Does the location of short-arm cast univalve effect pressure of the three-point mould?

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Abstract

Purpose Forearm and distal radius fractures are among the most common fractures in children. Many fractures are definitively treated with closed reduction and casting, however, the risk for re-displacement is high (7% to 39%). Proper cast application and the three-point moulding technique are modifiable factors that improve the ability of a cast to maintain the fracture reduction. Many providers univalve the cast to accommodate swelling. This study describes how the location of the univalve cut impacts the pressure at three-point mould sites for a typical dorsally displaced distal radius fracture.

Methods We placed nine force-sensing resistors on an arm model to collect pressure data at the three-point mould sites. Sensory inputs were sampled at 15 Hz. Cast padding and a three-point moulded short arm fibreglass cast was applied. The cast was then univalved on the dorsal, volar, radial or ulnar aspect. Pressure recordings were obtained throughout the procedure.

Results A total of 24 casts were analyzed. Casts univalved in the sagittal plane (dorsal or volar surface) retained up to 16% more pressure across the three moulding sites compared with casts univalved in the coronal plane (radial or ulnar border).

Conclusion Maintaining pressure at the three-point mould prevents loss of reduction at the fracture site. This study shows that univalving the cast dorsally or volarly results in less pressure loss at moulding sites. This should improve the chances of maintaining fracture reductions when compared with radial or ulnar cuts in the cast. Sagittal plane univalving of forearm casts is recommended.

Introduction

Forearm and distal radius fractures are among the most common fractures in children.[1,2] Many fractures are definitively treated with closed reduction and casting, however, the risk for re-displacement is high (7% to 39%).[3-6] Orthopaedic surgeons have been interested in determining risk factors for displacement for many years. The majority of risk factors can be placed into two broad categories which are either associated with the fracture or associated with the quality of the cast. Risk factors that are associated with the fracture include the obliquity of the fracture, initial displacement, fracture comminution and quality of the reduction. The risk factors associated with the quality of the cast include cast index, padding index, Canterbury index, second metacarpal radius angle, gap index and the three-point index.[6-12] The three-point mould refers to the three regions of the cast that apply force to the forearm for a typical dorsally displaced distal radius fracture; proximal and distal to the fracture site dorsally and at the level of the fracture volarly, to prevent re-displacement until bone healing occurs. Many of the risk factors correlate with the ability of the three-point mould to adequately apply force to the extremity as the fracture heals.

Paediatric forearm fractures are also at risk for compartment syndrome.[13] Many healthcare providers cut the cast on one side (univalve) to decrease the pressure inside the cast.[14,15] It is unknown how univalving effects the pressure of the three-point mould. Hypothetically, the location of the univalve cut may contribute to the loss of reduction. The aim of this study is to determine if there is a difference in how much pressure is lost over the three-point moulding sites based on the location of the univalve cast cut in a short-arm cast model.

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Material and methods

An arm model (SKU #1530-1-1; Sawbones, Vashon Island, Washington, USA) was used for all casting procedures. Nine force-sensing resistors (406 FSR, Interlink Electronics, Camarillo, California, USA) were used to collect pressure data. Five sensors were placed on the dorsal aspect and four sensors were placed on the ventral aspect of the forearm as previously described (Fig. 1).[16] Sensory inputs were sampled at a rate of 15 Hz using an Arduino Uno microcontroller and in-house software (Sparkfun, Niwot, Colorado, USA). The sensors were calibrated using traction weight plates stacked for a total of 6.76kg. We controlled for the sensor's hysteresis by calibrating the sensor through decreasing the pressure and then calculating a fit line using standard curving fit functions in Matlab (Mathworks, Natick, Massachusetts, USA).

A stockinette was placed over the sensors. Casts were applied using the same technique by one author. One layer of cast padding was applied to the arm, overlapping 50% with each wrap. The same amount of cast padding was used for each cast to minimize variability. In clinical practice, the amount of cast padding can affect the maintenance of reduction, therefore, minimal cast padding was used to simulate the actual clinical scenario. We use cast padding instead of waterproof liner after all acute fracture reductions. Three-inch fibreglass cast tape (Scotchcast Plus Casting Tape; 3M, Maplewood, Minnesota, USA) was dipped in room temperature water and applied to the arm model, two layers thick, overlapping 50% with each wrap. Fibreglass was chosen instead of plaster because it is common practice at our institution and region to place children in a fibreglass cast after fracture reduction. Fibreglass is favoured due to its durability and light weight. A three-point mould was applied to the arm as previously described by Charnley[17] (Fig. 2). Fluoroscopic images
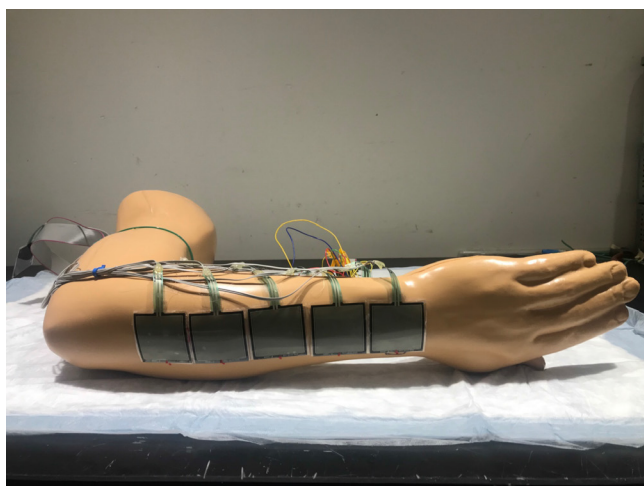
were obtained. The cast saw was then used to univalve cut either the dorsal aspect, volar aspect, radial border or ulnar border. The cast was then spread with a cast spreader, two standard 3-mm width cast spacers were placed along the forearm. One was placed at the junction of proximal and middle third of the forearm and one was placed at the junction of the middle and distal third of the forearm. The cast was lightly wrapped with Coban.[18] Pressure recordings were obtained over the distal radius mould as well as the mid volar mould and the proximal dorsal mould (the three points of the three-point mould). This was repeated six times for each cut.

