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Cost-benefits in orthopaedic technology by using thermoplastics in developing countries

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Abstract

A case is made for using thermoplastics in prosthetics and orthotics when available in developing countries due to the cost-benefits that may accrue.

Introduction

The first commercially important plastic material is said to have been celluloid. The material was developed during the 1860's and was used among other things for billiard balls, as a substitute for ivory. As celluloid is easy to set on fire, a more temperature stable plastic material was sought. In 1907 Leo Baekeland received a patent for a plastic material consisting of phenol-formaldehyde resin compressed with wood-powder which two years later was marketed under the name of Bakelite. The material was very successful and is still manufactured with different types of fillers.

Rubber materials were developed much earlier than plastics. Thus natural rubber was commercially obtained from the tree Hevea Brasiliensis in the beginning of the nineteenth century. After Goodyear's finding that sulphur could vulcanize the rubber (patented in 1839), the material made its real breakthrough.

In 1910, the world production of plastics material was about ten thousand tons. When Bakelite was introduced to the world market in 1930, the production increased to one hundred thousand tons. Rubber production, at the same time, was about eight times greater. The use of plastic materials passed aluminium during the fifties, as seen in Figure 1 which shows consumption variation over a fifty year period (Terselius, 1988).

During the 1980's, the production volume of polymer materials passed the sum of the volume of metals in western Europe, USA and Japan.

As a consequence of the 1973/74 oil crisis with a shortage of raw materials and energy, a marked lowering of the production of plastic materials occurred. After that incident, the increase has become somewhat lower but the

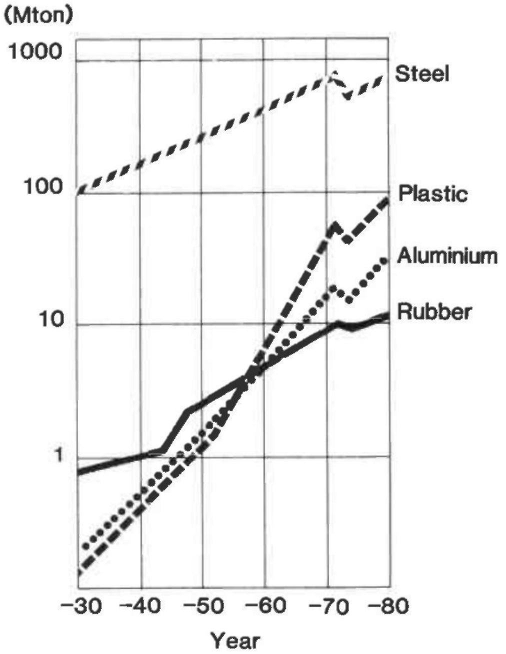

Fig. 1. Development of world consumption of selected materials.

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use of plastic materials in different designs has been increasing.

The case for thermoplastics

The 1973 oil crisis led to a high increase in oil prices and a lower volume increase for all design materials. As plastic materials consume lower energy when produced (Terselius, 1988), the process is often carried out at under 200° C, it will be favourably compared to metals in competitive situations (Fig. 2).

As shown in Table 1, the world production of plastic materials is about 50 million tons compared to that of rubber, which is about 12 million tons, with synthetic rubber accounting for twice as much as natural rubber (Terselius, 1988). It can also be seen that the most produced plastic materials in the world are polyethylene and PVC. The production of polypropylene is larger than the production of natural rubber. It could be noted that the plastic materials produced in large quantities have the same price as natural rubber or just slightly above it while a common material used in prosthetics and orthotics such as polyester is twice as expensive as common thermoplastic materials.

As prices of plastic materials now have become so competitive compared to the traditional metals and other materials, it has become common to use plastic materials also in developing countries especially in the construction and building industry. The common thermoplastic materials, polyethylene, PVC and polystyrene are therefore now also available in the developing countries. Other types of plastic materials are also becoming more and more available.

During the 1960's thermoplastic materials such as polyethylene and polypropylene became more commonly used in prosthetics and orthotics. The dropfoot brace was the first important application of thermoplastics in

Table 1. Plastic and rubber materials.

