ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 15, n. 5, p. 380-5, Sept./Oct. 2011

Influence of the number of layers of paris bandage plasters on the mechanical properties speciments used on orthopedic splints

Influência do número de camadas na propriedade mecânica de espécimes fabricados com atadura gessada usados para confeccionar *splints* ortopédicos

Gustavo C. Vieira[1], Rafael I. Barbosa[1], Alexandre M. Marcolino[1], Antonio C. Shimano[1], Valeria M. C. Elui[2], Marisa C. R. Fonseca[1]

Abstract

Objective: To evaluate the effects of varying numbers of layers of plaster of Paris bandages on the mechanical properties of specimens used on the construction of orthopedic splints. Methods: Rectangular plate-shaped and cylinder-shaped specimens were constructed and assigned to two groups simulating plaster slabs and cast and further divided into six subgroups according to the number of layers used: 3, 6, 8, 10, 12 and 14 layers. The specimens were subjected to either a three-point bending test (plates/slab) or compressive strength test (cylinders/cast). The following mechanical properties were evaluated: maximum load, elastic limit load and stiffness. Specimen weight was also calculated. Data was analyzed using Kruskal-Wallis and the least significant difference (LSD) tests. Results: Pairwise comparisons of the subgroups 10x12 and 10x14 revealed significant differences for all mechanical properties (p<0.05). The results of this study suggest that when the goal is to construct appliances with high mechanical strength, regardless of weight, such as serial plaster slabs splints for stimulating tissue growth through the application of gradual load, splints made with plaster of Paris bandages with 12 or 14 layers should be preferred. For orthotic devices such as positioning orthotics, the use of 10 layers plaster bandages slab splints is advisable as they were found to have better correlation between mechanical strength and weight in comparison to those made wtih 6 or 8 layers. Conclusion: Based on the findings of this study, we suggest the use of 10 layers of plaster of Paris for the construction of orthopedic splints.

Keywords: rehabilitation; orthotic; physical properties.

Resumo

Objetivo: Avaliar as propriedades mecânicas de amostras fabricadas a partir de ataduras de gesso que são utilizadas em órteses ortopédicas e que variam quanto ao número de camadas. Métodos: Foram confeccionados espécimes em forma de placa retangular e em forma cilíndrica, divididos em dois grupos que simulavam *splint* e gesso circular, os quais foram divididos em seis subgrupos de acordo com o número de camadas utilizadas, ou seja, três, seis, oito, dez, 12 e 14 camadas. Os espécimes foram submetidos a um teste de inclinação de três pontos (placas/*splint*) ou teste de resistência à compressão (cilindros/gesso circular). As seguintes propriedades mecânicas foram avaliadas: carga máxima e carga no limite de elasticidade e rigidez. O peso da amostra foi calculado. Os dados foram analisados estatisticamente pelos testes de Kruskal-Wallis e diferença mínima significativa (DMS). Comparações pareadas entre os subgrupos 10x12 e 10x14 revelaram diferenças significativas para todas as propriedades mecânicas (p<0,05). Resultados: Os resultados sugerem que, quando o objetivo é construir aparelhos com alta resistência mecânica, independente do peso, tais como órteses seriadas de posicionamento para simular força gradual aplicada no tecido para a melhoria da amplitude de movimento, talas de 12 ou 14 camadas devem ser preferidas. Para os aparelhos ortopédicos que irão ser submetidos a esforços de baixa intensidade, aconselha-se a utilização de dez camadas para as órteses, porque houve uma melhor correlação entre a resistência mecânica e peso para as amostras fabricadas com dez camadas de atadura gessada comparadas com aquelas confeccionadas com seis ou oito camadas. Conclusão: Baseado nos achados deste estudo, sugere-se a utilização de dez camadas na confecção de órteses ortopédicas.

Palavras-chave: reabilitação; dispositivos ortopédicos; propriedades físicas.

