EVALUATION OF THE MECHANICAL PROPERTIES OF PLASTER BANDAGES USED FOR ORTHOSIS MANUFACTURE, MARKETED BY THREE DIFFERENT MANUFACTURERS

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SUMMARY

Mechanical tests have been performed in plaster bandages used in orthosis supplied by three different manufacturers. For this, bodies of evidence (BOEs) were made with plates and cylinders shapes. BOEs were submitted to two kinds of mechanical assays: for the plate group, a flexion assay was performed at three points, and, for the cylinder group, a compression assay was performed. Mechanical assays were performed on the Universal Assay Machine EMIC®.
Three mechanical properties were assessed after assays: maximum limit load, proportional limit load and stiffness. Results show that a manufacturer was superior over the others for the properties assessed.

Keywords: Calcium Sulfate, Physical properties; Orthotic devices.

INTRODUCTION

Plaster cast still remains as the most used material for orthosis manufacturing, being of great value for health area, particularly for hand therapists.

The use of orthosis is an indispensable part of rehabilitation. There are several models and materials indicated to certain kinds of diseases and patients. Thus, their manufacturing is delivered in a customized way, considering many factors, such as physiopathology, joint biomechanics, function and patients' needs(1). According to Wytch et al.(2), the plaster cast is the most widely used material for orthosis manufacturing due to its good modeling properties and to its low cost.

Orthotic therapy is one of the most effective ideas to gain passive motion in stiff joints, fostering a gradual rearrangement or the growth of pericapsular structures and adherences elongation(3). For Tribuzi(4), the use of cast is very efficient, particularly for static serial orthosis manufacturing.

Wytch et al.(2) found in their study that the incidence of broken plastered orthosis is a matter of concern. Thus, knowing materials properties and manipulation techniques is of major importance to orthosis and prosthesis manufacturing(1).

The objective of this study was to evaluate and compare the mechanical properties of bodies of evidence (BoEs) manufactured with plastered bandages by three different manufacturers.

MATERIALS AND METHODS

The material selected for the study was a plaster cast (*POP = Plaster of Paris*), as a fast-dry plaster bandage,

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Study developed at the Department of Biomechanics, Medicine and Locomotive Apparatus Rehabilitation, Ribeirão Preto Medical College, University of São Paulo

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100 mm wide, supplied by different manufacturers: A (Cremer®), B (Medi House®) and C (Polar Fix®).

Bodies of Evidence (BoEs) were made and divided into two groups: plates and cylinders. BoEs were made by following the procedures as described in literature(2,5,6,7), simulating clinical application.

For performing standardized BoEs, the development of a matrix specific to each group was required. Those matrixes were built at the Precision Office at the University of São Paulo (USP) campus, Ribeirão Preto unit, after several preliminary studies (Figures 1, 2, and 3).

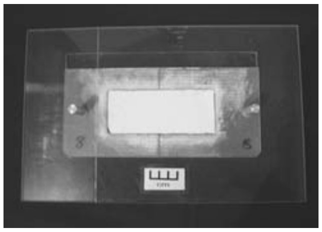


Figure 1 – *Matrix with BoE (plate)*

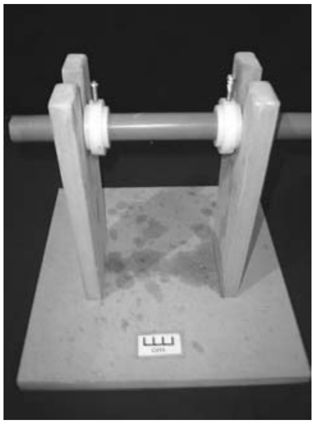


Figure 2 – *Matrix for cylinder group*

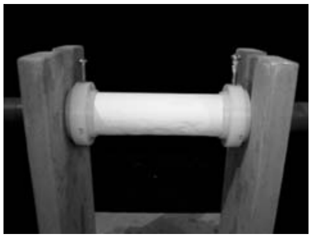


Figure 3 – *Matrix with BoE (cylinder)*

Two international technical rules were used (ASTM - American Society for Testing and Materials) which helped for study standardization(8,9). Aspects such as time of plaster bandage immersion in water (performed by only one researcher) and time for BoEs to dry before assays (72 hours) were also considered as essential to standardization.

In the plate group, BoEs were made in 120 x 47 mm and in the cylinder group, in 100 mm high and inner diameter of 25 mm. The number of plaster bandage layers was set as 8, which ended at an approximate thickness of 2.8 mm for plate group and of 33 mm outer diameter for cylinder group. Fifteen BoEs were made to each group, with 5 being excluded due to weight, considering the interval "Average ± Standard Deviation", reaching the final number of 10 (Figures 4 and 5).

