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## Original Article

# A simple idea for reducing the cost and weight of plaster-cast orthoses

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### A B S T R A C T

**Objective:** To reduce the cost and weight of plaster molded orthosis (increasing patient comfort), keeping the same resistance. **Methods:** 22 plaster orthosis were analysed, 11 with conventional shape and 11 with pyramidal shape. It was compared, in theory (mathematically) and practice, the change of weight (and consequently cost) and flexion resistance between conventional shape and pyramidal shape. **Results:** Theoretical analysis: weight and cost decrease of 26.7%-38.9%, according to the layers disposition of the cast. Laboratorial analysis: cast's weight decrease of 34.5% ( $p = 0.000005$ ) and resistance increase of 26.7% ( $p = 0.03$ ). **Conclusion:** plaster molded orthosis made in a pyramidal shape, have a statistically significant decrease of weight (and consequently cost) and statistically significant increase of resistance if compared with traditional shape.

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## Introduction

Plaster-cast orthoses do not need to have the same thickness throughout their length, given that the deforming forces to which they are subjected are not the same over the entire length. They are subjected to greater plaster fracture forces in the regions over joints, since the stress on the material is greater at the fulcrum of the potential movement.

This can be seen to be true in practice, given that plaster-cast orthoses generally break over joint areas (wrist, elbow, ankle or knee). Thus, a plaster cast covering the lower leg and foot tends to break in the ankle region and a plaster cast covering the forearm and palm of the hand tends to break at the wrist, and so on.

This experimental study was started with the idea of improving the way in which plaster-cast orthoses are constructed. No similar studies were found in the Bireme (Lilacs and SciELO), PubMed and RBO databases.

## Objective

To diminish the cost and weight of plaster casts, while maintaining similar resistance.

## Methods

### Theoretical foundation

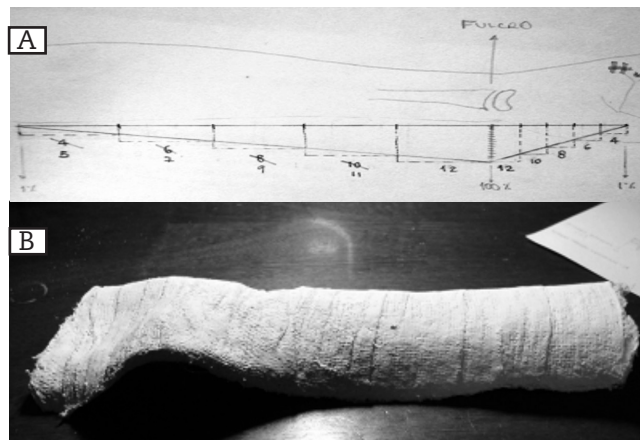
The flexion strength of the material is the main factor causing plaster casts to break. The stress on the material becomes greater with increasing proximity to the fulcrum of movement and thus, the cast thickness also needs to increase.

In this experiment, the arrangement of the layers of plaster was reorganized, with a greater number of layers in the region of the fulcrum of movement. This increase in the number of layers needs to be progressive, just as the tendency for plaster-cast orthoses to fracture progressively increases towards this location.

With this in mind, we decided to progressively increase the number of layers, in the form of "steps", towards the region of the fulcrum of movement (Figs. 1A and 1B).

However, two layers in the most peripheral steps were seen to break very easily. We therefore decided to use four layers in the peripheral steps. Furthermore, during the construction of the plaster cast, the side on which we started to unroll the plaster-covered bandage had one additional layer. However, the apex of the pyramid ended up with the same numbers of layers on both sides of the fulcrum if we finished unrolling the bandage on the same side on which we started.

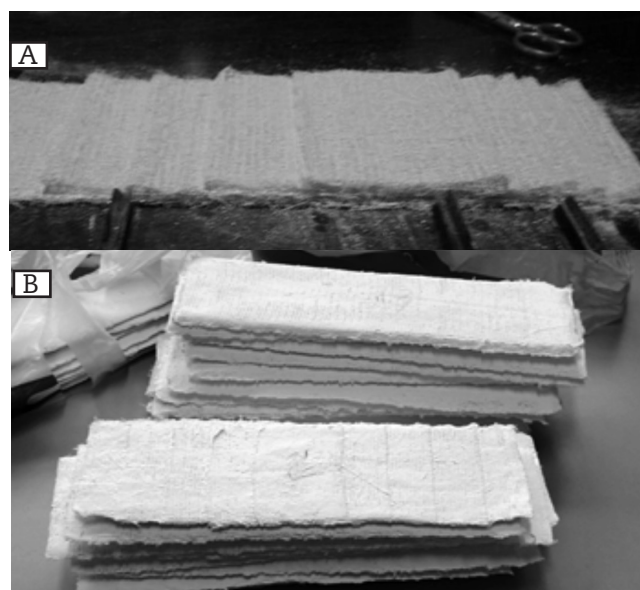
After defining the format of the plaster-cast orthosis, it was then possible to mathematically predict the weight decrease (and therefore the cost) of plaster casts constructed in this manner, through calculating the area. This is presented in the Results and Discussion sections.



