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New ecological wood–plastic composite materials for scaphoid-type casting: Material properties and clinical evaluation

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Abstract

Introduction: Immobilisation of limbs using splints and casts is a common procedure in both conservative and operative treatments. The most common splint materials are plaster-of-Paris, fibreglass and polyester cast materials. Despite the advantages of increased strength and comfort using fibreglass and polyester cast materials, disadvantages due to toxic and harmful components, such as cyanites, resulting in asthmatic responses have also been reported.

Methods: A new ecologically friendly, wood–plastic composite casting material was evaluated in a prospective study of 67 operatively treated patients needing a post-operative scaphoid-type cast. Thirty-seven patients (26 females and 11 males, mean age 53 years) were treated with a cast made of WOODCAST® 2 mm and WOODCAST® Ribbon, and another 30 patients (19 females and 11 males, mean age 53 years) were treated with a cast made of WOODCAST® Soft and WOODCAST® Ribbon. The casts were either removable or non-removable.

Mechanical stiffness properties of cylindrical WOODCAST® materials were also tested using a testing machine (LLOYD LR30K, Lloyd Instruments, Southampton, UK).

Results: The cast material was easy to handle without gloves. The pre-heated self-adhesive materials became completely three-dimensional-mouldable and could easily be cut with scissors. The median time in the cast was 4 weeks. Fifty-six patients responded to a questionnaire: Out of 56 patients, 36 considered the cast to be very comfortable or comfortable, 11 were neutral and four did not answer the question. The mechanical testing showed that the novel WOODCAST® materials can be used in different kinds of casting.

Conclusion: The ecological wood–plastic composite materials represent sustainable development in the field of casting materials.

Keywords

Cast, ecological, wood, scaphoid

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Introduction

Immobilisation of limbs with splints and casts is a common procedure in both conservative and operative treatments. During the first half of the 1900s plaster-of-Paris was the most commonly used material.[1] In the 1950s, fibreglass tape bandages became more popular, due to their improved mechanical properties and reduced weight.[2]

Despite the advantages of increased strength, rigidity and comfort, fibreglass tape bandages or polyester cast tapes, which are also in common use, have disadvantages, as they contain such toxic and harmful components as cyanates. Skin contact during application of fibreglass may cause itching and redness. In animal studies, skin exposure to chemical allergens has been observed to elicit asthmatic responses.[3] Occupational asthma after long-term exposure to casts containing methylene diphenyldiisocyanate has also been reported.[4,5]

To improve the shortcomings of existing casting materials, a novel non-toxic, wood–plastic composite

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casting material for immobilisation of the extremities has been introduced by Onbone Oy, Helsinki, Finland. The casting material (WOODCAST®) is ecologically friendly and has free three-dimensional (3D) moulding properties. In a previous series that included 33 patients with a distal radius fracture who were treated with this wood–polymer composite material (WOODCAST® splint), patient satisfaction was high and the feedback from experienced orthopaedic technicians was excellent.[6]

The mechanical properties of the cast play a significant role in successful treatment. To obtain a stable immobilisation, the cast must be stiff and be able to sustain loads. However, an overly rigid structure may be cumbersome, uncomfortable for the patient and increase discomfort in the case of swelling of soft tissue. The aim of this study was to develop a new casting method to obtain good scaphoid-type casts using new materials from the WOODCAST family (WOODCAST® Ribbon, WOODCAST® Soft, WOODCAST® 2 mm). The stiffness properties of the new materials and the first clinical series of 67 patients treated with this thermoplastic material are presented.

Methods

WOODCAST® materials are composed of woodchips and a biodegradable thermoplastic polymer. The materials used in this study were the rigid WOODCAST 2 mm, the semi-rigid 2 mm WOODCAST® Soft material and the WOODCAST® Ribbon 4-cm wide casting tape with a thickness of 1.3 mm. Pre-heated to a temperature of 65°C in a heating device specially developed for heating the Woodcast® materials, the material becomes completely mouldable and self-adhesive. The material hardens during cooling and the cast becomes load-bearing within 5–15 min.

