EFFECT OF VARIOUS ADDITIVES (LIME WATER AND SALINE) ON THE PHYSICAL PROPERTIES OF PLASTER OF PARIS IN ORTHOPAEDIC PRACTICE

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ABSTRACT

Background: Plaster of Paris is used in medicine, arts and construction industry. And the problems associated with plaster of Paris includes increased time to set, water permeability and strength/hardness. Purpose: this research is undertaking therefore to assess the effect of lime water and saline on the physical properties/indices of Plaster of Paris (POP). Methods: The standard mixing ratio for POP and water is two parts of POP to one part of water by weight which was used as control. 25%, 50% and 100% saline were used to mix the POP. The same procedure was repeated with lime water and all the samples (test and control) were allowed to set for 5 days at room temperature. Results: showed that the bulk densities of 25% saline, 25% lime water and 50% lime water were significantly reduced when compared with control. The bulk density of 50 and 100% saline were significantly increased compared with control. There is also dose dependent decrease between 50% and 100% saline. The Apparent porosities of 50% and 100% saline, 100% lime water were significantly increased but 25% saline, 25% and 50% lime water were significantly reduced compared to control. The hardness of 25% lime water was significantly increased while that of 100% lime water and 50% saline were significantly reduced compared to control. The values for 50% and 100% lime water and also 25% saline were not significantly affected. There is dose dependent reduction between 25 and 50% lime water when compared with 100% lime water. Conclusion: in the light of the above, addition of lime water in Plaster of Paris preparation will provide additional strength, decrease water permeability and at the same time, reduce its bulk density. All these advantages will improve casting in orthopaedic cases and construction industry.
KEY WORDS: Plaster of Paris, Lime water, Saline, Apparent porosity, Bulk density.

INTRODUCTION

Plaster of Paris (POP) otherwise known as Gypsum powder is calcium sulphate dihydrate \( \{2 \text{(caso}_4 \cdot \text{H}_2\text{O)} \} \). It is normally produced by heating gypsum to about 1200°C to remove water and grinding it to powder. POP has long been used by man since ancient time in building houses. The recent / modern use of POP include in Medicine where it has been found to be very useful, Arts, Construction industry \([1,2]\).

In medicine, POP usefulness has grown which include casts, splints and bandages. Once injury that requires immobilization has been established, the physician normally decides to apply cast or a splint which allows orthopaedic injuries to heal \([2]\). Splints are normally useful in simple or stable fractures, sprains, tendon injuries and other soft tissue injuries while casting is usually reserved for definitive and complex fracture management. Splints are known to offer advantage over casting because they are easier and faster to apply. Splints can also be made static in which case motion is prevented in the area under treatment or dynamic which provides controlled motion \([3,2]\). Generally bone fractures will be very difficult to heal without POP casting but there are problems or risk associated with casting. Complications associated with casting include “compartment syndrome” which is a condition of excessive pressure within the enclosed area that limits blood flow, tissue perfusion and causes ischaemia with the possibility of irreversible tissue damage \([4,1]\). Microbial infections like bacteria and fungi often with pruritic dermatitis can occur beneath cast or splint which can pose challenges \([5]\). But these challenges have not reduced the level of application of POP casts and splints in orthopaedic procedures.

POP is used to produce positive casts of amputated upper or lower limb stump which is used to produce prostheses. In dentistry, POP is used to produce moulds for lost tooth. POP is been used in fire protection on walls and ceiling of buildings and factories and also in making black board chalks and statues. In view of the varied uses of POP especially in medicine, this study is undertaking to assess the effect of lime water and saline in to the various physical properties of Plaster of Paris (POP).

PROTOCOL
The standard procedure for mixing Plaster of Paris (POP) is two parts of POP to one part of water by weight and this we did, using it as control. Then for the test samples, we replaced 25%, 50% of water with saline and also 100% saline that is without water were used to mix POP. Each of the three different concentrations and control were duplicated with 5 different containers for the purpose of reproducibility. The same procedure was repeated with lime water. In all, 35 different containers of 500ml capacity were used.

