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PROPERTIES OF A HYBRID PLASTER-FIBREGLASS CAST

Mark N. Charles, MD; David Yen, MD

OBJECTIVE: To examine the suitability of a plaster-fibreglass hybrid cast for orthopedic applications, comparing them to plaster of Paris (POP) and fibreglass constructs.

METHOD: Groups of 10 standardized hybrid, POP and fibreglass casts were studied. An Instron servo-hydraulic system was used to test the casts in 3-point bending and shear.

OUTCOME MEASURES: Strength, stiffness, weight, thickness and cost of the 3 types of cast, and shear strength at the interface between the POP and fibreglass in the hybrid casts.

RESULTS: The hybrid casts were twice as strong as the POP constructs, were stiffer and weighed 14% less but were thicker and cost 2.5 times more. They were almost as strong as and less than half the cost of the fibreglass constructs but were thicker, not as stiff, and weighed 42% more. The shear strength of the POP–fibreglass interface in the hybrid casts was higher than the 3-point bending strength of this construct by a factor of 3.

CONCLUSIONS: Plaster-fibreglass hybrid casts should be considered for orthopedic use on the basis of their strength, stiffness, weight and cost, combined with their acknowledged advantages of good moulding ability and water resistance.

OBJECTIF : Déterminer si un plâtre hybride en plâtre et fibre de verre convient pour des applications orthopédiques et le comparer aux appareils en plâtre de Paris (PDP) et en fibre de verre.

MÉTHODE : On a étudié des groupes de dix plâtres normalisés hybrides, en PDP et en fibre de verre. On a utilisé un système servohydraulique Instron pour soumettre les plâtres à des épreuves de courbure et de déchirement à trois points.

MESURES DES RÉSULTATS : Résistance, rigidité, poids, épaisseur et coût des trois types de plâtre et résistance au déchirement à l'interface entre le PDP et le fibre de verre dans les plâtres hybrides.

RÉSULTATS : Les plâtres hybrides étaient deux fois plus résistants que les appareils en PDP, étaient plus rigides et pesaient 14 % de moins, mais ils étaient plus épais et coûtaient 2,5 fois plus cher. Ils étaient presque aussi résistants que les appareils en fibre de verre et coûtaient moins de la moitié, mais ils étaient plus épais, n'étaient pas aussi résistants et pesaient 42 % de plus. La résistance au déchirement de l'interface PDP-fibre de verre des plâtres hybrides était plus de trois fois plus élevée que la résistance à la courbure en trois points de cet appareil.

CONCLUSIONS : Il faudrait envisager les plâtres hybrides en plâtre de Paris et fibre de verre en orthopédie à cause de leur résistance, de leur rigidité, de leur poids et de leur coût, sans oublier leurs avantages reconnus que sont la malléabilité et la résistance à l'eau.

Casting is the most common form of external splinting and is used for a wide array of bone and soft-tissue injuries. The function of the cast in this context is to immobilize and protect, especially to minimize motion across a fracture site.[1] The universal acceptance of plaster of Paris (POP) as a casting material is largely owing to its low cost and ease of moulding. The disadvantages of POP include long setting times, messy application, low strength:weight ratio, and high water permeability.[2] Synthetic casting materials such as fibreglass (fibres impregnated with a polyurethane-based resin) are feasible alternatives and are gaining popularity. They are stronger, lighter

From the Division of Orthopaedics, Department of Surgery, Queen's University, Kingston, Ont.

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Correspondence to: *Dr. David Yen, Apps Research Centre, Kingston General Hospital, 76 Stuart St., Kingston ON K7L 2V7; fax 613 549-2529, yend@kgh.kari.net*

and more radiolucent, and they may facilitate weight bearing in less time than traditional plaster-based materials.[3,4] Further, fibreglass casts are at least twice as strong as those based on POP.[1] However, the relatively high cost of fibreglass restricts the use of these casts. The rationale for using hybrid casts is to provide the ready moulding capability of POP close to the patient's skin and the water resistance of fibreglass externally. Also, there are potential cost savings relative to all fibreglass constructs.

The purpose of this study was to examine various additional properties of a hybrid cast that might have an impact on their utility in orthopedic practice. We rationalized that the hybrid's strength, stiffness, weight, thickness and cost would be intermediate between the POP and fibreglass constructs, but we wanted to verify and quantify this. In addition, the hybrid introduced the variable of a POP–fibreglass interface, which we wanted to test for stability.

Materials and methods

The plaster used was Gypsona LPL-4 (Smith Nephew, Lachine, Que.) and the fibreglass was Dynacast XR (Smith Nephew).

Cylindrical casts were formed by wrapping 10-cm wide rolls of plaster around a polyvinyl chloride (PVC) pipe-former (10 cm diameter, 46 cm long). Three layers of cast material were applied one immediately after another to facilitate bonding in conformity with standard clinical practice and following the manufacturer's guidelines.

The hybrid casts consisted of 2 inner layers of POP and a single outer fibreglass layer. The fibreglass layer was applied to the POP layers while they were still wet, to facilitate bonding. In the POP casts, the final layer was smoothed by rubbing which entails some loss of material. By contrast, in the hybrid casts there is no smoothing of the POP layers, so that the final thickness was greater than the POP casts (Table I).

After application of all 3 layers, each cast was allowed to dry for 24 hours before the PVC pipe-former was removed. Then an additional 48 hours was allowed for full drying before weighing, measuring the thickness and mechanical testing. Each cast's thickness was measured at both ends with calipers, then the 2 values were averaged to determine the given cast's thickness. The location of the measurement site at each end of the cast was selected at random.

