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VIABILITY OF CARDBOARD SPLINTS IN THE EMERGENCY MANAGEMENT OF LOWER LIMB FRACTURES

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ABSTRACT

At Mbarara Regional Referral Hospital Uganda, 60% of all admissions are due to severe trauma, 30-35% of which are from tibia/fibular fractures. Emergency splinting of these fractures can be lifesaving and ideally, Plaster of Paris (P.O.P) is the gold standard. Improvised cardboard splints have replaced P.O.P, since they were more readily available and thought to be less expensive to apply especially during the covid 19 pandemic supply chain crisis. While anecdotal evidence exists dating since the First World War, scarce published works exist in measuring the clinical effectiveness of cardboard splints in comparison to P.O.P. The aim of this study was to find out if cardboard can be an effective and cheaper emergency alternative splint to P.O.P especially during the supply chain crises frequent in low resource environments.

A prospective, experimental, cadaveric study was done where 44 open tibia-fibular fractures were splinted with both cardboard and P.O.P. The clinical effectiveness of cardboard and P.O.P splints was found through the measurement of immobilization at a fracture site via the use of 5 angular and 9 linear measurements. Cost comparisons of the splint were also done. Cardboard proved to be the non-inferior splint in 9 of the 14 measures of effectiveness. In the other 4 measures, no statistically significant differences were seen, while P.O.P was superior in 1 measurement. Cardboard proved to be the least expensive splint. During extreme shortages, cardboard could be considered as an emergency material for adequate splinting of lower limb fractures.

Introduction

Trauma accounts for a significant amount of hospital admissions in Africa, with road traffic accidents being a major cause of these accidents (CDC, 2018; Chalya et al., 2012; Chigblo et al., 2017). In Uganda, leg fractures are the commonest long bone fractures (Hsia et al., 2010), with very high complication rates and cost of treatment (Clelland, Chauhan, & Mandari, 2016; Heckman & Sarasohn-Kahn, 1997). At Mbarara Regional Referral Hospital (MRRH), the high incidence of assault and road traffic accidents (specifically motorcycle) make up a significant number of severe cases and hospital emergency admissions (Kisitu et al., 2016; Shikaro, Harborne, & Deus, 2018). With up to 35% of all emergency department visits being due to tibia-fibula fractures (Hsia et al., 2010; Shikaro et al., 2018), these injuries are a source of severe morbidity and mortality and places a significant burden on hospital resources.

As part of emergency treatment of these fractures, splints are the recommended first line modality. These are rigid material that maintain a body part in a fixed position, but do not encompass the circumference of the whole limb like a cast (Boyd, Benjamin, & Asplund, 2009). These temporary splints reduce bleeding, pain, infections, tissue damage and incidence of other complications (Surgeons, 2018). The recognized gold standard since 1852 remains Plaster of Paris (P.O.P) as is commonly used in most hospitals (Carl R. Chudnofsky; Louis solomon, 2010). At MRRH, just as in many African hospitals, the government subsidizes healthcare, but the number of patients typically overwhelms the hospital resources necessitating patients to go out-of-pocket and outrightly pay market prices for the medical services required (Biryabarema, 2018; Mawa, 2018). This is a challenge for a large proportion of Ugandans who live below the poverty line and are therefore cannot afford P.O.P (Statistics, 2018; Wandera, Kwagala, & Ntozi, 2015). Couple this with the myriads of perennial local supply chain challenges, the covid 19 pandemic unearthed a more severe crisis in local and international supply (Lugada et al., 2022). While some local manufacturing exists for P.O.P, majority of the country's supply was imported, leading to severe product shortages (Chowdhury, Paul, Kaisar, & Moktadir, 2021).

Cardboard has been used as a substitute for P.O.P for the temporary splinting of fractures since the First World War (core, 2000; Hu et al., 2011). This has since been extensively adopted in the prehospital care of patients as an emergency splinting material easily applicable with household resources (Austin Smith, 2019). It is a robust paper-based material mainly used for packaging and almost universally available both in and out of the hospital (Brouhard & Menna, 2019; Hao & Xie, 2014; Ranganadham, 2024). P.O.P is a gypsum rock that has been ground up and impregnated into cloth which when exposed to water, reforms back into a rock hard material in the shape it has been molded into (Colditz, 2002). When done right, cardboard can be splinted using similar techniques and materials as P.O.P, making them very similar, more-so in resource limited areas (Hu et al., 2011; Langley-Hobbs, Abercromby, & Pead, 1996; W.H.O, 2020).

