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Comparative study on stiffness properties of WOODCAST and conventional casting materials

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Eija Pirhonen¹, Antti Pärssinen¹ and Mika Pelto²

Abstract

Background and Aim: Plaster-of-Paris and synthetic materials (e.g. fibreglass) have been in clinical use as casting materials for decades. An innovative casting material, WOODCAST, brings interesting alternatives to the traditional materials. The aim of this study was to compare the stiffness properties of the WOODCAST material to traditional casting materials. **Technique:** In immobilization by casting, materials with variable stiffness properties are required. Ring stiffness of cylindrical samples correlates well with cast rigidity.

Discussion: For load-bearing structures, the use of the WOODCAST Splint is recommended as equally high stiffness was obtained with the WOODCAST Splint as was with fibreglass. The WOODCAST 2 mm product is optimal for structures where some elasticity is required, and WOODCAST Ribbon can be used in any WOODCAST structure where further reinforcement is needed. The results show that WOODCAST material can be used in replacing traditional casting materials used in extremity immobilization.

Clinical relevance

The mechanical properties of casting material play an important role in safe and effective fracture immobilization. Stiffness properties of the WOODCAST casting material and conventional materials – fibreglass and plaster-of-Paris – were analysed in this study. The WOODCAST Splint appears to compare favorably with traditional materials such as Scotchcast.

Keywords

Splint, cast, immobilization, casting, splinting, orthosis

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Background and Aim

Plaster-of-Paris (POP) has historically been the most widely used orthopaedic casting material, mainly because of its good moulding properties and low cost. However, POP has disadvantages such as poor mechanical and radiographic properties, long curing time and messy application. Since their introduction, polyurethane resin impregnated fibreglass materials have gained wide acceptance and are now widely used. Fibreglass casts have better strength, resistance to moisture and much shorter curing time.¹ However, the use of fibreglass still has some drawbacks such as poorer mouldability and the toxicity of the material.² The newly introduced WOODCAST casting materials (Onbone Oy, Helsinki, Finland) are composed of woodchips and biodegradable thermoplastic polymer. The WOODCAST material is currently available in 4- and 2-mm-thick sheets and as 4- and 8-cm-wide casting tapes with a thickness of 1.3 mm. The sales unit sizes of the products are shown in Table 1. The WOODCAST material is first heated to a

temperature of 65°C in the WOODCAST heating device; thereafter, the WOODCAST material becomes pliable and self-adhesive. When warm, any three-dimensional (3D) shapes can easily be contoured with this material. The material hardens when cooling and the cast or splint becomes load bearing within 5–15 min.³

Mechanical properties of the cast play a significant role in successful fracture treatment. In order to obtain stable immobilization, the cast has to be stiff and sustain loads. On the other hand, too rigid circular structures may be cumbersome, uncomfortable to the patient, introduce risks (e.g. in case of swelling of tissue) and in some cases also slow down

¹Onbone Oy, Helsinki, Finland

²Department of Biomedical Engineering, Tampere University of Technology, Tampere, Finland

Corresponding author:

Eija Pirhonen, Onbone Oy, Energiakatu 3, Helsinki, 33180, Finland.
 Email: eija.pirhonen@onbone.com

Table 1. Details of the materials tested and average ring stiffness values.

Trade name	Manufacturer	Size of sales units	Material	Ring stiffness average (standard deviations), kN/m ²
Cellona	Lohmann & Rauscher	8 cm × 2 m	Plaster-of-Paris	L6 = 166.4 (±31.5)
Scotchcast	3M	7.6 cm × 3.6 m	Fibreglass + polyurethane	L5 = 175.2 (±42.6) L4 = 80.8 (±4.4)
Soft Cast	3M	7.6 cm × 3.6 m	Fibreglass + polyurethane	L3 = 41.1 (±5.6) L5 = 4.6 (±1.0) L4 = 2.5 (±0.2) L3 = 0.8 (±0.2)
WOODCAST Splint	Onbone Oy	10/12.5/15 cm × 40 cm	Wood and biodegradable polymer	L1 = 154.4 (±28.1)
WOODCAST 2 mm	Onbone Oy	10/12.5/15 cm × 80 cm 14.5 cm × 34/80 cm	Wood and biodegradable polymer	L1 = 33.0 (±1.2)
WOODCAST Ribbon	Onbone Oy	4 cm × 5 m 8 cm × 7.5 m	Wood and biodegradable polymer + textile	L3 = 137.2 (±27.6) L2 = 60.6 (±2.8) L1 = 7.9 (±0.8)

Ln: number of layers.

the healing of the injury.⁴ Therefore, there is a need to find improved casting and splinting materials for clinical use.