Received: 10/05/2010 – Revised: 04/01/2011 – Accepted: 06/17/2011

[1] Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Escola de Medicina de Ribeirão Preto, Universidade de São Paulo (USP), Ribeirão Preto, SP, Brazil
[2] Department of Neurology, Psychiatry and Medical Psychology, Escola de Medicina de Ribeirão Preto, USP
Correspondence to: Alexandre Marcio Marcolino, Av. Bandeirantes, 3900, Monte Alegre, CEP 14049-900, Ribeirão Preto, SP, Brazil, e-mail: ammfisio@usp.br

Introduction

Orthotics are important therapeutic resources in Hand therapy. An orthoses (splint) is a custom-made or prefabricated device applied to a segment to stabilize, protect, promote healing, prevent or correct deformity or assist function[1-4]. Historically, plaster of Paris have been the most commonly available material used both for immobilization of acute lesions or mobilization splinting. More recently, in the 1970s, low-temperature thermoplastic material revolutionized Hand Therapy and incorporated to the interventions used in rehabilitation[5].

Fess[6] affirmed that orthotic construction should not be based on a "cookbook" approach. Instead, splints must be constructed individually, taking into account several factors such as anatomy, physiopathology, joint biomechanics, kinesiology, rehabilitation goals and personal needs of the patient[3,6]. Fess[6] classified as mobilization splints the ones that may be used to control a movement and improve increase in range of motion or can be used to correct pre-existing deformities through application of force[6].

Bell-Krotoski[7] highlighted the outstanding work of Brand[8] who developed a splint for tissue remodeling that uses a serial plaster of Paris splinting for clubfeet in children and for interphalangeal joint claw deformity in Hansen´s disease.

Current literature have shown high levels of evidence for the use of mobilizing splints and casting as a technique to lengthen tissues beyond their elastic limit and apply low prolonged stress load over long periods of time for the management of joint contracture[1,9]. This technique allows tissue growth with the advantage of keeping the joint and skin close to their elastic limit, which is the desired position[10,11].

Plaster of Paris (gypsum) bandage is a widely used orthopedic splinting material because of its good casting properties and low cost. In some specific situations this material can be used for the treatment of acute fractures and also correction splints[12-16]. Colditz[17] reviewed the importance of plaster of Paris as a material used for making mobilization orthoses. She also defined the use of the term splint as an orthotic that is removable, regardless of the material it is made of, and cast as the orthotic that is made of plaster of Paris and cannot be removed from the patient. Bell-Krotoski[11] serial static plaster orthotics in slabs, constructed volar or dorsally or circumferential cast.

Splinting is indicated for use in many situations. For instance, in the conservative treatment of leprous neuritis, a protective splint is usually molded in plaster of Paris in the volar aspect of the upper extremities or the posterior (plantar) aspect of the lower extremities, aiming to keep the segment and nerve temporarily in a resting position[18]. Splinting can be used in the rehabilitation of flexor tendon repair; fracture and for low load application for stimulating slow growth but not damaging tissues[9,19].

Wytch et al.[12] reported that the incidence of breaks of plaster of Paris splints is a concerning matter. Therefore, knowledge of the materials properties and handling techniques is of great importance when constructing prostheses and splints[3].

If the relationship between weight and thickness was better known, results related to splinting in plaster of Paris could be achieved. In clinical practice the number of layers is mostly decided based on therapist expertise. Therefore, laboratory studies could provide further information about the mechanical properties of the materials and stimulate clinical application.

Thus, the purpose of this study was to evaluate the mechanical properties of specimens constructed with varying numbers of layers of plaster of Paris bandages for use in orthopedic casts and splints.