Measurement of immobilization of splints is done by looking at the splints ability to resist deformity, typically first tested in animals (Langley-Hobbs et al., 1996; Louis solomon, 2010). Due to the challenges of measuring effectiveness of these splints in-vivo (such as worsening deformities, increasing pain or bleeding and the possibility of inflicting permanent damage while performing the proposed measurements), a cadaveric approach was used to circumvent this. The use of angles (degrees) and linear measurement (centimeter) is used to compare the modality of splinting that is most resilient. Certain set-points are used to measure the distance the limb has moved when force is applied, and an angle at the fracture site can also be measured with the help of a goniometer, where the fracture is considered as a pathological joint (Burrows, 1966; Malanga & Mautner, 2017).

While cardboard is considered a waste material in many institutions, P.O.P is costly (Parmar et al., 2014).While the raw material costs may favor cardboard, many experts believed it took longer to splint with cardboard as opposed to P.O.P, therefore negating its advantage (Gocke, Tintinalli, Cline, Ma, & McGraw-Hill Education (Firm), 2015).

Although widely used and unofficially endorsed, minimal published data exists in the use of cardboard as a splinting material, even less when comparing it to the gold standard in-vivo. With patient safety being of paramount importance, studies of effectiveness would prelude safety research. This endeavor therefore sought to find out if cardboard was an effective alternative to P.O.P in terms of effectiveness and costs.

Methods

The study was conducted at the Anatomy and Pathology dissection laboratories where 44 cadaveric limbs suitable for dissection were used, following a pilot study of 10 limbs prior, in a prospective, experimental study design. These were adult unclaimed cadavers without any missing tissue, fractures, or obvious deformity. Cadavers were considered unclaimed after a minimum of 2-week storage, all reasonable methods of tracing were deemed futile and confirmation by local police, judiciary or follow up from local political leaders in local media publications yielded no next of kin or tangible results. Outright donation of bodies was also considered in the study. Cause of death was ascertained from the official mortuary record after confirmation by a pathologist. A steel frame jig was designed to enable accurate and reproducible measurements where 3 different fracture types were created using a hand saw based on the most common fracture patterns. These were all open fractures and a combination of proximal, mid-shaft and distal third fractures in proportion to their prevalence of presentation (Brown, Skaggs, Brady, Tumusiime, & White, 2020; Chigblo et al., 2017; Clelland et al., 2016). Both limbs for every cadaver was used during the study. Three trained research assistants would then take baseline measurement and follow by randomizing which splint was applied first (but both splinting modalities would be applied on the same leg as to act as its own control). Each research assistant was responsible for each splinting modality as well as data collection. Five angular and nine linear measurements were recorded after the standard WHO based splinting protocol was used using a tape measure and a goniometer (W.H.O, 2020). Both linear and angular measurements were used for better demonstration of the more effective splint. These angles and linear measurements were chosen based on what would be feasible, safe and most dramatically different when measured, others were chosen on what was considered clinically unacceptable deformities. Standard weights were used to reduce the effects of rigor-mortis, compensate for different BMIs, and simulate forces that would occur on patient transport as well as to accentuate the differences between the 2 splints for clearer outcomes.

This 5kg standard weight was placed at the toes of the cadaver creating a fulcrum at the fracture and therefore a more clearly defined fracture deformity. An independent observer was availed to confirm adequate and correct splinting technique. These splinting materials were standard government of Uganda supplied P.O.P 10cm wide and cardboard boxes of 4mm thick, double layered, corrugated, unpainted boxes typically used for packaging IV fluids. Each limb received 10-12 layers of P.O.P ½ circumference of the limb while cardboard was 2 layers thick, ¾ circumference of the limb (circumference of cardboard was described by the inventor(Sheldon & Sebastian, 1959)).

