ECRONICON OPEN ACCESS

EC ORTHOPAEDICS
Review Article

Thermoplastic Sheet for Orthoses, A Review of Literature

Mohammad Karimi[1,2]*, Mahsa Kavyani[1], Ali Mohammadi[3] and Mohammad Ebrahimi[3]

[1]Musculoskeletal Research Center, Isfahan University of Medical sciences, Isfahan Iran

[2]Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz Iran

[3]Biophysics of Bone and Cartilage Group, Eastern Finland University, Finland

***Corresponding Author:** Mohammad Karimi, Musculoskeletal Research Center, Isfahan University of Medical sciences, Isfahan and Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran.

Received: March 13, 2017; **Published:** April 07, 2017

Abstract

Background: Various types of orthoses have been used in treatment of musculoskeletal disorders. Most of them have being manufactured based on use of thermoplastic materials. The aim of this review was to define various thermoplastic materials used for orthoses with emphasize on their physical properties.

Method: A search was done in some data bases including: ISI Web of Sciences, Pub Med, Google Scholar, and Scopus. Some key words such as orthosis, brace and splint were used in combination with thermoplastic sheet. The results of studies were categorized based on working temperature of the materials.

Results: The thermoplastic sheet could be categorized based on working temperature into three main groups including, those without need to be heated, low temperature materials and high temperature materials. There is another possibility to categorize the thermoplastic sheet based on density and stiffness.

Conclusion: It is very important to categorize the thermoplastic sheet due to their variations. It is recommended that use of thermoplastic sheet be done based on their mechanical properties, life time and their formabilities.

Keywords: *Thermoplastic Sheet; Orthosis; Splint; Mechanical Properties*

Introduction

Treatment of orthopedic diseases and skeletal abnormalities requires using different treatment strategies from using drugs and assistive devices to operations based on type of disease. Using assistive devices plays an important role in treatment which may be prescript to reach to the following purposes [1-3]:

1. Increase the efficiency of a structure, particularly for diseases with muscle paralysis.
2. To improve or correct alignment.
3. To protect the damaged organs before and after surgery.

The orthopedic aids which are also called orthosis are produced from different materials including metal and plastic depending on their function [2]. In the new generations of the orthoses using plastic is very common because of following purposes:

1. Fast and easy fabrication of orthoses.
2. Easy to use and wear.
3. Easy to change the alignment of orthoses.

Choosing the appropriate material is the key factor for fabrication of orthosis. Basically, elasticity, material memory, cooling and forming rate, durability, strength and toughness would be considered for choosing plastic materials [1]. It should be mentioned that beauty and elegance of orthosis is very important factor to motivate the patients, therefore, manufacturer has to pay attention to color, thickness and other related factors [4,5]. Moreover, it is obvious that orthosis function should be considered in choosing the material. For instance, the orthosis which is used for lower limb correction should not deform in the direction of corrective forces. Due to, lack of knowledge of plastic material properties, the appropriate and optimized factors for orthosis are not considered by technical orthopedic specialists. This issue can effect on orthosis function and output. Therefore, the main aim of this study was to introduce available plastic materials (Thermoplastic sheets) in orthosis fabrication with regard to functions and mechanical properties.

Methods

A search was done in some data bases including Google Scholar, Scopus, PubMed and ISI Web of Knowledge. Some key words such as orthosis and splint were used with thermoplastic sheet. The search was done for a period between 1960 and 2016. In the initial review papers have been chosen based on the subjects and the research question of interest. In the next step, the content of the article was evaluated and the mechanical properties of plastic materials and the applications were highlighted. Due to the aim of this study which was to introduce the plastic materials (Thermoplastic sheets) for brace fabrication, no quality assessment for the reviewed papers was done.

Results

In this study five related articles among twenty articles were chosen. It should be mentioned that, although, there are some information about orthosis materials in the textbooks, it is very difficult to find broad information about mechanical properties.