Methods

In order to determine the mechanical properties of the material a model was constructed and tested *in vitro*. Rectangular plate-shaped specimens (group slab) (120 x 47 mm) and cylinder-shaped specimens (group cast) (100 mm high with an internal diameter of 25 mm) were made using 100 mm wide bandages (Cremer®, Blumenau, SC, Brazil) and were impregnated with quick-drying plaster of Paris (gypsum). The manufacturers of the bandages used were chosen based on the methodology of a previous study[20]. The specimens were fabricated in compliance with the specifications of ASTM-C472-93 and ASTM - C59-95 standards[21,22]. To obtain specimens with standard dimensions, custom-made moulds were prepared at our local precision workshop (Universidade de São Paulo, Ribeirão Preto Campus, SP, Brazil). Additionally, three basic aspects were controlled to guarantee standardization: immersion of all plaster bandages in room temperature water for 3 to 5 seconds, construction of all specimens by a single operator and plaster drying time before mechanical testing of 72 hours[23].

Each group of specimens were divided into 6 subgroups according the number of layers of plaster of Paris bandages used: 3, 6, 8, 10, 12 and 14 layers. Fifteen specimens were obtained for each subgroup. Five specimens for each group were discarded on the basis of weight, considering the mean±standard deviation interval, resulting in a final sample size of 10 specimens *per* subgroup (Figures 1 and 2 - cast and slab specimens. Specimens were then weighed on an analytical scale (Marte, AS2000, São Paulo, SP, Brazil).

Temperature and air humidity conditions were monitored throughout the experiment: from specimen fabrication to mechanical testing. The temperature ranged from 20 to 29°C and air humidity ranged from 32 to 59%, both measured using a digital thermohygrometer (Hygrotherm, TFA, Germany).

Two types of mechanical tests were carried out: three-point bending test for plates (using 3 equidistant supports positioned 100mm apart from each other) and compressive strength test for cylinders. The assays were performed on a universal testing machine (Model DL - 1000; EMIC; São José dos Pinhais, PR, Brazil) with a 500 N load cell for three-point bending and a 20,000 N load cell for compressive strength testing. A 10mm/min load speed was used for both tests.

The following mechanical properties were evaluated: maximum load (load at the moment of rupture and breaking of the material), elastic limit load, (return to resting after load removal) and stiffness (resistance load to elastic deformation). Means were calculated and load *vs* deflection graphs were obtained for each specimen. Data was analyzed using Kruskal-Wallis non-parametric test and Fisher's least significant difference (LSD) to determine significant differences among the subgroups for each mechanical property evaluated. Significance level was set at 5%.

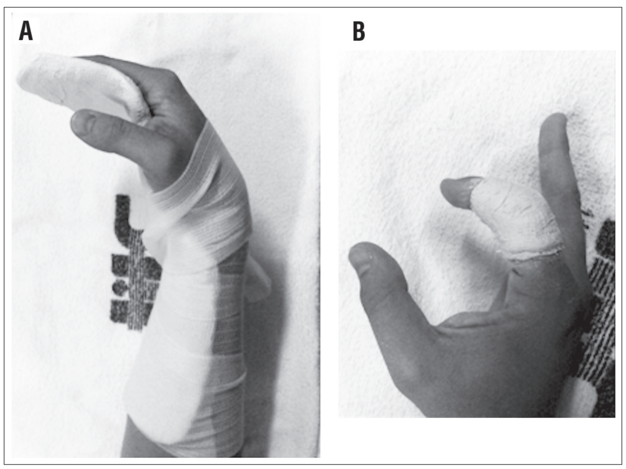


Figure 1. Progressive slab splint for wrist stiffness after flexor tendon injuries (A) Progressive circumferential casting for contracture of index interphalangeal joint (B).