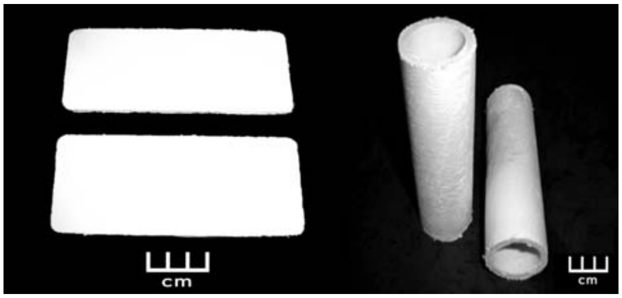


Figure 4 – *Bodies of Evidence*

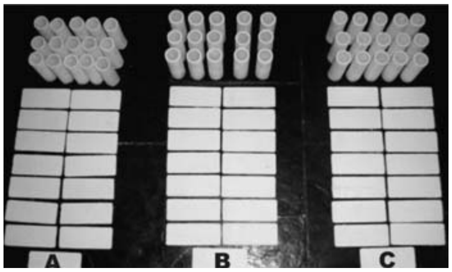


Figure 5 - *Manufacturers A, B, and C.*

BoEs were weighted by using a precision scale, Marte® brand, from the Laboratory of Bioengineering, Ribeirão Preto Medical College (FMRP) - USP.

Room temperature and air humidity were monitored during the period of manufacturing until mechanical assays. For that procedure, a digital thermal hygrometer (Hygrotherm) TFA® brand was used.

Flexion assays on three points and compression assays were performed for plate and cylinder groups, respectively . For performing the assays, an universal assay machine EMIC® brand (DL 10,000) was used equipped with a load cell of 500 N (flexion assay) and 2,000 N (compression assay), from the Laboratory of Bioengineering, FMRP-USP (Figures 6 and 7). That assay machine is attached to a computer, which, through TESC 1.13® software, provides the "load x deflection" graphs related to assays, in real time. The speed for both kinds of assays was 10 mm/min.

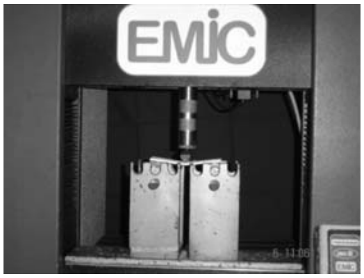


Figure 6 – *Flexion assay on 3 points (plates).*

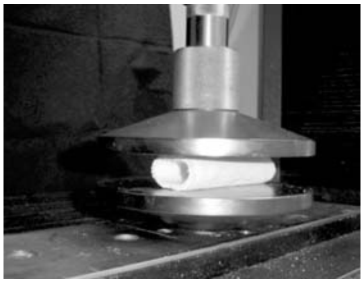


Figure 7 – *Compression assay (cylinders).*

The mechanical properties assessed were maximum load, load at proportionality threshold, and stiffness. Data were analyzed by using the average among the values for each property.

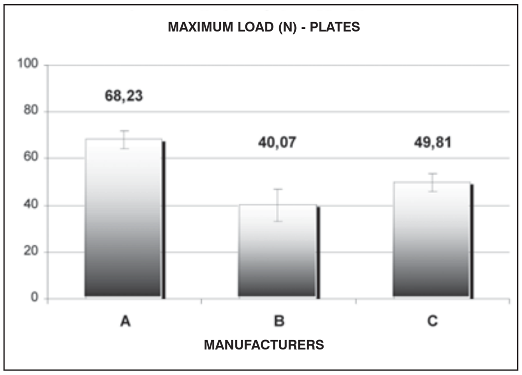
For statistical analysis purposes, data were first submitted to KOLMOGOROV and SMIRNOV test, and then the ANOVA (simultaneous analysis) and TUKEY-KRAMER (comparative analysis) tests were applied.

RESULTS

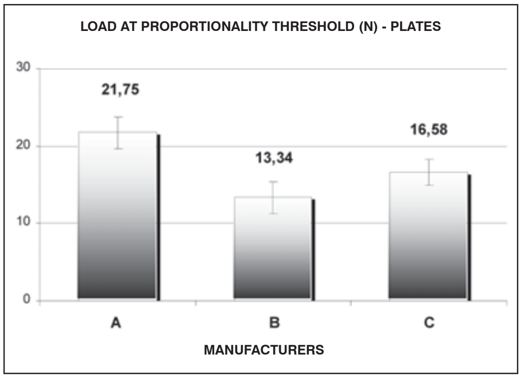
During the period between BoEs building and the completion of assays, room temperature ranged from 24 to 30° C and the air relative humidity was 36 – 64%.