Polymer material	World Production (KTON/Year)	Price Index Per weight
Thermoplastics (1978)		
Polyethylene (PE)	17,900	1–1.2
PVC	12,100	1–1.3
Polystyrene (PS)	6,850	1.1–1.2
ABS	1,770	2.5
Polypropylene (PP)	5,150	1.1
Polyamide (PA)	430	3.5
Polycarbonate (PC)	225	4.1
Acrylic (PMMA)	90	2.3
Thermosetting Plastics (1978)		
Phenol-Plastics (PF)	400	1.4–1.7
Polyester (UP)	1,500	1.8–2.4
Urethane-Foam-Plastics (PUR)	2,400	Approx 4
Aminio-Plastics (UF, MF)	2,500	1.1–2
Epoxy (EP)	300	6–17
Total Plastics	Approx 50,000	
Rubber Materials (1983)		
Natural Rubber (NR)	4,000	1
Synthetic Rubber	8,200	1.1
Total Rubber	12,200	

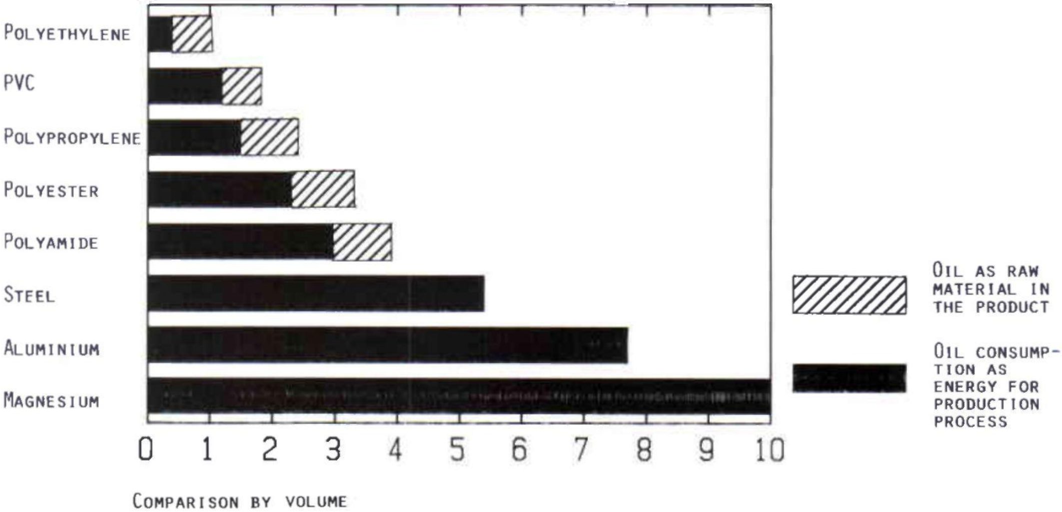

Fig. 2. The need for oil to produce different raw materials.

orthotics and is perhaps still the most produced orthopedic device made of thermoplastic material (Fig. 3). In addition thermoplastics are commonly used with metal joints to produce long-leg braces (knee-ankle-foot orthoses) and for the manufacture of spinal orthoses (Öberg, 1988).

During the 1970's, when new innovations in prosthetic sockets occurred more and more, thermoplastic materials were used instead of fibre-reinforced resins. Because of the properties of thermoplastic materials, the concept of flexible sockets could be introduced (Fig. 4). Another advantage of introducing thermoplastic materials in prosthetics was the possibility of making much lighter prostheses.

The concept of the ultralight below-knee prosthesis using polypropylene was developed at Moss Rehabilitation Hospital and at Rancho Los Amigos Hospital in USA (Quigley et al., 1977).

At Rancho Los Amigos Hospital, the evaluation of the ultralight prosthesis included measurement of oxygen consumption, comparing the difference between the ultralight prosthesis and the standard prosthesis in oxygen consumption per kg body weight per minute. The standard prosthesis required 21% more energy to use than the ultralight prosthesis. It should be noted that the standard prosthesis was twice as heavy as the ultralight one (Fig. 5).

Another clinical evaluation of an ultra-lightweight polypropylene below-knee prosthesis was completed at the National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde (Convery et al., 1986). The study included the comparative evaluation of 24 patients with a standard prosthesis and an ultralight prosthesis which, on the average, had a reduced weight of 30%. They found two evident conclusions from this study:

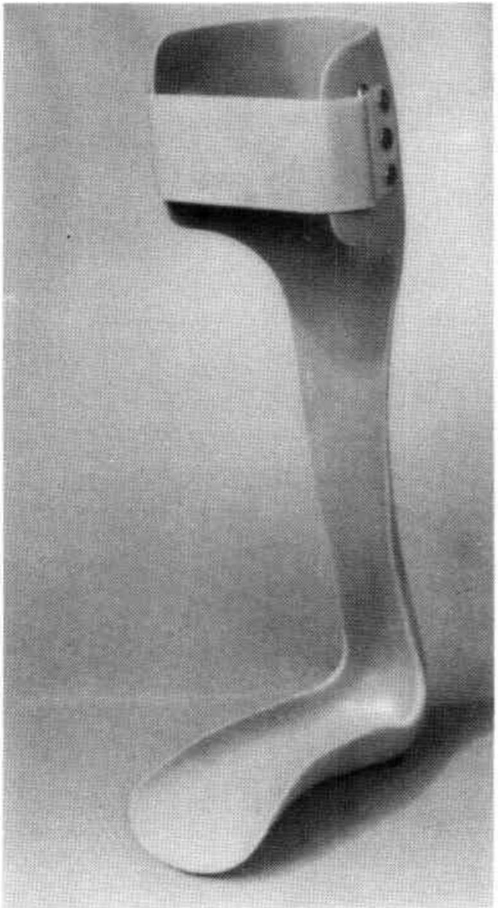

Fig. 3. Dropfoot brace (AFO) in a thermoplastic material.

Fig. 4. A flexible socket in thermoplastic with a rigid carbon fibre reinforced frame for an AK prosthesis.

- the amputees preferred the ultra-lightweight prosthesis
- the clinical team considered the ultra-lightweight prosthesis to be inferior to the resin-laminated one.

A review of orthopaedic technology in developing countries was carried out in 1988 by the author visiting sixteen different centres in Asia on behalf of WHO. A report on these visits was submitted to the WHO headquarters (Öberg, 1988).

Traditional western orthopaedic technology with, for example, laminated plastic sockets and wooden parts for the prosthesis structure were mostly observed. Aluminium and leather sockets were also utilized in a few centres. In an effort to impove effectiveness and quality, some centres were turning to the use of thermoplastics. Some centres in Africa already show good results in thermoplastic techniques for both prostheses and orthoses (Öberg and Goerdt, 1989).

For an inter-regional WHO meeting in Dakar, Senegal, centres throughout the developing world have been asked to give their view on the application of thermoplastic materials in orthotics and prosthetics in their own practice. Answers were obtained from fourteen different centres with almost comparable information which has been structured and set up in charts.

Six centres were from South America, six from Africa and finally only two from Asia. Looking at the results, it seems that they all are involved in the application of thermoplastics but it should be noted that all these centres, in varying amount, also are utilizing conventional techniques with polyester laminated sockets and wooden parts for prostheses as well as leather and steel for orthoses.

It is apparent from this review that the availability of thermoplastics around the world has increased. PVC and polyethylene was available in 93% of responding countries and polypropylene in 71% at the same time prices have decreased. Prices were regarded as low by 64% (9), medium by 29% (4) and high by 7% (1). The review is also a sign that the thermoplastic technology for these centres is fairly new as the complaints often indicated a lack of experience and equipment (Table 2). The technology therefore, still needs further development and also training and education is required for professional staff.

It is evident that there are considered to be numerous advantages in using thermoplastics in both prosthetics and orthotics when scanning the list (Table 3) recorded from the fourteen different centres.

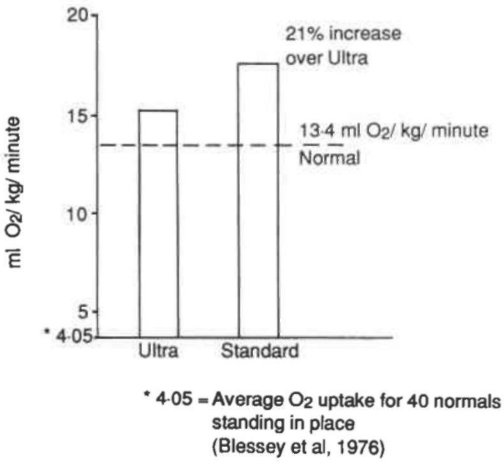

Fig. 5. Preliminary results of energy consumption (mlO_2/kg/min) when walking with BK prostheses (ultra-lightweight and Standard Trend from 4 patients, free cadence (Quigley et al., 1977).

Conclusions

It is to be concluded that appropriate materials in developing countries are not necessarily bamboo and leather or even wood.

When assessing materials, which would be appropriate for a certain developing country, major costs and benefits of the fitted appliances should be considered.

Table 2. Current Problems with Thermoplastics

High import restrictions	(4/14)
Heat from large surfaces (corsets)	(2/14)
Some skin irritations	(3/14)
Difficult to repair	(2/14)
Private exploitation	(3/14)
New technique with no experience	(6/14)

Table 3. The costs and benefits of Thermoplastics

Low weight	Good or better:
Durable	Fitting
Ease of fabrication	Function
Fast and efficient fabr	Comfort
Low cost materials	Cosmesis
Low cost appliances	Acceptance
Water resistance	Hygiene
Can be recycled	Tissue tolerance
Eaty to adjust	

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