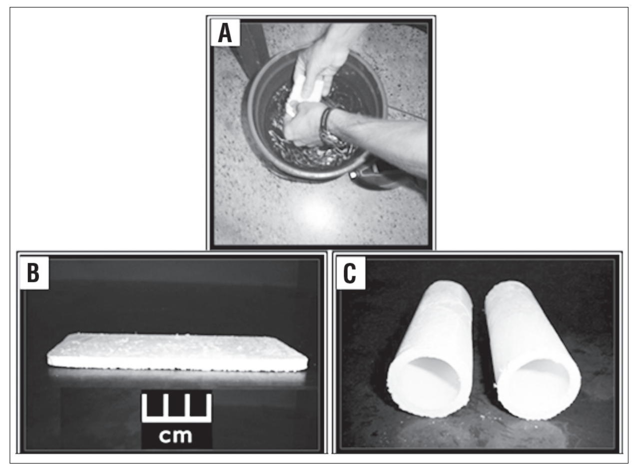
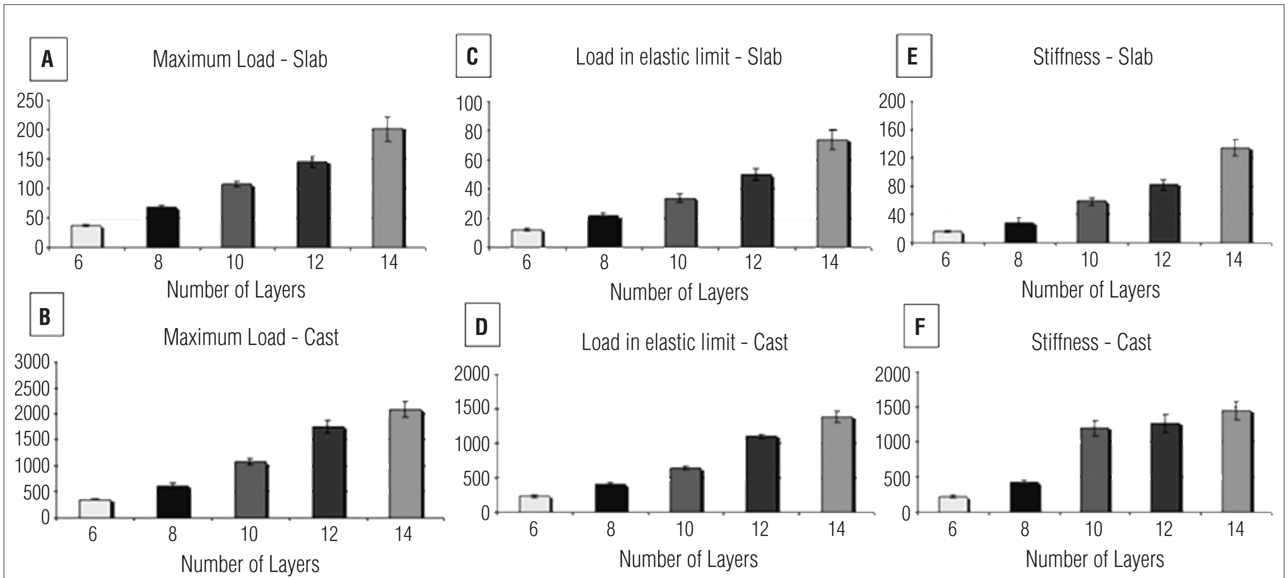


Figure 2. Immersion in cool temperature water (A). Slab specimen (8 layers) (B). Cast specimen (6 layers) (C).



A) Slab Group; B) Cast Group. Load in elastic limit means values (N); C) Slab Group; D) Cast Group. Stiffness means values (N/m x10³); E) Slab Group; F) Cast Group.

Figure 3. Maximum load (N) mean values of 6, 8, 10, 12 and 14 layers.

Results

Maximum load

The slab group results demonstrated that the maximum load means for the 3 layers specimens were low 5.15±0.67 N and that this amount increased 7 times when the number of layers doubled to 6 layers. The maximum load means increased another 1 fold from 6 to 8 layers, 5 times from 8 to 10 layers and 2 times from 10 to 12 and 14 layers (Figure 3). Multiple pairwise comparisons using LSD tests showed statistically significant differences ($p<0.05$) between the following subgroups: 3x8; 3x10; 3x12; 3x14; 6x10; 6x12; 6x14; 8x10; 8x12 and 8x14.