All values showed a normal distribution at KOLMOGOROV and SMIRNOV test and a significant difference at ANOVA ($p < 0.05$), except for the stiffness property in cylinder group ($p > 0.05$).

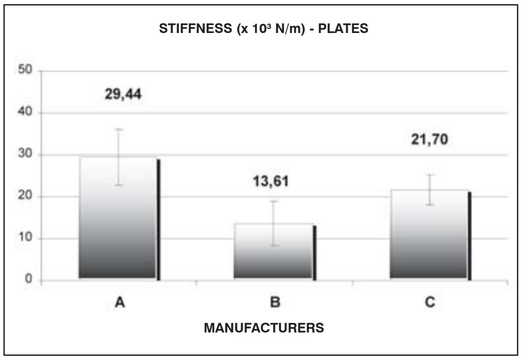
For the plate group, regarding maximum load property, the results were as follows: “A” brand achieved an average of (68.23 ± 3.76)N, “B” brand (40.07 ± 6.97)N and “C” brand (49.81 ± 3.88)N. For load at proportionality threshold property, the values for brands A, B and C were, respectively: (21.75 ± 2.07)N, (13.34 ± 2.04)N and (16.58 ± 1.66)N. Values for stiffness property were: (22.44 ± 6.68) x 10^3 N/m for brand A; (13.61 ± 5.24) x 10^3 N/m for brand B, and; (21.70 ± 3.66) x 10^3 N/m for brand C (Graphs 1, 2 and 3).



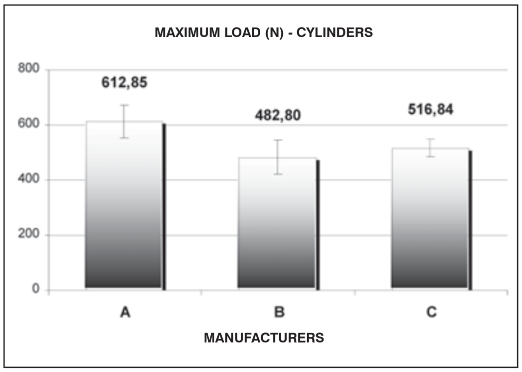
Graph 1 – *Average values for maximum load (N), plates group. TUKEY-KRAMER: AxB, AxC and BxC ($p < 0.001$).*



Graph 2 – *Average values for load at proportionality threshold (N), plates group. TUKEY-KRAMER: AxB and AxC ($p < 0.001$); BxC ($p < 0.01$).*



Graph 3 – *Average values for stiffness (x 10^3 N/m), plates group. TUKEY-KRAMER: AxB ($p < 0.001$); AxC and BxC ($p < 0.01$).*



Graph 4 – *Average values for maximum load (N), cylinders group. TUKEY-KRAMER: AxB and AxC ($p < 0.001$).*

In cylinder group, for maximum load property, the results were as follows: (612.85 ± 58.61)N for brand A; (482.80 ± 60.54)N for brand B, and; (516.84 ± 32.04)N for brand C. Concerning the load at proportionality threshold property, values for brands A, B, and C were, respectively: (312.10 ± 40.80)N, (266.17 ± 25.31)N and (327.38 ± 30.36)N. And, for stiffness property, values were: (457.44 ± 225.60) x 10^3 N/m for brand A; (513.01 ± 136.92) x 10^3 N/m for brand B, and; (455.80 ± 97.66) x 10^3 N/m for brand C (Graphs 4, 5 and 6).

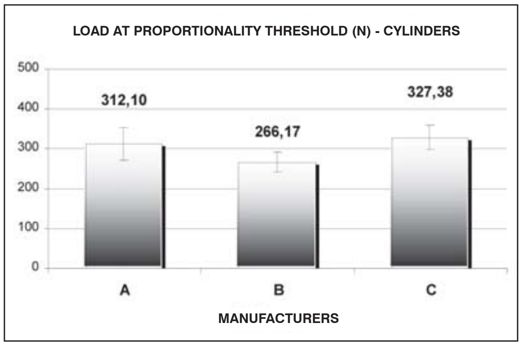
DISCUSSION

Currently, the materials most used for orthosis manufacturing are the cast (plastered bandage type), and the low-temperature thermoplastics. Despite the advantages of using plaster casts (low cost, easy molding and application), there are some disadvantages to be considered, such as, for example, short durability, heaviness, and difficult cleaning. Furthermore, the cast is intended for temporary and single use.