In the majority of scientific papers, the materials for splint fabrication has been introduced. In the current study, efforts have been made to categorize the introduced materials based on the application and physical properties. Basically, the materials for orthosis fabrication can be categorized based on working temperature into three main groups including, those without need to be heated, low temperature materials and high temperature material. The most important examples of the formable materials without temperature are athletic tapes, gypsum and fiberglass bandage. Low temperature materials are generally used for the fabrication of upper limb splints and orthoses which does not require high strength. Depending on the added materials such as filters, plasticizers, lubricants and added color materials have different properties [4-6]. High temperature materials, are used for spinal orthoses and lower limb orthoses which requires high strength.

Materials without need to temperature: Table 1 illustrates the characteristics of these materials [7,8].

No Heat or Layered*	Low Temperature* (60-77°C)	Moderate Temperature (77-107°C)	High Temperature (149-177°C)
Gypsona" or plaster of paris Tape Coban™ Fiberglass-based Scotchcast™ Soft Castt Scotchcast™ Plus Silicone rubber RTV-11 311 0-RTV Gore™ cast liner PQ® Viscoelastic Polymer Neofrakt®	Rubber-based Ezeform® Orthoplast® Plastic/Rubber-based Polflex II® NCM Preferred® Plastic-based Orthoplast II® Polyform® Elastic-based Aquaplast® Treated Orfit® Soft	Bioplastic® High-impact vinyl®	Royalite® Plastazote® Kydex® Nyloplex™ Nickelplast™

Table 1: *The classification of materials used to immobilize various parts of injured body segments based on working temperature (adapted from Canelon 1995) [4].*

Low Temperature: As mentioned above the properties of these materials is depends on added materials but they have general features such as hardness, material memory, coating, adhesion ability, forming ability, thickness and forming rate which should be considered. Table 2 shows the main properties of this group material.

Material	Description	Activation	Curing Time (minutes)
Tape	Cotton backcloth adhesive	Pull, tear and apply	NA
Fiberglass			
Scotchcast Soft Cast	Knitted fiberglass fabric impregnated with polyurethane resin	Immerse in room temperature water 21 - 24^{0}C	4-6
Silicone rubber			
RTV 11 or 3110 RTV	Two-part liquid-based silicone rubber	Apply catalyst agent to base material	Varies*
Low-temperature thermoplastics			
Rubber based	Polyisoprene base variation amounts with fillers	Immerse in spilt pan with water set at 60 - 75^{0}C for 1 - 2 minutes	3-5
Elastic based	Polycaprolactone base with small amounts of stabilizers and modifiers	Immerse in spilt pan with water set at 60 - 75^{0}C for 1-2 minutes	3-5

Table 2: *Some low temperature material used for splints (adapted from Canelon 1995) [4].*

High temperature materials

1. **Polypropylene:** Basically, Polypropylene plastics are considered as the part of Polyolefin and categorized into two subsets including Thermolyn polypropylene homopolymer and Thermolyn polypropylen copolymer.

2. **Polyethylene thermoplastic sheets:** They can be categorized into 2 categories including: Thermolyn RcH500 and Thermolyn PE 200 based on the density.

3. **Kydex:** They are high density plastics covering soft foams. They can be reheated several times and reform.

4. **Nyloplex:** Generally used for upper limb orthosis, and also for spinal orthoses.

5. **Vitra Thene Sheet:** This is a special group of polyethylene which has low density and high strength compared with conventional polyethylene.

6. **Thermo-Vac (Surlyn):** This is categorized as transparent thermoplastic sheets used for prosthesis socket control.

7. **Lexao:** Transparent, orthosis socket check materials with high strength which can be used temporarily.

Discussion

Although there are some information about thermoplastic material from manufacturers, there are limited references which can be relied completely. In this study five papers have been reviewed in details which most of them focused on the materials for hand splints. Generally, it should be considered that depending on types of orthoses and prostheses some plastic materials have higher efficiency. The problem here is that most of the times choosing the materials has been done based on experience and not the knowledge [6]. Therefore, introducing the thermoplastic materials and recommended applications are of a high importance.