The fractures once created, would be splinted using either P.O.P or dry cardboard and measurements taken. These measurements were meant to show difference in limb reduction, resistance to deformation and resilience of the splint. For effective reduction, the length of the limb was measured pre and post splinting and a better splint would be the one closest to baseline.

Distraction and compressive forces were also used to demonstrate effective resistance against limb lengthening and reduction. For resilience, the angles made at the fracture site would be measured after application of a standard weight as well as measuring the distance from a set point on the jig to the limb. Bigger angles at the fracture site as well as shorter lengths to set points when compared to baseline, would demonstrate worse immobilization. Flexion at the knee and ankle were also used for comparison.

Cost data was collected in terms of resource costs and time. The total amounts of materials needed per splint were costed to the nearest whole item and compared to average cost of items from the Joint Medical Store Uganda (JMS)- a parastatal organization for supplying pharmaceutical items to hospitals. Time was also used. The average time taken to create the splint was measured. This was converted into monetary value by multiplying the time with the most recent salary scale for a medical officer who would typically be applying the splint.

Data was then collected in tables, entered into Epidata Version 3.1, and analyzed using STATA version 12.1 or EXCEL 2013. Variables were expressed using frequencies, means and standard deviations while comparison was done using T-Test and confidence intervals. A power of 80% and an alpha of <0.05 was considered significant.

Ethical Considerations

Express consent was received from the relevant departments including the office of the dean of medicine for Mbarara University of Science and Technology. Further approval was given by Mbarara University of Science and Technology Research Ethics Committee (MUST REC) (ref: MUST-2021-50) and Uganda National Council for Science and Technology (ref: HS1357ES). All cadaveric specimens were handled with dignity and respect as per the code of tissue handling of anatomists.

Results

Table 1 Baseline characteristics of cadavers

Characteristic	Frequency	Percent
Male sex	44	100
Age in years #		
<25	8	18
25-49	28	64
≥50	8	18
BMI in Kg/m2		
<18.5	6	14
18.5 to <25	24	55
>25	14	31
Cause of death		
Trauma	16	36
Other	28	64
Other causes of death*		
Alcohol intoxication	2	7

Characteristic	Frequency	Percent
Drowning	4	15
Hanging	6	21
Medical illness	12	43
Old age	2	7
Respiratory illness	2	7
Duration since death		
<15 days**	6	14
15-29 days	10	22
>30 days	28	64
Fracture location		
Proximal 1/3	9	21
Mid shaft	12	27
Distal 1/3	23	52

#Median age=31 years (IQR 25-42); BMI: Body mass index

* Assessed only among non-trauma cadavers (n=28)

** Duration since death minimum is 12 days

All samples are from 22 cadavers which yielded 44 cadaveric legs/ samples.

Table 2 comparison of cardboard and plaster of Paris measurements (liniear limb length).

	Cardboard	Plaster of Paris	
Measurement	**Mean (95% CI)**	**Mean (95%CI)**	**P value**
Average limb length in Cm	103 (101 - 104)	102 (101 - 104)	0.2082
Distraction with standard weights in Cm (limb length)	106 (104 - 107)	105 (104 - 107)	0.502
Compression with standard weights in Cm (limb length)	104 (103 - 105)	103 (102 - 105)	0.520

As shown above, the results of what would be considered the efforts of reduction. These show that for both modalities, there would be similar degree of reduction at the fracture site as compared to the other splinting modality as this was being compared to the average limb length.

Table 3 Comparison of cardboard and plaster of Paris measurements (linear measurements)

	Cardboard	Plaster of Paris	
Measurement	**Mean (95% CI)**	**Mean (95%CI)**	**P value**
Maximum knee flexion in Cm	74 (71 - 78)	67 (64 - 70)	0.001
Maximum ankle plantarflexion in Cm	81 (80 - 83)	81 (79 - 83)	0.702
Fracture lateral rotation with standard weights in Cm	32 (29 - 35)	24 (23- 25)	<0.001
Fracture Posterior bending with standard weights in Cm	55 (52 - 58)	43 (41 - 45)	0.001
Fracture Valgus deformity with standard weights in Cm	31 (30 - 33)	26 (24 - 27)	<0.001

Referencing above table 3, cardboard was a more resilient splinting material than plaster of Paris in all measurement except for maximum plantarflexion. For all values above, a higher value signifies a more effective splint.