Sixty-seven operatively treated patients needing a post-operative scaphoid-type cast were asked to participate in this study. The main reason for the operative treatment was osteoarthritis in the region of the carpometacarpal joint of the thumb (41 patients), followed by rupture of the ulnar collateral ligament of the thumb (12 patients), pseudarthrosis of the scaphoid bone (six patients), instability or osteoarthritis of the metacarpal joint of the thumb (three patients), transection of tendons in the thumb (three patients) and fractures in the thumb (two patients). The operative treatment included removal of the trapezium bone, arthroplasty of the carpometacarpal bone of the thumb, ligament reconstruction, tendon suture and fracture treatment of bones. Post-operatively, the hand was covered with a large bandage and the upper extremity was immobilised for 1–3 weeks with a cast made of plaster-of-Paris. The patients were then seen at the outpatient department.

Thirty-seven patients (26 females and 11 males) with a mean age of 53 years were treated with a cast made of WOODCAST® 2 mm and WOODCAST® Ribbon (Cast-1-group). The casts were made by two experienced nurses who were instructed in how to use the new composite cast materials. According to the instructions of the surgeon, either a short cast leaving the radio-carpal joint free or a longer cast immobilising the radio-carpal joint was made. The casts were either removable (25 patients) or non-removable (12 patients).

Thirty patients (19 females and 11 males) with a mean age of 53 years were treated with a cast made of WOODCAST® Soft and WOODCAST® Ribbon (Cast-2-group). As in the first group, either a short cast leaving the radio-carpal joint free or a long cast was made. The casts were either removable (18 patients) or non-removable (12 patients) (Figure 1).

Due to the excellent moulding properties, padding was not used in about half of the casts in both groups. In those cases, a self-adhesive padding (Delta-Terry Net, BSN Medical Inc., Rutherford College, USA) was used, around the thumb or it partly covered the inside or the edges of the cast (Figure 2).

After applying the cast, the nurses responded to a questionnaire designed for the study. Parameters concerning the use of the composite cast, status of the skin and opinion of the patient were recorded using both open questions and rating scales. The follow-up was conducted according to the normal protocol of the hospital. During the study the patients were treated or examined at the outpatient department by orthopaedic surgeons or residents. After removal of the composite cast, the surgeons responded to another questionnaire. The following parameters were recorded: immobilisation time, conservative or operative treatment, change of the cast to another, mechanical properties of the cast, skin appearance or irritation caused by the cast, allergic reactions and subjective opinion of the patient. All parameters were collected in clinical report forms and transferred to a computerised database for detailed analyses.

This study was conducted in accordance with the latest version of the Declaration of Helsinki, applicable regulatory requirements, including the standards of the International Organization, and Finnish law and regulations. The study protocol was approved by the Ethics Committee of Helsinki University Central Hospital (HUCH) and authorised by the Operative Unit of HUCH. Written informed consent was obtained from all participants.

Mechanical testing

The mechanical stiffness properties of the WOODCAST® materials compared with Soft Cast