**Figs. 1A and 1B - Progressive increase in the number of layers, going towards the fulcrum of movement, in the form of "steps", to accompany the flexion deformation forces on the plaster-cast orthosis. The first step should have four layers. The side on which unrolling the bandage starts has one layer more, but the apex has the same number of layers on both sides.**

### Practice – weighing and flexion testing

Twenty-six plaster-cast orthoses were then constructed: 13 with the conventional format and 13 with the pyramidal format. They were all 30 cm in length, had a central fulcrum and 12 layers (five steps on each side). Two boxes each containing 20 plaster-covered bandages (measuring 8 cm x 2 m), of a brand that is well-regarded in the market, were used (Figs. 2A and 2B).



**Figs. 2A and 2B - The cast acquires a pyramidal format, with the apex of the pyramid in the region over the joint.**

Five days later (the time taken for the casts to dry out), they were taken to the Mechanical Engineering Laboratory of the Pontifícia Universidade Católica - Paraná, where they were weighted that then subjected to flexion testing at three points, with spans of 26 cm between the supports. An EMIC DL500 test machine was used, with a load cell of capacity 200 kg and advancing velocity of 50 mm/min. The machine was activated until reaching plaster cast deformation of 30 mm, in a manner very similar to a flexion test that was performed to test the quality of three different brands of plaster, which was published in *Ata Ortopédica Brasileira* in 20061 (Fig. 3).

Two plaster-cast orthoses in each group were excluded, due to errors in cast construction or in the flexion test.



Fig. 3 - Flexion test at three points.

## Results

### Theoretical foundation

The areas of three types of pyramidal plaster-cast orthoses that differed in numbers of layers and position of the pyramidal apex were calculated. These were compared with the equivalent area of a plaster cast of conventional format:

1) Calculation of the area of a pyramidal plaster-cast orthosis consisting of 12 layers and a central fulcrum, in comparison with a conventional plaster cast (Fig. 4).

2) Calculation of the area of a pyramidal plaster-cast orthosis consisting of 12 layers and a fulcrum between the first and second quarters, in comparison with a conventional plaster cast (Fig. 5).

3) Calculation of the area of a pyramidal plaster-cast orthosis consisting of 22 layers and a central fulcrum, in comparison with a conventional plaster cast (Fig. 6).

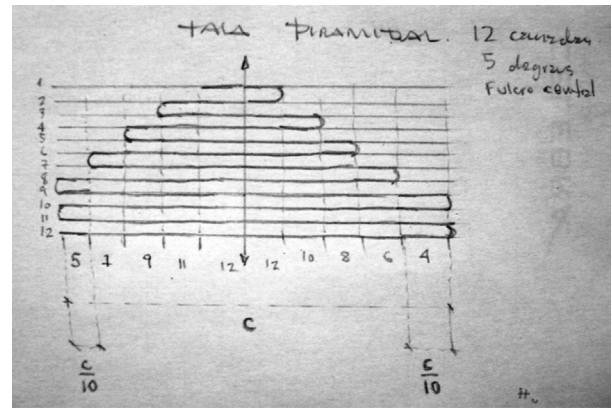


Fig. 4 - Graphical representation of the area occupied by a pyramidal plaster-cast orthosis with 12 layers and a central fulcrum. While the conventional cast occupies an area of  $12c$ , the pyramidal cast occupies an area of  $8.4c$ .

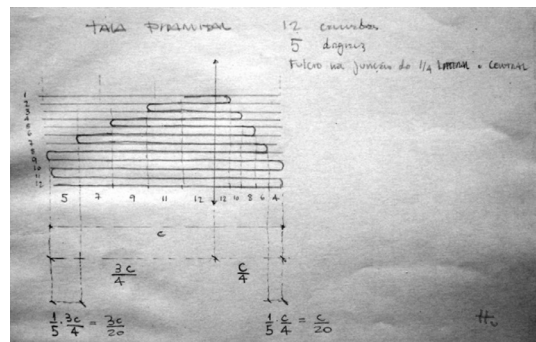


Fig. 5 - Graphical representation and mathematical calculation of the area. While the conventional cast occupies an area of  $12c$ , the pyramidal cast with 12 layers and a peripheral fulcrum occupies an area of  $8.8c$ .

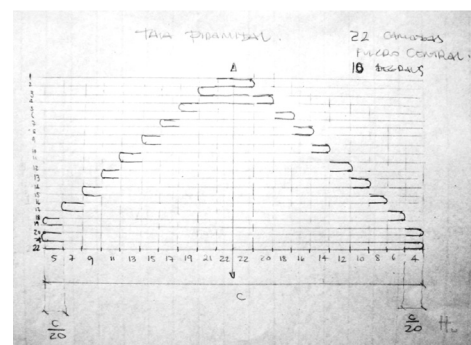


Fig. 6 - Cast with 22 layers and a central fulcrum. While the conventional cast occupies an area of  $22c$ , the pyramidal cast occupies an area of  $13.45c$ .

## Weighing and flexion testing

The plaster-cast orthoses were then taken to the Mechanical Engineering Laboratory of "University X", where the plaster-cast orthoses were weighed and the flexion test at three points was performed, as described above. The results were expressed as the force in newtons that would be needed to deform the cast by 3 cm, and as the respective weight of each cast, in grams, and these are presented in Table 1.