Table 4 Comparison of plaster of Paris and cardboard measurements (angular measurements)

Measurement	Cardboard	Plaster of Paris	P value
	Mean (95% CI)	Mean (95%CI)	
Maximum knee flexion in degrees	15 (10 -21)	49 (42 - 57)	<0.001
Maximum ankle plantarflexion in degrees	42 (38 - 47)	49 (45 - 53)	0.001
Maximum ankle lateral rotation in degrees	38 (33 - 43)	39 (36 - 43)	0.536
Fracture lateral rotation with standard weights in degrees	43 (39 - 48)	54 (51 - 58)	0.001
Fracture posterior bending with standard weights in degrees	10 (9 - 12)	21 (18 - 23)	<0.001
Fracture valgus deformity with standard weights in degrees	9 (8 - 10)	14 (12-15)	<0.001

The above table shows that cardboard was a more resilient splinting material as compared to Plaster of Paris except for in maximum lateral rotation in degrees. For all values above, lower value signifies a more effective splint.

Table 5 Cost Comparisons

Cost variable	Cardboard	Plaster of Paris	P value
	Mean (95%CI)	Mean (95%CI)	
Time in minutes	5.5 (4.9 - 6.2)	5.4 (5.0 - 5.8)	0.587
Labor costed in time in UGX	13,807 (12,197-15,417)	13,523 (12,444-14,601)	0.768
Cotton cost in UGX	3,738 (2,454 - 3,022)	3,022 (2,742 - 3,303)	0.007
Crepe bandage cost in UGX	2,920 (2,751 - 3,090)	3,475 (3,323 - 3,626)	<0.001
Total cost in UGX*	**36,645 (35,009-38,281)**	**55,199 (54,081-56,318)**	**<0.001**

*Includes costs for cotton, Plaster of Paris (18,000/= per splint for Plaster of Paris), labor costs of 75,000/= per hour per doctor for two doctors, other costs amounting to 17,179/= per splint for gowns, gloves, bandages and tape and other sundries. **1 USD = 3563 UGX.**

Table 5 above shows that time and resource cost being considered, cardboard was significantly cheaper. Although there was no significant difference in the time it took to splint between the two modalities.

Overall, Cardboard was found to be the more resilient of the two splinting materials, and the relatively cheaper option.

Summary

- Fracture reduction after splinting- Limb length was similar when reduction was done with both cardboard and P.O.P, meaning both modalities offered similar tissue reduction.
- Resistance to deformation-Cardboard had more resilient linear and angular measures across multiple parameters meaning cardboard was better at resisting deformation.
- Cost per Splint- Cardboard would cost 18,554 UGX (5.1 USD) cheaper than plaster of Paris per splint and cardboard was the cheaper method of splinting an open tibial-fibula fracture.
- Time needed to splint- Equal time was experienced when using both splinting modalities. Equal time may translate to similar ease of application per splint

Data was collected for 3 months, and all data was eligible for analysis, and those not normally distributed transformed by multiplying with Log base 10. The cadavers were mainly male, middle aged with normal BMI, who died of non-traumatic causes.

Discussion

Several findings were noted in the study. In terms of demographics', only men were found in the study. This is comparable to other studies in different countries where cadavers are sourced through unclaimed bodies. This was similar for the age at death as well as cause of death This was also noted as males were more commonly associated with fatal traumatic incidents. Other social factors such as religion, support structure (i.e. children) and homelessness are more likely to have women claimed by family and buried appropriately, while men would remain unclaimed (Hunt & Albanese, 2005; Independent, 2020; Kramer, Hutchinson, Brits, & Billings, 2019; Oporia et al., 2018; Srimani, Mazumdar, & Majumdar, 2017). Since anatomists typically screen against trauma patients, those with gross deformities or missing tissue, this value is skewed away from trauma patients. Even with this skew, the number of non-traumatic cases were not disproportionately higher than what is the expected cause of mortality as seen in many cadaveric specimens (Noriki et al., 2019; Srimani et al., 2017). As seen in the correlating study, many of the cadaveric samples favor medical illness due to preservation of tissue making them suitable for dissection.