The aim of this study was to compare the stiffness properties of the innovative WOODCAST material and the clinically used POP and fibreglass materials. Furthermore, the fracture behaviour of the casting materials was observed during the tests.

Technique

In order to compare the functional stiffness properties of various casting concepts, the ring stiffness was assessed to best correlate the real clinical situation and give a standardized value for the stiffness of various casting concepts. The principles of standard ISO 9969:2007 were followed in the test set up for the materials, as shown in Table 1. A series of cylindrical test specimens of approximately 75 mm diameter and 80 mm length were manufactured according to the instructions from the manufacturer. With tape casting materials, namely Scotchcast™, Soft Cast, Cellona® and WOODCAST Ribbon, the number of layers sampled was varied according to the instructions from the manufacturer and common practices in clinics.^{5,6} With the WOODCAST Splint and WOODCAST 2 mm products, only one layer of material was used.

The diameter and length of each cylinder were measured with calipers (an average of three measurements was used with each specimen). The ring stiffness was measured by recording the force as a function of deflection while compressing the cylinder at a constant cross-head speed (20 mm/min) at vertical direction, as shown in Figure 1(a). Loading of the specimen was continued until

50% deflection of the original diameter of the cylinder was achieved (see Figure 1(b)). A plot of force versus deflection was generated using a materials testing machine (LLOYD LR30K; Lloyd instruments, Southampton, UK) with 1 kN load cell for each specimen. In each series, six samples were tested. The ring stiffness is calculated as a function of the force necessary to produce a 3% diametric deflection of the cylinder. With the Cellona material, a 1% deflection point was used to calculate ring stiffness due to fracture of the material prior to the 3% deflection point.

The ring stiffness values of the cylinders were calculated using the following equation (ISO 9969:2007)

$$S = \left(0.0186 + 0.025 \left(\frac{y}{d_i} \right) \right) \left(\frac{F}{Ly} \right) \times 10^6 \text{ (kN/m}^2\text{)}$$

where *F* is the force that corresponds to a 3.0% deflection (kN), *L* is length of the test piece (mm), *d_i* is inner diameter of the ring (mm) and *y* is the deflection that corresponds to a 3.0% deflection (mm).

For each series, averages and standard deviations were calculated. An independent paired two-tailed t-test was used to test the hypothesis that there is a difference between two materials. A value of *P* < 0.05 indicates a statistically significant difference between the two materials.

Discussion

In Table 1, the details of tested casting materials as well as obtained ring stiffness results are shown. *Ln* refers to number of layers used in specific circular structures.