The mean weight of the conventional plaster-cast orthosis was 152.70 g and that of the pyramidal cast was 100.06 g, i.e. 34.5% lower ( $p = 0.000005$ ).

The mean force in newtons that was needed to flex the plaster cast was 1.62 N in the conventional casts and 2.05 N in the pyramidal casts, i.e. 26.7% greater ( $p = 0.03$ ).

**Table 1 - Results from weight analysis and flexion testing at three points.**

	Conventional plaster-cast orthosis		Pyramidal plaster-cast orthosisl	
	Weight(g)	Strength(N)	Weight(g)	Strength(N)
1	148.6	1.49	93.4	1.17
2	150.2	1.82	93.8	2.16
3	154.1	1.47	95.1	2.21
4	156.3	1.11	99.8	2.19
5	152.1	1.35	96.7	1.83
6	144.7	1.32	94.2	1.6
7	156.1	1.55	108.3	2.58
8	151.8	2.53	96.5	2.39
9	154.5	1.6	108.8	2.53
10	157.4	1.18	105.8	1.96
11	154	2,39	108,3	1,96

## Discussion

### Theoretical matters

It is important to progressively increase the number of layers in the plaster-cast orthosis, so that the resistance increases harmoniously as the fulcrum is approached, and to avoid the presence of layers within the cast, which could cause discomfort for the patient.

The number of steps should be calculated according to the length of the plaster cast and the number of layers. With five steps on each side, 12 layers are achieved; with six steps, 14 layers; with seven steps, 16 layers; and so on progressively, adding two layers for each step added, as shown in Table 2.

For example, a plaster cast covering the forearm and palm of the hand could be constructed with four steps, which would result in 10 layers, a thickness that is generally enough for this type of plaster cast. A plaster cast extending from the inguinal region to the malleolus could be constructed using eight steps, thus resulting in 18 layers.

**Table 2 - Number of steps and resultant plaster-cast orthosis thickness.**

Degrees	Layers
3	8
4	10
5	12
6	14
7	16
8	18
9	20
10	22

Through the mathematical calculation on the area occupied by the plaster-cast orthosis, it can be seen that the saving varies according to the position of the fulcrum in relation to the plaster cast, and is greatest when the fulcrum is central. It also varies according to the number of steps, and becomes slightly greater as the number of steps increases. It varies in another manner with the number of layers used, since the greater the number of layers is, the greater the saving is in relation to plaster casts constructed conventionally.

Another point that needs to be made is that this format of plaster cast is only possible when there is only one fulcrum, such as in casts extending from the forearm to palm of the hand, from the upper arm to the forearm, from the inguinal region to the malleolar region and from the sural region to the foot. In practice, it is not technically possible to calculate two pyramidal apexes in plaster casts with two fulcrums, such as those extending from the upper arm to the palm and from the inguinal region to the foot.

## Practical matters

There is greater technical difficulty in constructing plaster-cast orthoses of pyramidal format: marking out the fulcrum, dividing the steps and submersing the cast in a basin of water without the steps sliding. Regarding this last point, surgical forceps or ordinary clothes pegs can be used, attached to the fulcrum so that the layers do not slide over each other.

Thought should also be given to the applicability of this concept in small plaster casts versus large casts. In large casts, the advantage is greater, both economically and in terms of diminished weight.

Regarding the results from diminishing the weight of plaster casts, it is more reasonable to analyze this based on the weight reduction seen in the practical test (weighing), and not in the theory (mathematical calculation on the area), considering that the plaster was totally dry at the time of weighing it, i.e. five days after constructing the cast. It should be emphasized that this decrease in weight is directly proportional to the cost reduction. Thus, a plaster-cast orthosis extending from the forearm to the palm of the hand, with 12 layers would give rise to a weight reduction from around 150 g to 105 g and a cost

reduction from around R\$ 2.00 to R\$ 1.40 (considering that the saving is 30% and that two bandages measuring 8 cm x 2 m are used, each costing US\$ 1.00). Even better, with a plaster cast of 22 layers extending from the inguinal region to the malleolar region, the weight would reduce from around 1500 g to 915 g and the cost from around R\$ 20.00 to R\$ 12.00 (considering that the saving is 38.9% and using four bandages measuring 20 cm x 4 m, each costing R\$ 5.00).

Regarding the resistance results, although the objective of this study was to achieve similar resistance, the resistance to flexion achieved with the pyramidal format was even greater. At this initial stage, we have not been able to explain this.

The importance of this study when scaled up to apply these concepts to the magnitude of hospital expenditure on plaster-covered bandages should be emphasized. Moreover, finally and just as importantly, diminishing the weight of the plaster cast is beneficial for the patient.

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## Conclusion

The plaster-cast orthosis with pyramidal shape presented a statistically significant decrease in weight, and consequently in cost, with increased resistance in comparison with plaster casts with the conventional format.

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## Conflicts of interest

The authors declare that there was no conflict of interests in conducting this study.

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## R E F E R E N C E S

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