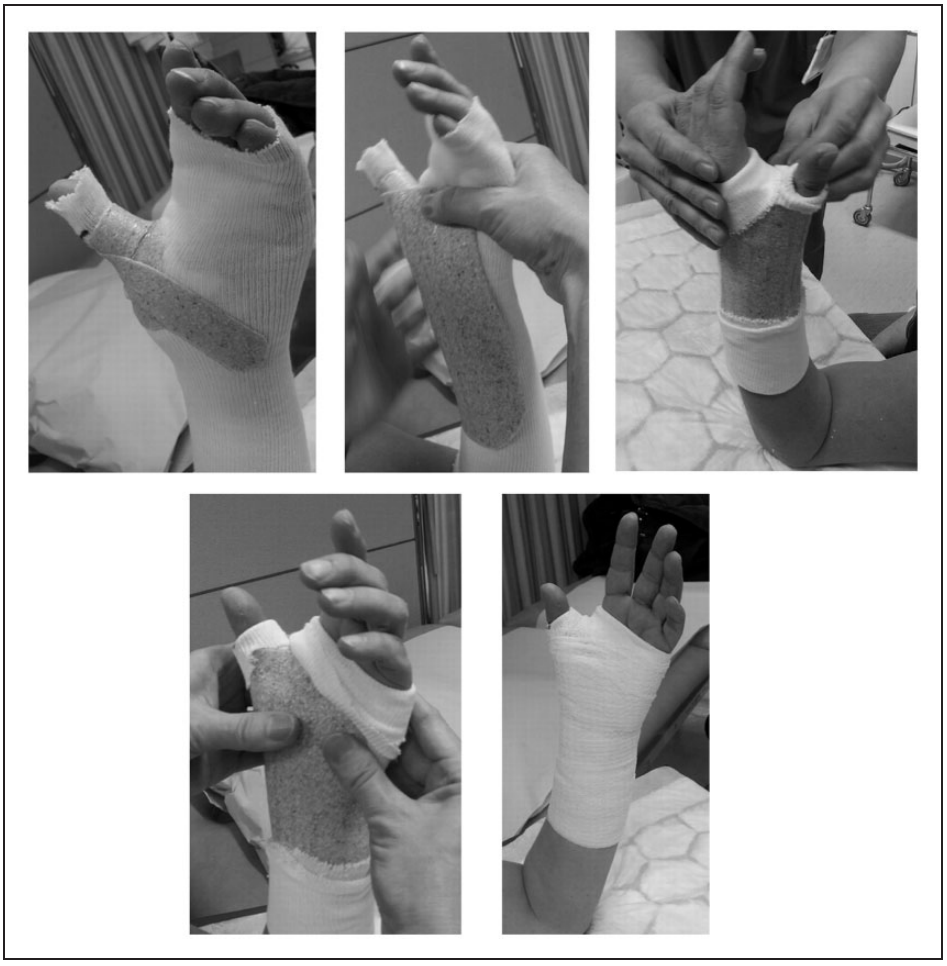

Figure 1. Applying a non-removable cast using WOODCAST® Soft and WOODCAST® Ribbon.

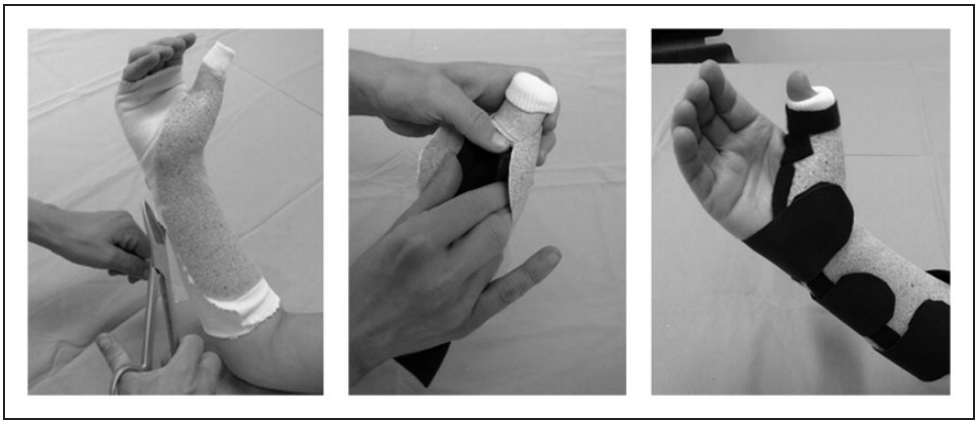

Figure 2. A removable cast made of woodcast® soft and woodcast® ribbon. A self-adhesive padding was used around the thumb or partly covering the inside or the edges of the cast.

(3M Health Care, Hamnfelddamm Neuss, Germany) were evaluated using a material testing machine (LLOYD LR30K, Lloyd Instruments, Southampton, UK) (Figure 3). A cylindrical test specimen was assessed to best correlate with the clinical use of the casting material. A series of cylinders with a diameter of 75 mm and a width of 80 mm were manufactured according to the instructions of the manufacturer.

