diminish the incidence of rupture in high stress areas. If desired, a soft foam plastic interface may be positioned on the positive model, and the hot polypropylene will adhere to it during the vacuum forming process.

High Temperature Plastic	Most common applications	Properties	Forming temperature	Time Required to Heat	Forming Process	Available thickness, density, color
Kydex	Reinforcing material on Philadelphia collars, Milwaukee girdles, TLSO, orthospinal orthoses & upper extremity orthoses	Acrylic-polyvinyl chloride, chemically resistant, very rigid, resistant to tearing, finishes nicely	350°–400°F	moldable within seconds	Drape mold over positive cast (can not be vacuum formed)	1/8" Beige, white
Nyloplex	Upper extremity orthoses, spiral & hemispiral AFO's	Clear acrylic bonded with nylon, may be sanded or buffed, subject to rupture under repeated stress	285"–300°F temp for 2 hours at 90°C)	moldable within minutes	drape mold over positive cast can not be vacuum formed)	2mm–4mm transparent
Ortholen	AFO with flexible trimline, W.H.O.	thermosetting, self lubricating, tough, and corrosion resistant. Does not become brittle or absorb perspiration, can be sterilized	356°F	3-5 minutes	Drape and wrap (can not be vacuum formed)	1 mm–6mm
Vitrathene	TLSO, Milwaukee pelvic girdles, upper extremity fracture orthoses	odorless, non-toxic, compression molded polyethylene resistant to alkalines, dimensionally stable, non allergenic	350°–375°F	10-15 minutes	drape molding with or without vacuum over positive cast	1/8"–1/4" Flesh tone
Polyethylene	TLSO, Milwaukee pelvic girdles, custom-molded lower limb orthoses, fracture	tough, waxy, flexible, odorless, tasteless, well tolerated by skin tissue	350°F	7-15 minuites	vacuum formed over positive	1/8"–1/4" low density flesh or natural

Poly-propylene (standard grade)	AFO, KO, KAFO, HKAFO, TLSO, LSO, HO, WHO, EWHO, SEWHO	cosmetic orthoses tacky when heated, rigidity with in-creased thickness, gets brittle, discolors with age.	400"–425°F	8-10 minutes	drape vacuum form over posi-tive cast	1/8", 1/4", 3/8" stress relieved or non stress relieved natural or flesh
CoPolymer	Lower limb orthoses	for permanent orthosis wearer, very durable & rigid enough	400°–425°F	8-10 minutes	drape vacuum form over posi-tive cast	1/8, 3/16", 1/4" natural natural
Poly-propylene (orthopedic grade)	AFO, KO, KAFO, TLSO, LSO, HO, WHO, EWHO, SWEHO	an additive (Butyrate) to standard grade polypro-pylene gives added flexibil-ity & durability	400"–425°F	8-10 minutes	drape vacuum form over posi-tive cast	1/8", 5/32", 3/32", 1/4" Natural Natural

Figure 2.

Ortholen

The most frequent use for ortholen is in the posterior leaf spring type AFO, which is usually used when weak dorsiflexors co-exist with active plantarflexors. Durability at the posterior section of the orthosis is questioned by some practitioners who, therefore, prefer not to use this plastic. *Subortholen* is a new material, which is reported to be more durable than ortholen.

Vitrathene

Vitrathene is a pink colored form of polyethylene used by some orthotic practitioners, who feel that this plastic is more durable than the low density polyethylene. The most frequent use of this material is in the custom molded low profile T.L.S.O. "body jacket," as it is commonly called, used in the treatment of idiopathic scoliosis or for stabilization of the spine following surgical treatment, such as Harrington rod placement. In addition, Vitrathene could be used for any upper or lower limb orthoses where flexibility is desired, but caution should be taken when considering this material where high stress conditions may be expected or where rigidity is essential.

Polyethylene

Similar in characteristics to Vitrathene, polyethylene is next to polypropylene in popularity with orthotists and prosthetists. One of the reasons the Prosthetic and Orthotic lab of the Hospital of the University of Pennsylvania prefers polyethylene to vitrathene is the color matching which is possible when combining both polyethylene and natural polypropylene in an orthosis.

Other important reasons for its popularity are cost effectiveness, variety of different thicknesses, flexibility, and availability through most local plastic manufacturers. It is also relatively easy to work with during fabrication, provides a pleasant appearance, and is easier to smooth the edges on than with many other sheet plastics.

The most frequent uses for polyethylene are the anterior forms on custom molded AFO's and KAFO's, TLSO's, and upper extremity orthoses where joints are seldom used, such as in passive types of HO's, WHO's, and EWHO's. Polyethylene is an excellent choice when immobilization of a joint is required for a patient who needs a durable, flexible, and removable device. An additional advantage is that when vacuum forming over soft plastic foam, the polyethylene will adhere securely to the soft interface, providing improved comfort for the patient.

TRANSPARENT HIGH TEMPERATURE PLASTICS

*Thermo-vac (Surlyn)®**

The most recent addition to the list of sheet plastics used in orthotics and prosthetics is thermo-vac® which has the unique characteristics of flexibility and transparency. It is commonly used as a check socket for trial fittings on difficult cases. It may also be used in the finished orthosis or become a part of the definitive prosthesis.

Thermo-vac can be vacuum formed with a frame, drape vacuum formed, or drape molded without vacuum. Extreme care must be taken when working with this material when it is hot because it will readily adhere to the skin, causing a burn. This caution also applies to sanding and finishing of the material, which will quickly raise an area of the thermo-vac to the melting point.