When comparing the linear measurements, it was of note that cardboard splints were able to offer similar fracture reduction as compared to P.O.P. Considering the study used a variety of different fracture locations to increase generalizability, cardboard proved to be a versatile splint. Surprisingly, the degree of immobilization across the different types of fracture sites was similar across the two different splinting materials, but a larger sample may improve on this data. As per the other linear measurements, cardboard proved to be the resilient splint. This was also replicated in angular measurement. Maximum ankle plantarflexion was significant in degrees since a small linear change could result in a larger angular change.

Although no studies have been previously done directly comparing these splinting materials, some mechanical studies have been done separately to investigate this. 12-layer cylindrical pieces of P.O.P were found to withstand about 36.6 N/mm² which would be equivalent to 36.6 kg of force before significant deformation (Langley-Hobbs et al., 1996; Parmar et al., 2014; Vieira et al., 2011). This is compared to similar cylindrical double layer cardboard which could withstand approximately 43.0N/mm², equivalent to 43 kg of force before deformation. Although the methods of these mechanical study were not the same, they were sufficiently similar for direct comparisons to be made, showing cardboard could be a great splinting modality (Langley-Hobbs et al., 1996; Parmar et al., 2014; Vieira et al., 2011).

Time is a critical factor in the emergency department and the faster things can be done, the better results are achieved for the patient (Carl R. Chudnofsky). Therefore, a splint that takes a shorter time to apply indicates that it is user friendly and versatile. Splinting done by an experienced practitioner takes 3-15 minutes depending on the type of fracture (Anne S. Boyd, 2009) , this falls in line with both the times seen in cardboard and Plaster of Paris. Since there was no significant difference in time seen in splinting of both cardboard and Plaster of Paris, it would suggest both are equally versatile and user friendly.

In terms of cost, although the difference between the two splinting modalities appears insignificant (5.1 USD), but when taking the average household expenditure and average income into consideration, the difference is compounded. A cardboard splint would cost an average Ugandan 22% of their monthly income and 39 % of their monthly household expenditure (Statistics, 2018). This is in comparison to P.O.P which would cost approximately 33% of monthly income and 57% of monthly household expenditure. This may make P.O.P unattainable to many citizens and thus access to this specific type of healthcare, and thus encouraging the unofficial use of cardboard as the cheaper option.

Limitations

This was a cadaveric study. Although extremely similar, some biomechanics may be different when

compared to live patients. It was evident, that no female and pediatric cadavers were available for use in this study. Also, this being a lower limb study, findings may not be directly translatable to other limb or different presentations of fractures. This was also a point assessment and temporal assessment of the effectiveness of the splints was not done to compare its efficiency over time or with wear and tear. We could not account for microscopic pathologies of the limbs not clinically apparent or recorded. We only tested brands of materials typically sourced by and supplied to government hospitals.

Conclusions

Cardboard was not inferior to Plaster of Paris in splinting of various types of open tibia-fibular fractures and would be considered a more resilient splint than Plaster of Paris in many of the parameters used to measure effectiveness of splints. Plaster of Paris and cardboard are both great modalities of splinting leg fractures and both would adequately immobilize a limb if adequate care and technique are employed, with emphasis on open tibia-fibular fractures. Cardboard was also a cheaper alternative to Plaster of Paris for the emergency splinting of open tibia-fibular fractures. While the authors do not advocate for the outright splinting of fractures with cardboard, as an emergency use material such as during supply chain shortages and pre-hospital care, cardboard would a reasonable material for the splinting of lower limb fractures.

Conflict of Interest:

None

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Appendix

Figure 1 Standard Jig

Demonstration of the standard jig. It is adjustable in both height and length (a) but not width. It has 2 clamps for securing the leg at the same point every time (b). Multiple clamps are available for different sizes of the leg. The set points were to the edges of the width (c) which was standard since the leg was secured in the same way every time. The standard weight (d) was a 5 L (5kg) container.