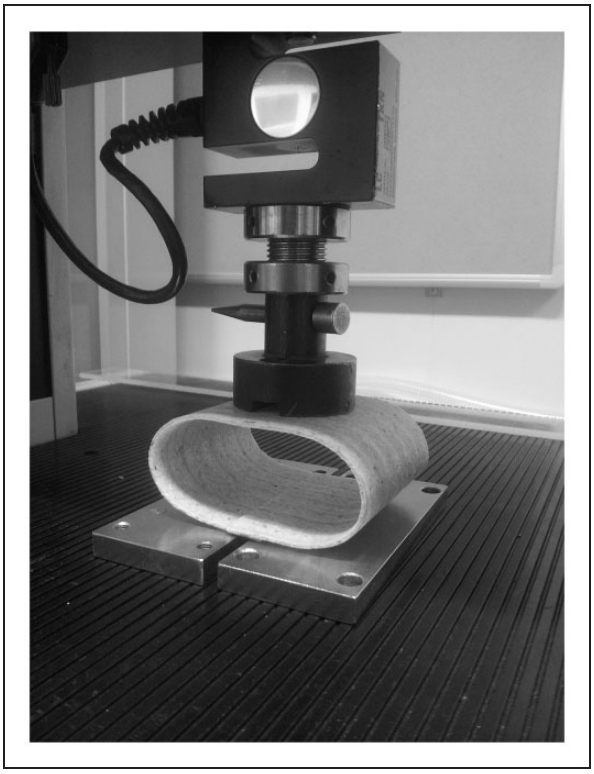

Figure 3. The material testing machine (lloyd lr30k, lloyd instruments, southampton, uk).

The cylinders of WOODCAST® 2 mm and WOODCAST® Soft were made of only one layer of casting material, whereas the WOODCAST® Ribbon and the Soft cast cylinders comprised three or five layers according to the manufacturers' instructions and common clinical practice. Compressing the cylinder with a constant cross-head speed of 20 mm/min, the functional stiffness was evaluated by measuring the compression force and the subsequent deflection. In each series, six cylinders were tested.

The functional stiffness values of the cylinders were calculated by using the following equation

$$\text{Functional stiffness} = \Delta F/\Delta y \text{ [N/mm]}$$

where:

ΔF = change in linear dynamic part of the graph [N]

y = corresponding change in deflection [mm]

For each series, the average and standard deviation of the stiffness were calculated. An independent two-tailed t-test was used to test the null hypothesis that there is no difference between the two materials. $P < 0.05$ indicates a significant difference between two materials.

Results

The mean time for applying the cast in the Cast-1-group was 15 min for the non-removable cast and 18 min for the removable cast, compared with 14 min and 18 min in the Cast-2-group. The nurses stated that preheating of the cast occurred without problems for 65 of 66 patients (data missing for one patient). During the moulding procedure, the cast material was easy to handle without gloves and could readily be shaped with scissors and reheated if necessary. The opinion of the nurses was in 63/66 of the cases (three answers missing) that they would favour future use of the composite cast.

The median time (range) using the cast was four (1–6) weeks in the Cast-1-group and four (1–10) weeks in the Cast-2-group. All casts except one had retained their shape and contour. In the Cast-1-group, the casts were changed during the follow-up in five patients: in three patients, to another WOODCAST® due to discomfort related to insufficient padding, and in two patients to another cast material for the same reason. In the Cast-2-group, the cast was changed from a non-removable to a removable cast in one patient, and a new cast was made for another patient to correct the position of the thumb. Fifty-six patients responded to the questionnaire. In the Cast-1-group, out of 26 patients 15 considered the cast to be very comfortable or comfortable and five were neutral. In the Cast-2-group, out of 30 patients 20 considered the cast to be very comfortable or comfortable and six were neutral. Four patients did not answer this question. Many patients commented on the nice lightweight feeling of the cast. Nine patients in total complained of compression or discomfort: five in the Cast-1-group and four in the Cast-2-group. This was mainly due to insufficient padding around the thumb. Eleven patients complained of an odour: five in the Cast-1-group and seven in the Cast-2-group.