On the cast group maximum load means for the 3, 6, 8, 10, 12 and 14 layer consecutively increased 2.2; 1.7; 1.7; 1.6 and 1.2 with the addition of layers. Multiple pairwise comparisons using the LSD test revealed significant differences ($p<0.05$) between 3x8; 3x10; 3x12; 3x14; 6x10; 6x12; 6x14; 8x10; 8x12 and 8x14 subgroup.

Elastic limit load

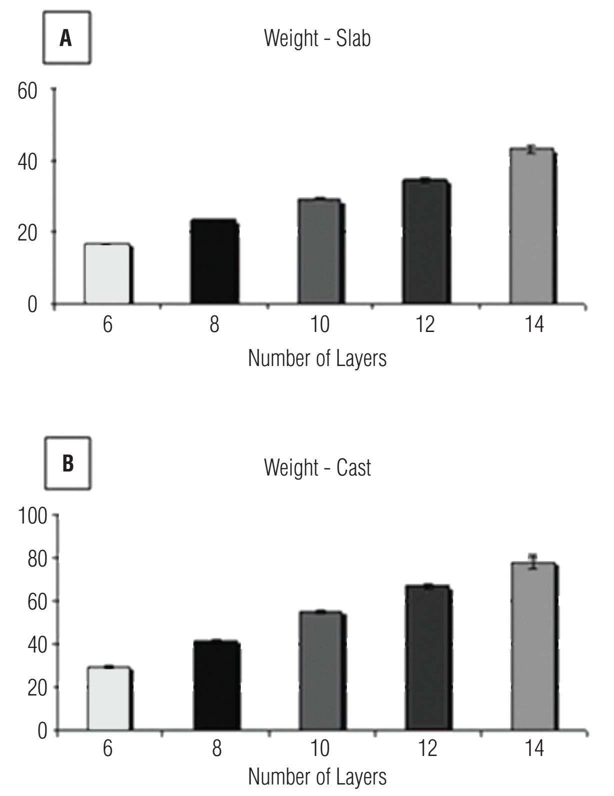
Mean values obtained for the plate-shaped specimens showed greater load increase from 3 to 6 layers; 4.4 times. Between the groups with 6, 8, 10, 12 and 14 layers the values increased 1.6 times with the increase of each 2 layers (Figure 3). The LSD test showed statistically significant differences ($p<0.05$) between the subgroup pairs 3x10; 3x12; 3x14; 6x12; 6x14; 8x12; 8x14 and 10x14.

The cast group behaved in the same manner. There were significant differences ($p<0.05$) between the following subgroups: 3x8; 3x10; 3x12; 3x14; 6x10; 6x12; 6x14; 8x12; 8x14; 10x12 and 10x14.

Stiffness

On the slab group, stiffness means raised between 1.3 to 2 times for each increment of 2 layers (Figure 3). LSD tests showed statistically significant differences ($p<0.05$) between the following subgroup pairs 3x10; 3x12; 3x14; 6x10; 6x12; 6x14; 8x12; 8x14; 10x14 and 12x14.

On the cast group, stiffness means increased 5.7 times between 3 and 6 layers, however; the progressive increment of 2 layers did not show proportional increase of stiffness. Multiple pairwise comparisons using the LSD test showed significant differences ($p<0.05$) for the following subgroup pairs: 3x8; 3x10; 3x12; 3x14; 6x10; 6x12; 6x14; 8x10; 8x12 and 8x14.



A) Slab Group; B) Cast Group.

Figure 4. Weight mean values (g) for 6, 8, 10,12 and 14 layers.

Weight

Weight means for plate-shaped specimens increased 2.1 times after the addition of 3 layers and 1.4; 1.3; 1.9 and 1.2 for the others consecutevily (Figure 4). LSD tests revealed significant differences ($p<0.05$) between the following subgroup pairs 3x10; 3x12; 3x14; 6x12; 6x14; 8x12; 8x14 and 10x14.