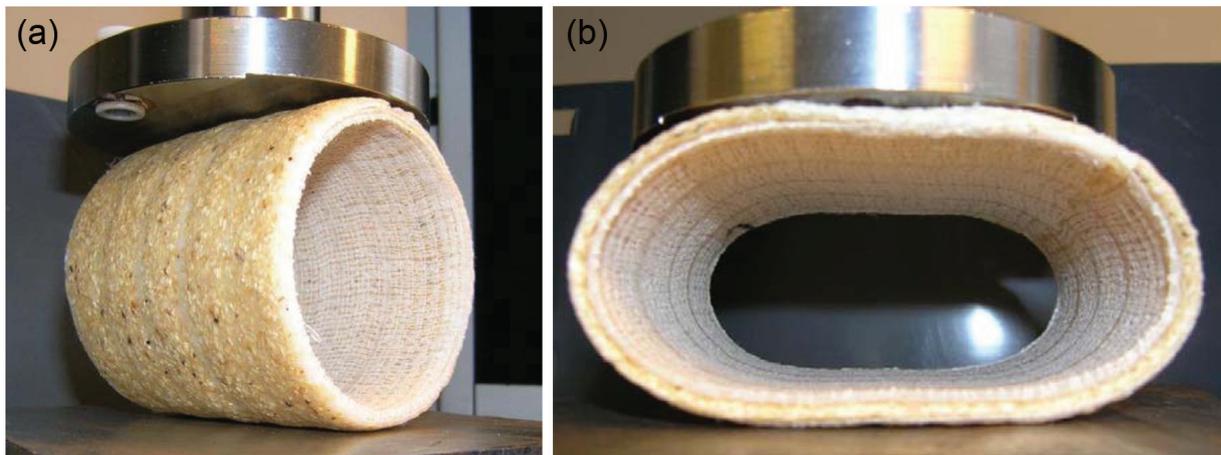


Figure 1. (a) Compression test set up with WOODCAST Ribbon test specimen being tested and (b) WOODCAST Ribbon test specimen after compression to final deflection point (50% of diameter).

There is a clear trend seen in the literature and clinical practices that the bulky and totally rigid circular casts are more rarely used, and functional removable casts with tailored mechanical properties are taking over. Rigid circumferential casts have been reported to have more severe complications relating to limited capacity to accommodate ongoing limb swelling that may cause pressure sores, increased tissue pressure and neurovascular compromise.⁷ In addition to considerable economic savings and improved physical functioning, lower pain scores and better cast satisfaction have been reported by patients with functional casts when compared to traditional rigid circular casts.⁸⁻¹⁰

In relation to the optimal structure of functional cast, it has to have adequate stiffness and provide ‘three-point support’ to provide secure immobilization for the fracture site. On the other hand, there are segments in a cast where the structure has to be flexible to allow functional movements of muscles or removal of cast.

Based on the test results, similar high stiffness values were obtained with the WOODCAST Splint and Scotchcast with five layers of tape, which is graded to be adequate for load-bearing structures.⁵ Comparable high stiffness values were also obtained with WOODCAST Ribbon 3L and Cellona 6L. Any pair in this group (WOODCAST Splint, Scotchcast 5L, WOODCAST Ribbon 3L and Cellona 6L) did not indicate significant difference between them in terms of stiffness. Statistical analyses indicate significant differences between the rest of the tested group pairs.

Scotchcast 3L and WOODCAST 2 mm have very similar force versus deflection profile (not shown), though the stiffness of Scotchcast 3L is slightly higher. WOODCAST 2 mm is optimal in structures where some elasticity is required; however, further rigidity in desired parts of cast can be obtained by an extra layer of material, for example, using a strip of WOODCAST Ribbon. Soft Cast material owes clearly the lowest stiffness values as expected.

All the test samples except Cellona and Scotchcast L5 were able to resist the compression up to 50% of diameter of test cylinders without any fractures in the materials. However, in Scotchcast L5 samples, structural fractures occurred only after ~33% deformation, so it does not have any clinical relevance, whereas Cellona samples fractured already after ~2% deflection. Therefore, with Cellona material, the 1% deflection stiffness is used in the calculation of ring stiffness. In Cellona cylinders, small fractures in the gypsum were observed in both sides of the cylinders throughout the specimen. However, the inner textile layers inside the structure enabled the samples to resist further compressive loading, and no total failure of the specimen occurred. Due to the brittle nature of POP, there is no possibility that the POP cast could be removed without it being broken.

Soft Cast material performed elastically throughout the test (up to deflection of 50% of diameter), and all Soft Cast cylinders totally recovered their circular shape after tests. The circular shape of WOODCAST Ribbon, WOODCAST Splint and WOODCAST 2 mm samples and Scotchcast L3 and L4 mostly recovered, and no visual damage was observed in the tested samples. In none of the tested materials, there were no signs of delamination between the layers.

With POP and fibreglass materials, the hardening occurs due to the activation of gypsum or polyurethane by water, and the cast has to be formed ready without delay. There is no possibility to add reinforcing layers or make any modification to the shape of these casts after primary hardening. With the WOODCAST material, the cast can be tailored layer-by-layer if appropriate, as the material is self-adhesive when warm. The WOODCAST material becomes highly pliable when heated and allows the fine-tuning of the shape of the cast for up to 5 min, which is much more than with any other casting material currently in use. Moreover, any further modifications are easily done using a heat gun to heat the material in the area needing further contouring or