In each of the 35 containers used, POP powder was gently added stirring gently and slowly to avoid air bubble after which the mixtures were exposed to air at room temperature for five days (120hrs) to set properly.

**Procedure for Bulk Density and Apparent porosity:** After allowing the mixtures to set for five days, a constant mass of POP was cut out from each container, weighed and called \( W_d \) (weight dry). Then the samples were tied with fiber rope and then suspended in a beaker half filled with water and weighed. The beaker with water had previously been weighed. The weight of beaker with water was subtracted from the weight of beaker and water plus the suspended POP to get weight suspended \( W_{sus} \). The POP suspended in water was removed and weighed that is, weight soaked \( W_s \). These weights were used to calculate bulk density and apparent porosity.

**Procedure for Relative Density and Hardness:** We weighed a density bottle \( W_1 \). A weighed piece of the POP was cut, crushed and labeled as \( W_2 \) and put into density bottle. Water was poured into the density bottle containing the crushed POP and weighed \( W_3 \) and lastly we weighed empty washed dry density bottle \( W_4 \). For hardness, Rockwell hardness tester was used. A piece of the POP sample was put in the hardness tester and reading for hardness was taken.

**Formulae used in the calculations are**

- Bulk Density \[ \frac{W_s - W_d}{W_{sus} - W_d} \times D \]  
- Relative Density \[ \frac{Mass\ of\ substance}{Mass\ of\ equal\ volume\ of\ water} \]
Mass of bottle = W1g, Mass of bottle + solid = W2g, Mass of bottle + solid + water = W3g,

Mass of bottle filled with water = W4g, Mass of substance = (W2-W1)g, Mass of water filling bottle = (W4-W1)g, Mass of water filling space left solid = (W3-W2)g, Mass of water volume equal to the solid = (W4-W1) - (W3-W2)g

Hence, Relative Density = \( \frac{(W2-W1)}{(W4-W1)-(W3-W2)} \) -------- 2

Apparent porosity = \( \frac{W4-W2}{W2-W3} \times 100 \)-----------------------------3.0

**STATISTICAL ANALYSIS:** The data we generated were analysed using statistical package for social sciences (SPSS) version 16. Student’s t test was used to test the difference between two groups of continuous variables and \( P \leq 0.05 \) is considered significant.

**RESULTS**

The results as indicated in table one reveals that the bulk densities of 25% saline, 25% lime water and 50% lime water were significantly reduced when compared with control (100% water). The Bulk density of 50 and 100% saline were significantly increased compared with control. There is also dose dependent decrease between 100% and 50% saline.

The Apparent porosities of 100% of saline, 100% of lime water and 50% saline were significantly increased but 25% saline, 25 and 50% lime water were significantly reduced compared to control. There is dose dependent significant increase between 25 and 50 % lime water on one side and 100% lime water.

The hardness of 25% lime water was significantly increased while that of 100% lime water and 50% saline were significantly reduced compared to control. The values for 50% and 100% lime water and also 25% saline were not significantly affected. There is dose dependent significant reduction by 25 and 50% lime water when compared with 100% lime water.
Table 1: Comparable Effects of Saline and Lime water on the Properties of Plaster of Paris (POP)