On the cast group, weight means increased 2.3 for the addition of 3 layers and 1.4,1.3, 1.2 and 1.2 for the others consecutevely. Multiple pairwise comparisons using the LSD test revealed statistically significant differences ($p<0.05$) between 3x10; 3x12; 3x14; 6x12; 6x14; 8x12; 8x14 and 10x14 subgroups.

Discussion

Plaster of Paris bandages and low-temperature thermoplastics are currently used on the construction of orthopedic splinting and cast[2,5,6].

The reasonable cost, its ability to closely conform and it's porosity among other features are commonly referred to advantageous characteristics of plaster of Paris[5,11]. Its disadvantages include low durability, heavier weight, difficulty to clean, in addition to being a temporary and non-reusable material, not resistant to water[5] and the possible presence of allergic contact dermatitis[24].

The construction of specimens from plaster of Paris bandages is a delicate and meticulous process. One of the most important aspects of this study was the construction of custom-made moulds specific for each group. These moulds, composed of several parts, allowed the inclusion of a standard and highly homogeneous sample. Schmidt, Somerset and Porter[25] affirmed that plaster bandages usually achieve its optimal mechanical characteristics after 24 hr of a drying period. Therefore, in this study all tests were performed after 72 hours of drying. The temperature of the water was maintained cool, avoiding increase setting of the plaster that can occur when the water is hot[11].

Most studies published in the literature[12,26-29] compare mechanical properties of specimens made from plaster of Paris to those of specimens made from other materials, but without standardization of specimen dimensions. Furthermore, these study use different methodology.

Regarding the weight of the rectangular plate-shaped specimens (slab group), no statistical significant differences ($p>0.05$) were found between 6x8, 6x10, 8x10, 10x12 and 12x14 subgroup pairs. As the increase in the number of layers did not influence significantly the weight of the specimens, it would be advisable to use 10 layers of plaster of Paris bandages, which is an intermediate value among those tested in this study, for making splints,. The 10 layer specimens were neither significantly heavier than the 6- and 8-layer specimens, nor significantly lighter than the 12 layer specimens.

When other properties were evaluated, there were statistically significant differences ($p>0.05$) between the 10x12 and 10x14 subgroup pairs on both slab and cast groups. In view of these findings, it may be inferred that when the goal is to construct specimens with high mechanical strength, regardless of weight, such as serial orthotics for improvement of mobilization amplitude through low prolonged stress load technique splints[9], these splints should be preferably made of 12 or 14 plaster of Paris layers. On the other hand, for orthotic specimens such as positioning orthotics, the use of 10 layer plaster of Paris splints might be recommendable because they are likely to be mechanically more resistant and not significantly heavier than 6 and 8 layer splints.

For rectangular plate-shaped and cylinder-shaped specimens, statistically significant differences ($p>0.05$) were found among the subgroups regarding maximum load. For example, the 6 layer subgroup differed significantly from all subgroups, except for the 8 layer subgroup, which suggests that with respect to maximum load, there might be no difference in using either 6 or 8 layer plaster of Paris splints. Likewise, no statistically significant differences ($p>0.05$) were observed between the 10x12, 10x14 and 12x14 subgroups pairs.

The findings of this study showed that when the elastic limit load was evaluated on the plate group, no significant differences were found between the subgroup pairs 6x8 and 6x10. These results indicate that, the load in elastic limit did not increase significantly with the increase of the number of layers of plaster of Paris bandages such as when comparing the 6 layer subgroups to the 10 and 12 layer subgroups. Similar outcomes were observed for the following subgroup pairs 8x10, 10x12 and 12x14. On the cylinder group, however; there were statistically significant differences ($p<0.05$) between 6x10; 6x12; 6x14; 8x12; 8x14; 10x12 and 10x14 subgroup pairs. For plate and cylinder groups, comparisons between the 6x8, 8x10 and 12x14 subgroup pairs exhibited the same results, thus specimens made with larger number of plaster bandage layers did not show statistically significant higher means of elastic limit load.