Some of the mechanical properties of thermoplastics are characterized by: 1. Tensile test, 2. Hardness test, 3. Impact test, 4. Creep and relaxation tests. The mechanical strength of thermoplastic sheets used in technical orthopedics is based on available mechanical testing

in literature. It should be noted that formable thermoplastic materials are deformed at the temperature above 320 F. Those materials are crystalized following decreasing the temperature to below 290 F. This phenomenon affects the final strength of orthosis. Table 2 illustrates the formability temperature and glass transition temperature of different materials [1,2,6].

The point which is rarely considered is the hotness of positive mold. Since it decreases the cooling rate leading to less crystalize and higher strength. It should be noticed that the fast cooling rate results in forming and growing the cracks and consequently failure of material.

Therefore, one should regard slow cooling rate of positive mold and the containing plastic. Other important point is that the positive mold should not be heated when it is wet. Because the vaporized water can bring about a failure of mold. With regard to temperature formable material, the choosing of proper material is of a high importance and their special characteristics should be considered. Since some has poor durability and can be used for a limited time. The highlighted characteristics that should be considered are:

1. Density
2. Strength and rigidity
3. Comfortability: How comfort is the splint so that it would not press anatomical places.
4. Self-adherence: The ability of edge adhesion is called self-adherence.
5. Durability: The ability of material to absorb dynamic loads.
6. Easy to fabricate
7. Cost and availability

The material and plastics used to fabricate the splints can be categorized in four groups:

The first group includes Tape, gypsum and fiberglass bandage. The low temperature thermoplastic materials includes rubber and elastic materials which include Polyisoprene and Polycaprolactone- based sheets. Among rubbers ezeform and orthoplast can be mentioned. Those materials have low density, low adherence and relatively low hardness. The second group is known as plastic-rubber like which includes polyflex and NCM-preferred. These materials benefit from relative comfortability, but low adherence and hardness. Third group is semi-plastic which includes the materials like ortoplast 2 and polyfoam. They have high comfortability but low adherence and hardness. The thickness should also be taken into account. Generally, the thickness of thermoplastic materials differ from 1.6 - 4.8 mm. It can be claimed that 1.6 mm thickness is suitable for finger splints and 3.2 mm thickness is suitable for hand and wrist splints.

Conclusion

Choosing the proper material for orthosis and assistive devices plays an important role in treatment. Basically, it is better to categorize them based on the patient limited mobility, the severity of diseases and the time required to create movement restrictions. Accordingly, the thermoplastic materials based on working temperature could be categorized into three main groups including, those without need to be heated, low temperature materials and high temperature materials. Therefore, it is recommended that orthosis fabrication specialists choose the materials based on the criteria described in the current study.

Bibliography

1. American Academy of Orthopaedic Surgeons. "Atlas of orthotics. 2nd Ed". St. Louis, Mo.: Mosby; (1985): 199-237.
2. Rose GK. "Orthotics: principles and practice". Heinemann (1986).

3. Rose J and Gamble JG. "Human walking. 3rd ed". Philadelphia, Pa; London: Lippincott Williams and Wilkins (2006): 234.

4. Canelon MF. "Material properties: a factor in the selection and application of splinting materials for athletic wrist and hand injuries". *The Journal of Orthopaedic and Sports Physical Therapy* 22.4 (1995): 164-172.

5. Breger-Lee DE and Buford WL. "Properties of Thermoplastic Splinting Materials". Journal of Hand Therapy 5.4 (1992): 202-211.

6. Groth GN and Kamwesiga J. "Splinting materials old and new". *Journal of Hand Therapy* 15.2 (1998): 202-204.

7. Rowley DI., *et al*. "The comparative properties of plaster of Paris and plaster of Paris substitutes". *Archives of Orthopaedic and Traumatic Surgery* 103.6 (1985): 402-407.

8. Bowker P and Powell ES. "A clinical evaluation of plaster-of-Paris and eight synthetic fracture splinting materials". *Injury* 23.1 (1992): 13-20.

Volume 5 Issue 5 April 2017