<table>
<thead>
<tr>
<th></th>
<th>Bulk Density</th>
<th>Relative Density</th>
<th>Apparent Porosity</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>POP+100% water</td>
<td>4.53±0.01</td>
<td>2.03±0.002</td>
<td>77.89±0.84</td>
<td>35.72±0.44</td>
</tr>
<tr>
<td>POP+100% saline</td>
<td>5.86±0.04</td>
<td>1.92±0.001</td>
<td>82.94±0.12</td>
<td>35.00±0.70</td>
</tr>
<tr>
<td>POP+50% saline</td>
<td>10.51±0.07*</td>
<td>2.05±0.05</td>
<td>90.48±0.06*</td>
<td>25.40±0.89*</td>
</tr>
<tr>
<td>POP+25% saline</td>
<td>3.60±0.01+++</td>
<td>1.99±0.01</td>
<td>72.27±0.11+</td>
<td>36.5±0.71</td>
</tr>
<tr>
<td>POP+100% lime water</td>
<td>12.65±0.33*</td>
<td>1.92±0.01</td>
<td>92.22±0.92*v</td>
<td>30.28±0.44#</td>
</tr>
<tr>
<td>POP+50% lime water</td>
<td>2.76±0.01+</td>
<td>1.11±0.015</td>
<td>63.80±0.015+</td>
<td>35.10±0.54</td>
</tr>
<tr>
<td>POP+25% lime water</td>
<td>2.76±0.01+</td>
<td>2.057±0.06</td>
<td>63.86±0.04+</td>
<td>38.5±0.86*</td>
</tr>
</tbody>
</table>

* Significantly increased compared to control (P < 0.05)
+ Significantly decreased compared to control (P < 0.05)
# Dose dependently and significantly reduced compared to 25% and 50% lime water
V Dose dependently and significantly increased compared to 25 and 50% lime water
+++ Dose dependently and significantly decrease compared to 50 and 100 % saline

DISCUSSION

We reported in this study that the bulk density of 25% saline and 50% lime water were significantly reduced but 50 and 100% saline were significantly increased. Also 100% saline was dose dependently increased compared to 50% saline. Bulk density (BD) refers to the total weight of a substance per unit volume and to that extent, saline increased the total weight of a Plaster of Paris (POP) as a result of increased BD. In the construction industry, where POP is used as decorative and fire protection material, increased BD of a material will ultimately deter and insulate fire. In medical / orthopaedic procedures, increased BD directly connects with increased weight which becomes a burden to the patient.

In all, 25% lime water showed significantly increased hardness when compared with control and other treatment groups. Hardness refers to overall strength of a material and in orthopaedic casting, strength is highly required. POP is a dependable casting material in orthopaedic/rehabilitation medicine [2,6]. And increasing the overall strength of POP brings an
additional advantage. Also, the 25% saline had significantly reduced BD as against all the treatment group and control which presented increased values.

It is obvious that with increased hardness and reduced BD recorded by 25% lime water as against the traditional use of water as the sole solvent for POP, the weight usually associated with POP in orthopaedic procedure and practice will be significantly reduced. There are instances were casting is required to bear load in which case strength and increased hardness is in focus. In lower limb casting that involves the heel, adding lime water will increase the strength of POP that can withstand weight and/ or pressure.

Also the significantly lower apparent porosity recorded with 25% lime water supports the finding here that states increased hardness for 25% lime water. Reduction in apparent porosity translates to lower permeability to water which is an advantage for POP casts in general both for orthopaedic, arts and construction purposes.

Pozzi et al [6], reported POP impression casts that was used to manufacture endoprosthesis yielded good result and with lime water added, the resultant increase in hardness and low BD will assure better guarantee in the production of endoprosthesis. Serial casting has been shown to be a viable alternative to surgical procedure in the early onset scoliosis [8,9]. Strength and low weight with less water permeability is the hallmark of POP casts. Twenty five percent (25%) lime water as demonstrated in this study will provide additional advantage to serial casting for early scoliosis management.

CONCLUSION
In the light of the foregoing, addition of lime water in Plaster of Paris preparation will provide additional strength, decrease water permeability and at the same time, reduce its bulk density. All these advantages will improve casting in orthopaedic cases and construction industry.

ACKNOWLEDGEMENTS
I most sincerely acknowledge the entire staff and students of Prosthetics and Orthotics Department, Federal University of Technology Owerri Nigeria for their support to us during the work.

Conflict of interest: Non declared
Grant support: Non
REFERENCE