Regarding stiffness, there were no statistically significant differences ($p>0.05$) between the 6x8, 8x10 and 10x12 subgroup pairs for the plate group. On the cylinder group, no significant differences were found between the subgroup pairs 6x8, 10x12, 10x14 and 12x14. For both types of specimens, comparisons between 6x8 and 10x12 subgroups showed no statistically significant differences making clear that there was no stiffness gain with increase from 6 to 8 layers or from 10 to 12 layers.

There are still controversies about how many layers would be ideal for orthesis construction when using plaster of Paris, especially when considering small joints. Bell-Krotoski[11] suggested that six to eight layers of plaster slabs and one to two layers for circumferential finger cast are usually sufficient in what Brand called "eggshell casting"[11]. Boyd, Benjamin and Asplund[30], recommended that the construction of orthotic devices for adults should contain 6 to 10 layers for upper extremities and 12 to 15 layers for lower extremities. The authors reported that the larger number of layers would results in higher resistance to the specimen which is in line with the result of this study.

The results of this study may be helpful when choosing the number of plaster bandage layers for making plaster of Paris splints, in order to optimize material usage and increase the effectiveness of orthotics in rehabilitation.

Conclusions

Based on the findings of this study, the following conclusions may be drawn: the mechanical properties evaluated in this study improved as the number of layers of plaster of Paris bandages increased. The weight of the specimens, however; also increased. The results of the *in vitro* mechanical assays suggested that the use of 10 layers of plaster of Paris yields a better relationship between material's weight and final strength. Other studies are needed to evaluate clinical splinting and casting *molding in vivo*.