Orthotists frequently use this material for nonambulatory MAFO's, custom molded knee orthoses without hinges, upper limb fracture orthoses, T.L.S.O.'s, and custom molded cervical orthoses. Prosthetic applications include check sockets for BK, AK, and upper limb amputees, and it may also be used in the socket of an intermediate or definitive prosthesis when an optimum fit has been achieved in the check socket.

*A product of DuPont

Transparent High Temperature Plastic	Most common applications	Properties	Forming temperature	Time Required to Heat	Forming Process	Available thickness, density, color
Thermo-vac	TLSO, fx. orthoses, W.H.O., A.F.O., clear check sockets	Clear optics, high tensile strength, thermoplastic polymer, difficult to finish, not recom- use in areas of high stress	250°–300°F	5 minutes mended for	drape or vacuum form	1/8", 3/16", 1/4", 3/8"
Lexan	clear check socketsmust be	Hydrophilic, Heat to pre-dried, odorless, high tensile strength and impact strength, clear polycarbonate, rigid, may be sanded and buffed	Dry: 275"F minimum form 400°–450°F	Dry 48 hours frame form 10 to 30 minutes	vacuum form with holding	1/2" transparent

Figure 3.

Patient acceptance of this material has been favorable compared to other sheet plastics due to the cosmesis of a clear device. However, it will rupture in high stress areas sooner than the other plastics, making it unacceptable for many applications. Moreover, it is much more expensive than the available alternatives.

Lexan

Lexan is a very rigid, high impact strength, transparent sheet plastic which has been found to be a good material for prosthetic check sockets. Its clarity is superior to that of thermo-vac, and its rigidity more closely simulates that of the laminated plastic socket it preceeds. Lexan may be bonded to an extension block and attached to an alignment fixture, and safely used for dynamic fit and alignment trials. The major disadvantage is that, being hydrophilic, this material must be predried for two to six days, requiring a separate drying oven. Moreover, it must be vacuum formed using a holding frame and platen, and, therefore, is not readily accepted by many practitioners who do not already have this equipment. A Lexan check socket may be relieved by grinding, but not by spot heating as may thermo-vac. The Lexan check socket also cannot be used as a part of a definitive prosthesis.

SOFT FOAM INTERFACE PLASTICS

Pelite

Pelite is a light weight, moisture proof, sponge foam polypropylene with excellent

Soft Foam Interface Plastic	Most common applications	Properties	Forming temperature	Time Required to Heat	Forming Process	Available thickness, density, color
Pelite	lining material for orthotic and prosthetic applications, molded tongue flaps	light-weight foam foam polyethylene, non-allergenic, soft, washable, thermoplastic, shock absorbant	300°–400°	less than one minute	drape & wrap (thermo bonds to polyethylene & polypropylene)	variety of thicknesses Perforated and non-perforated Firm, medium, or soft white and flesh
Plastozote	interface for orthotic and prosthetic applications	closed cell polyethylene, auto adhesive in dry heat, non-toxic, low flammability, easily cut & sanded, shock absorbing	285°–300°F	less than one minute	drape molding (may be reinforced with vitrathene & clear polyethylene)	perforated, 1/16″–1″ white flesh non perforated: 1/16″–1/2″ white flesh (other colors, thicknesses, and densities available)
Aliplast	general padding and lining material for orthotic & prosthetic applications	light-weight foam, easily cleaned, exceptional padding, anti-shear, self-adhesive is available	300–350°F	one minute	drape form or vacuum form	1/8″–1/2″ white

Figure 4.

shock absorption characteristics. It is available with invisible ventilation holes, or with visible perforations. It also comes in a wide variety of thicknesses, densities and colors. Pelite is most frequently used as a BK liner material, but is also used in pads or complete liners in pelvic girdles, AFO's, and other orthoses.

Fabrication is relatively simple, requiring only a heat gun (or oven) and an elastic bandage to hold the material in place over the positive model until it cools. Because of its ease of fabrication, durability, and washability, it has largely replaced the Kemblo and leather BK liners in most areas.

Plastizote

A commonly used soft foam, plastizote is used as a liner material in both orthoses and prostheses. It may be used in insoles, pads in MAFO's, KAFO's, and in spinal orthoses. It may also be used in upper extremity orthoses for arthritic patients. As a BK prosthesis liner material, it should be used only for inactive patients, as plastizote will compress under weight bearing whether in a prosthesis or orthosis. On the other hand, it is very popular in the medical field because it is relatively easy to work with and may be vacuum formed or drape molded.

Aliplast

Aliplast is a lining material that is smoother in appearance than plastizote. It is popular with orthotists because of its softness as an interface, and for its ability to adhere to polypropylene, polyethylene, and thermo-vac during their vacuum forming. Prosthetists have found Aliplast to be of use as a BK liner material for patients who have very sensitive residual limbs or where skin breakdown seems probable. This liner material is not as durable as others and should only be used where these special problems exist.

At the laboratory of the Hospital of the University of Pennsylvania, we use an Aliplast liner for a temporary prosthesis and for patients who have difficulty wearing a hard socket. Whenever it becomes practical, we will use Pelite as the liner for its longer life and superior performance under active wear. The Aliplast liner for prosthetic or orthotic use is fabricated using a drape molding technique, with or without vacuum.

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