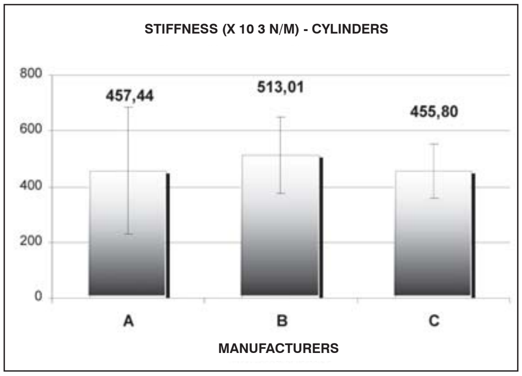
Making BoEs of plastered bandages is a delicate and detailed process. One of the major aspects of this study was the matrix building for each group. Those matrixes, composed of several pieces, provide great homogeneity between samples.

Most of the studies existing

in literature(2,5,6,7) compare mechanical properties of plaster BoEs to those made of other materials, differing only by the number of layers. Within those studies, there is no standardization of BoEs' dimensions, with each author describing his/ her own method.



Graph 5 – *Average values for load at proportionality threshold (N), cylinders group. TUKEY-KRAMER: AxB ($p < 0.05$) and BxC ($p < 0.001$).*



Graph 6 – *Average values for stiffness (x10^3 N/m), cylinders group. No significant difference ($p > 0.05$).*

In the present study, our findings were considered as relevant, with a statistical difference being evidenced for all properties assessed, except for stiffness in the cylinder group. For all properties, "A" manufacturer was superior to the others, except for load at proportionality threshold in the cylinder group, where the manufacturer "C" was superior.

In order to foster adherences elongation and the growth of pericapsular structures, plaster orthosis are molded in a position promoting tension on involved structures, also receiving a load from those structures. Thus, there is a major need to manufacture plastered orthosis with a high degree of stiffness.

Therefore, many factors must be considered before selecting a given manufacturer to make plastered orthosis.

From this study, and using a previously determined manufacturer, further studies must be conducted aiming to compare different numbers of plastered bandage layers for producing BoEs, targeting the evaluation of mechanical properties differences.

CONCLUSION

Based on the results, we concluded that the manufacturer "A" was superior to the others concerning the assessed properties. Furthermore, when aspects such as material handling and workability were taken into account, that manufacturer was also considered significantly superior.

The manufacturer C has also showed superior results when compared to manufacturer B.

REFERENCES

1. Kogler GF. Materials and tecnology. In: Lusardi MM, Nielsen CC. Orthotics and prosthetics in rehabilitation. Woburn: Butterworth-Heinemann; 2000. p. 11-32.
2. Wytch R, Ashcroft GP, Ledingham WM, Wardlaw D, Ritchie IK. Modern splinting bandages. J Bone Joint Surg Br. 1991; 73: 88-91.
3. Fess EE. Principles and methods of splinting for mobilization of joints. In: Hunter JM, Callahan AD, Mackin EJ. Rehabilitation of the hand and upper extremity. 5th ed. St. Louis: Mosby; 2002. p. 1818-27.
4. Tribuzi SM. Serial plaster splinting. In: Hunter JM, Callahan AD, Mackin EJ. Rehabilitation of the hand and upper extremity. 5th ed. St. Louis: Mosby; 2002. p. 1828-38.
5. Zmurko MG, Belkoff SM, Herzenberg JE. Mechanical evaluation of a soft cast material. Orthopedics. 1997; 20: 693-8.
6. Rossi JDMBA, Caffali FAS, Leivas TP, Menezes Filho LA, Quintela AA, Schmitz CA. Estudo mecânico comparativo entre aparelhos gessados clássicos e de material sintético. Rev Bras Ortop. 1987; 22:297-300.
7. Wytch R, Wardlaw D, Ross N. Glass fibre versus non-glass fibre splinting bandages. Injury. 1992; 23:101-6.
8. ASTM - Standard specification for gypsum casting plaster and gypsum molding plaster. Philadelphia: Annual book of ASTM standards; 1993. p. C 472-93.
9. ASTM -. Standard specification for gypsum casting plaster and gypsum molding plaster. West Conshohocken: Annual book of ASTM standards; 1996. p. C 59-95.