Mechanical test

The results from the compression test, that is, the functional stiffness of different numbers of layers of casting material are shown in Table 1. Equal functional stiffness values were obtained for one layer of WOODCAST®Soft and five layers of Soft Cast ($p = 0.2$). Relative to five layers of Soft cast, approximately 10–15 times higher stiffness was observed for one layer of WOODCAST® 2 mm and two layers of WOODCAST® Ribbon.

Discussion

A clear trend in casting from bulky and totally rigid circular casts to more functional and removable casts

Table 1. Functional stiffness [N/mm] of different numbers of layers of casting materials.

Trade name	Material	Number of layers	Functional stiffness [N/mm]/SD
WOODCAST® 2 mm	Wood + Biodegradable polymer	1	9.7/0.5
WOODCAST® Soft	Wood + Biodegradable polymer	1	1.0/0.3
WOODCAST® Ribbon	Wood + Biodegradable polymer	1	1.9/0.2
			15.2/1.0
Soft Cast/3M	Fibreglass + polyurethane	3	0.6/0.1
		5	1.3/0.3

with tailored mechanical properties has been observed in clinical practice and the literature. An optimal functional cast has adequate stiffness to provide a secure immobilisation. However, some segments in a cast must be flexible to allow functional movements of muscles and removal of the cast.

In the literature, the definition of a scaphoid-type cast varies from an over the-elbow-cast to a cast leaving the thumb free and everything between. At our clinic, a scaphoid-type cast immobilising the radio-carpal and carpometacarpal joint of the thumb is frequently used in both conservative, for example, in treatment of scaphoid fractures, and post-operative treatments, for example, in treatment of osteoarthritis of the carpometacarpal joint of the thumb. Depending on the treatment either a removable or non-removable cast is made.

In this study, a new wood–plastic composite cast material for this purpose was used with excellent results. The material is easy to apply on the hand, due to the free 3D-moulding properties of the cast. If needed, the cast can be reheated during the application procedure, thus achieving optimal fitting and comfort for the patient. In some of the casts, a self-adhesive padding covering the cast was used. The padding can be attached to the cast already in the pre-heating device, making casting fast and easy. No gloves are needed and the contour of the cast can easily be formed with scissors to the desired size and shape.

Initially, the purpose of developing these cast materials was to overcome or eliminate some of the problems related to casting such as toxicity or limited 3D-moulding properties. According to Risk phrases (R-phrases) defined in Annex III of the European Union Directive 67/548/EEC, synthetic casts made of fibreglass or polyester are categorised as harmful and may cause sensitisation by inhalation, may irritate the eyes and respiratory system and may irritate or cause sensitisation by skin contact (R20, R36, R37, R38, R42, R43). Occupational asthma and skin irritation after exposure to methylene diphenyldiisocyanate-containing casts have been reported in several papers.[4,5] The 3D-moulding properties of the cast material are excellent. The cast can easily be formed on the arm, hand and fingers. The self-adhesive property, due to the warm polymer, enables a combined use of different thicknesses from the WOODCAST® family. In this study, two different combinations were used: a softer and a harder cast material in combination with a thin cast strip around the proximal phalange of the thumb. The casts were well accepted by most of the patients, and patient satisfaction was similar in both groups. Some of the patients complained of an odour. This has been noted and is for the softer cast thought to be related to the larger amount of polymer in the cast. Therefore, a new soft cast version with small incisions to enable respiration has been developed.

A by-product of medical treatment is an enormous amount of produced waste. Benefits of the WOODCAST® material lie on its non-toxicity for the patient, healthcare professionals and nature. After the material is removed it can be burned, thus representing sustainable development in the field of casting materials.

Conflict of interest

Both authors act as clinical advisors for the Onbone company.

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Ethical approval

Written consent was obtained from all patients. The study protocol was approved by the Helsinki University Central Hospital and the local Operative Ethics Committee of the Helsinki University Central Hospital, reference number: DNRO 37713/03/02/2011.

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