Ten examples of each type of cast were tested with an Instron Model 1122 (Instron, Canton, Mass.) servohydrolic system to apply a 3-point bending load. All casts were loaded at a constant rate of 10 mm/min. The ends of the casts were supported on wooden blocks that were shaped with concavities matching the curvature of the casts. The Instron applied a load perpendicular to the long axis in the middle of the cast through a wooden block shaped like an inverted "V."

The signal from the Instron load cell was amplified, transduced and traced on an Instron A 1030 x-y recorder. Cast failure was described as the point on the load–displacement curve where deviation from linear behaviour first occurred.

A further 10 hybrid casts were used to measure the strength of the POP–fibreglass interface in shear using standard mechanical engineering technique.[5] Specifically, all of the casts were supported by an internal PVC pipe-former that had been divided along its length into equal thirds. Testing was by application of a load perpendicular to the long axis of the cylinder. The load was applied centrally with the ends of the cast immobilized to create a shearing force at the POP–fibreglass interface. Shear failure was determined by the point on the load–displacement tracing where deviation from linear behaviour first occurred.

The data were analysed by analysis of covariance (ANCOVA) to compare the 3 groups of casts, taking into account the differences in thickness between them.

Table I

Properties of the 3 Types of Cast*

	Cast type					
	Plaster of Paris		Fibreglass		Hybrid	
Property	Mean (and SD)	95% CI†	Mean (and SD)	95% CI	Mean (and SD)	95% CI
Weight, g	341 (18)		206 (20)		297 (11)	
Thickness, mm	3.9 (0.4)		3.5 (0.4)		5.4 (0.9)	
Bend strength, N	313 (64)	236–405	880 (158)	798–993	711 (118)	570–805
Shear strength, N	Not tested		Not tested		2421 (222)	
Young's modulus	36 (9)	28–52	166 (29)	159–187	60 (10)	32–66

*Data are the means (and standard deviations) from tests of 10 samples in each case.
†95% confidence interval using analysis of covariance.

Results

Failure in 3-point bending invariably occurred on the compression surface. Bending failure in the fibreglass group was of a plastic deformation pattern whereas in the POP, it was brittle in nature. The failure pattern in the hybrid group was a combination of those of each of its constituent ma-

terials; namely plastic deformation of the fibreglass as it accepted the initial load, followed by brittle failure of the underlying POP.

Statistically significant differences were noted in the bending strengths of the 3 types of cast, with the fibreglass being stronger than the hybrid cast, which was stronger than the POP cast. The shear strength at the POP–fibreglass interface of the hybrid casts was more than 3 times greater than the strength of these casts under 3-point bending loads. Consistent with this standard testing technique for shear strength, the fibreglass and POP constituents of the hybrid series of casts consistently separated at the points located directly over the sectioned PVC pipe-former. The fibreglass casts had the greatest stiffness and the POP the least, with the hybrid in between.

The hybrid casts were wider in cross-sectional thickness than the fibreglass as well as the POP series. They were intermediate in weight when compared with the POP and fibreglass types, weighing 42% more than the fibreglass but 14% less than the POP constructs. The material cost of each construct was calculated on the basis of 3 rolls of material per cast. The costs were: POP $4.11; fibreglass $22.23; hybrid $10.15. Therefore, the hybrid was about 2.5 times the cost of the POP, but less than half the cost of fibreglass.

Discussion

The hybrid casts were wider in cross-sectional thickness than the fibreglass and the POP casts. The finding in the latter was unexpected and found to be owing to the material lost when the outer layer of plaster in the POP casts was smoothed out.

The 3-point bending model has been shown to be appropriate for the objective comparison of different casting materials.[6] It is clear from this study that casts containing fibreglass were much stronger in 3-point bending than the POP casts. Although this may be primarily ascribed to the superior mechanical strength of fibreglass, it is not immediately clear why the single outer layer of fibreglass in the hybrid casts should confer such an increment of strength. The reason may be that since the modulus of elasticity of fibreglass is greater than that of POP, in the hybrid casts, the outer fibreglass coat sustains less deformation at a specified load than its plain POP counterpart. The effect would be to shield the underlying POP layers in the hybrid casts thus enhancing the their overall strength. It is true that the hybrid casts were wider in cross-sectional thickness than the plain POP casts (Table I) and this attribute would make them stronger.[7] However, we have calculated using ANCOVA, which takes into account the thickness covariate between the 3 groups, that despite the difference in thickness, there was a statistically significant difference in strength between the groups. Further, considering all the types of casts, the strength correlated with the fibreglass content of the cast rather than its thickness.

The ability to control motion at the fracture site is a function of both a cast's breaking point (strength) and its ability to resist deformation (stiffness). The fibreglass casts were the most stiff, the POP the least, and the hybrid in between.

The critical strength and stiffness of a cast is a clinical question without a defined numeric value. However, POP casts are the standard and therefore included as a comparison group in this mechanical study. The study results show that hybrid casts exceed the strength and stiffness of the POP casts; therefore, it is possible that a thinner hybrid with concomitant further reductions in cost and weight will maintain clinically acceptable stiffness and strength.

Apart from their advantage over POP in terms of bend strength and stiffness, the hybrid casts were notable for the high shear strength between their composite layers of POP and fibreglass. We believe that this property augers well for long service with a low incidence of failure due to interfacial delamination.

The practicality of the hybrid cast is also favoured by cost and weight factors: it is clearly superior to fibreglass in terms of cost and to plain POP in terms of weight, while not exacting a large penalty in cost.

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