References

1. Fess EE. Principles and methods of splinting for mobilization of joints. In: Hunter JM, Callahan AD, Mackin EJ (eds). Rehabilitation of the hand and upper extremity. 5th ed. St. Louis: Mosby; 2002. p. 1818-27.
2. Gravlee JR, Van Durme DJ. Braces and splints for musculoskeletal conditions. Am Fam Physician. 2007;75(3):342-8.
3. Kogler GF. Materials and technology. In: Lusardi MM, Nielsen CC (eds). Orthotics and prosthetics in rehabilitation. Woburn, MA: Butterworth-Heinemann; 2000. p. 11-32.
4. Mckee P, Rivard A. Foundations of Orthotic intervention. In: Skirven TM, Osterman AL, Fedorczyk JM, Amadio PC. Rehabilitation of the hand and upper extremity. 6th ed. Philadelphia: Mosby; 2011. p. 1565-80.
5. Salter MI, Cheshire L. Hand therapy, principles and practice. Oxford, UK: Butterworth-Heinemann; 2000.
6. Fess EE. Orthoses for mobilization of joints: principles and methods. In: Skirven TM, Osterman AL, Fedorczyk JM, Amadio PC. Rehabilitation of the hand and upper extremity. 6th ed., Philadelphia: Mosby; 2011. p. 1588-98.
7. Bell-Krotoski JA. Plaster serial casting for the remodeling of soft tissue, mobilization of joints and increased tendon excursion. In: Fess EE, Gettle KS, Philips CA, Janson JR. Hand and upper extremity splinting-Principles & Methods. 3rd ed. St. Louis: Elsevier Mosby; 2005. p. 599-606.
8. Brand P. Lessons from hot feet: a note on tissue remodeling. J Hand Ther. 2002;15(2):133-5.
9. Glasgow C, Tooth LR, Fleming J. Mobilizing the stiff hand: combining theory and evidence to improve clinical outcomes. J Hand Ther. 2010;23(4):92-400.
10. Bell-Krotoski JA, Breger DE, Beach RB. Biomechanics and evaluation of the hand. In: Mackin E, Callahan AD, Skirven TM, eds. Rehabilitation of the hand and upper extremity. 5th ed. St. Louis: Mosby; 2002. p. 240-62.
11. Bell-Krotoski JA. Tissue remodeling and contracture correction using serial plaster casting and orthotic positioning. In: Skirven TM, Osterman AL, Fedorczyk JM, Amadio PC. Rehabilitation of the hand and upper extremity. 6ª ed. Philadelphia: Mosby; 2011. p. 1599-609.
12. Wytch R, Ashcroft GP, Ledingham WM, Wardlaw D, Ritchie IK. Modern splinting bandages. J Bone Joint Surg Br. 1991;73(1):88-91.
13. Tribuzi SM. Serial plaster splinting. In: Hunter JM, Callahan AD, Mackin EJ (eds). Rehabilitation of the hand and upper extremity. 5th ed. St. Louis: Mosby; 2002. p. 1828-38.
14. Boutis K, Willan A, Babyn P, Goeree R, Howard A. Cast versus splint in children with minimally angulated fractures of the distal radius: a randomized controlled trial. CMAJ. 2010;182(14):1507-12.
15. von Keyserlingk C, Boutis K, Willan AR, Hopkins RB, Goeree R. Cost-effectiveness analysis of cast versus splint in children with acceptably angulated wrist fractures. Int J Technol Assess Health Care. 2011;27(2):101-7.
16. Firmin F, Crouch R. Splinting versus casting of "torus" fractures to the distal radius in the paediatric patient presenting at the emergency department (ED): A literature review. Int Emerg Nurs. 2009;17(3):173-8.
17. Colditz JC. Plaster of Paris: the forgotten hand splinting material. J Hand Ther. 2002;15(2):144-57.
18. Ministério da Saúde. Manual de prevenção de incapacidades: Séria A. normas e manuais técnicos - Cadernos de prevenção e reabilitação em hanseníase; n.1 [Internet]. Brasilia DF: 2008. Disponível em HTTP://www.saúde.gov.br/svs.
19. Bell-Krotoski JA, Figarola JH. Biomechanics of soft-tissue growth abd remodeling with plaster casting. J Hand Ther. 1995;8(2):131-7.
20. Vieira GC, Fonseca MCR, Shimano AC, Mazzer N, Barbieri CH, Elui VCM. Evaluation of the mechanical properties of plaster bandages used for orthosis manufacture, marketed by three different manufacturers. Acta Ortop Bras. 2006;14(3):122-5.
21. American Society for Testing and Materials - ASTM - C 472-93. Standard specification for gypsum casting plaster and gypsum molding plaster. Annual book of ASTM standards, Philadelphia: 1993.
22. American Society for Testing and Materials - ASTM - C 59-95. Standard specification for gypsum casting plaster and gypsum molding plaster. Annual book of ASTM standards, West Conshohocken: 1996.
23. Vieira GC. Avaliação das propriedades mecânicas do gesso utilizado para confecção de órteses [dissertação]. Ribeirão Preto: Universidade de São Paulo, Faculdade de Medicina de Ribeirão Preto; 2006.
24. Wong DA, Watson AB. Allergic contact dermatitis due to benzalkonium chloride in plaster of Paris. Australas J Dermat. 2001;42(1):33-5.
25. Schmidt VE, Somerset JH, Porter RE. Mechanical properties of orthopedic plaster bandages. J Biomech. 1973;6(2):173-6.
26. Wytch R, Ross N, Wardlaw D. Glass fibre versus non-glass fibre splinting bandages. Injury. 1992;23(2):101-6.
27. Zmurko MG, Belkoff SM, Herzenberg JE. Mechanical evaluation of a soft cast material. Orthopedics. 1997;20(8):693-8.
28. Rossi JDMB, Cafalli FAS, Leivas TP, Menezes Filho LA, Quintela AA, Schmitz CA. A comparative mechanical study between classic and synthetic plaster casts. Rev Bras Ortop. 1987;22(10):297-300.
29. Stewart HD, Innes AR, Burke FD. Functional cast-bracing for Colles' fractures. A comparison between cast-bracing and conventional plaster casts. J Bone Joint Surg. 1984;66(5):749-53.
30. Boyd AS, Benjamin HJ, Asplund C. Splints and casts: indications and methods. Am Fam Physician. 2009;80(5):491-9.