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A Comparative Study of Fibre Composites and Thermoplastics as Rigid Components of Orthoses ⋆

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Abstract

The use of rigid materials to adequately support the joints and exert corrective forces that control the deformities of the bones is a key pre-requisite in prescribing custom-fit orthoses in rehabilitation treatment. Traditional orthotic materials are heavy in weight, bulky and completely unbreathable, which reduce the quality of life, comfort and satisfaction with the orthosis and result in poor patient compliance and even significant curve progression. The present study aims to explore the use of carbon fibre, fibreglass and fibreglass-carbon composites to develop an orthotic brace. Apart from the mechanical testing, the thermal discomfort properties and in-brace pressure with the use of traditional orthotic braces were also examined. Compared to traditional thermoplastic materials, the fibre composite materials have good resistance to breakage, more flexibility in bending with improved water vapour transmission, air permeability and thermal conductivity which advance orthosis use and wear comfort. An increase in the number of layers of composite materials increases the bending rigidity and also considerably augments the corrective forces. The corrective forces and/or support that control the deformity of joints or bones can therefore be adjusted by altering the number of layers of composites. The use of fibre composite materials in orthoses not only improves the prevailing problems of wear discomfort, but also facilitates the control of corrective forces, thus enhancing the quality of orthotic intervention.

Keywords: Orthosis; Composites; Fabrication; Mechanical; Thermal properties

1 Introduction

Orthoses and/or braces are commonly used for rehabilitation treatment and/or specific clinical interventions. They generally involve the use of rigid devices to stabilise, heal, or prevent injuries

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and deformities in weak joints or bones [1]. Nevertheless, orthoses are typically perceived as cumbersome, uncomfortable and mobility restricting, which impede the effectiveness and progression of orthotic treatment.

Amongst the various orthoses, the spinal orthotic is a popular custom-engineered brace used to exert optimal corrective forces onto strategic areas with respect to the specific needs of patients [2, 3]. The brace is conventionally made of thermoplastic materials, i.e. polypropylene (PP) and polyethylene (PE), forming a thick cage around the body. To prevent the progression of spinal deformities, it is recommended that the brace is worn for 18-23 hours a day until the child has completed growth (4-6 years) [4, 5]. Traditional spinal braces are bulky, heavy and uncomfortable, limit mobility, reduce ventilation and affect appearance, and consequently their acceptance and compliance with treatment. Peery et al. revealed that a 1 °C to 2 °C increase in skin temperature inside an orthosis could cause discomfort [6]. However, little attention has been paid to the study of the thermal comfort properties of orthotic materials. Proper evaluation of the thermal properties of orthotic materials in terms of water vapour transmission, air permeability and thermal conductivity will therefore provide insights with regard to the prevailing problems with thermal comfort and its importance in the use of orthoses.

With good strength, stiffness, rigidity, chemical stability, lightness in weight and outstanding fatigue characteristics, composites made of fibreglass and carbon fibre are largely used in the automotive industry and aerospace, as well as for naval structures and aircrafts [7, 8]. Carbon fibre and fibreglass in various woven or knitted structures and coated with a resin not only offer a high strength-to-weight ratio, but most importantly, hybrid composites can be moulded into desired shapes which are useful as biomaterials for custom-fit orthoses [9-12]. There are studies and numerous applications of carbon fibre or fibreglass composites in orthotics and prosthetics treatment, particularly for the lower limbs and foot biomechanics since the 1970s [13, 14]. The aim of the present study is to therefore investigate the potential use of fibre composites as the major means of support in retaining the corrective properties of orthoses for reducing cumbersomeness and improving ventilation so as to facilitate their practical use in normal activities of daily life and increase patient compliance. In considering the long duration of the treatment of spinal deformities and the associated psychological stress and impacts on children [15, 16], it is imperative to improve the wear comfort and the rate of patient compliance during the continuous use of spinal orthoses. The required properties of the support and practical use of a spinal orthosis, including tensile and bending behaviours, water vapour transmission, air permeability and thermal conductivity are examined in the fibreglass and carbon fibres composites, and compared with those of traditional PE and PP materials.

2 Experimental

2.1 Materials

In this study, 2 types of carbon fibre and 2 types of fibreglass sheet materials are sourced from the commercial market. The two carbon fibre sheet materials are made of carbon bundles. Each bundle consists of 3000 carbon filaments. CF2 has 7 picks/cm and 5 ends/cm while CF1 only has 4 picks/cm and 4 ends/cm (Table 1). In order to ensure that the carbon fibre and fibreglass sheets are suitable for orthoses, reinforcement with resin (which was first mixed with a hardener at a ratio of 5:1) would need to be carried out. A lightweight, thixotropic, pre-promoted resilient