Pressure change (pre-valve pressure minus post-valve pressure) at the three-point moulding sites were determined for each trial. The difference in pressure of each sensor was calculated for each trial. This allowed for internal standardization. The difference in pressure was averaged for each group. The average change across the three-point mould sites was compared between groups using two-sample t-tests and one-way analysis of variance tests with a two-sided level of significance of 0.05. Additionally, the pre-valve pressures were averaged and compared with the averaged post-valve pressures. Averaging

Fig. 2 Moulded cast on arm model. The arrows represent the forces that are being applied at the three-point mould sites as described by Charnley.[17]

Fig. 1 Arm model with force sensing resistors.

pressure forces in this manner does not allow for internal standardization, however, it does provide helpful information about Newton forces at mould sites. The cast index was calculated and normalized to the dimensions of the arm model.[9]

Results

Cast index

The mean cast index was 0.58 (SD 0.015) and all cast indices were below 0.7 which demonstrates appropriate cast moulding.

Loss of force after univalve cut

The process of univalving the cast decreases pressures at the three-point mould sites (Fig. 3). Cutting the casts along the volar surface decreased the pressure at the three-point mould by 29%, cutting the casts on the dorsal surface decreased the pressure by 26%, cutting the casts along the radial border decreased the pressure by 44%, and cutting the casts along the ulnar border decreased the pressure by 43%.

The cast univalve cut location differentially affected the forces at the three-point mould. Casts that were univalved in the sagittal plane (volar or dorsal surface) retained 16% more force over the three-point mould when compared with casts univalved in the coronal plane (ulnar or radial border) (p < 0.001; 95% confidence interval (CI) 8.3 to 23.9) (Fig. 4). There was no difference in pressure loss in casts cut on the volar surface compared with casts cut on the dorsal surface (p = 0.643; 95% CI -10.7 to 17.0). There was also no difference in casts cut on the radial border compared with casts cut on the ulnar border (p = 0.802; 95% CI -9.4 to 7.3). A post hoc power analysis determined that the power for the comparison of interest (sagittal plane versus coronal plane) is 98.4%.

The casts univalved in the sagittal plane still maintained more pressure over the three-point mould sites when the data was calculated by averaging the pre-valve Newton forces and comparing it with the post-valve Newton forces. The casts univalved in the sagittal plane lost 3.0 N (SD 2.7) force at the mould sites, while casts univalved in the coronal plane lost 4.6 N (SD 2.1) force (p = 0.005) (Table 1).

Discussion

Forearm fractures and distal radius fractures account for 26% of fractures in children.[19] The majority of these injuries are managed with closed reduction followed by a cast moulded to apply three points of pressure, however, the risk of re-displacement may be as high as 39%.[5] Orthopae-
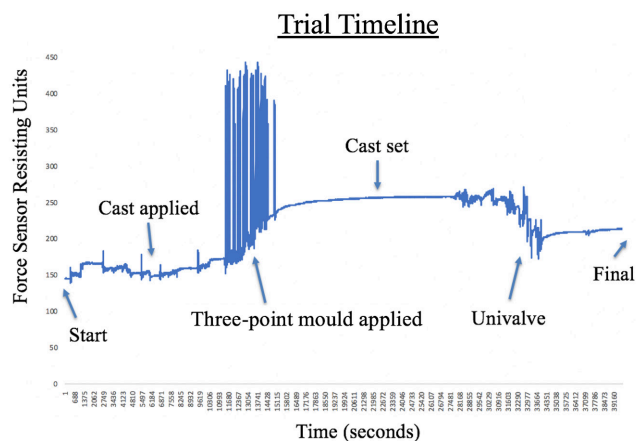

Fig. 3 Trial timeline demonstrating the forces throughout the process of casting, moulding and univalve cutting a cast.
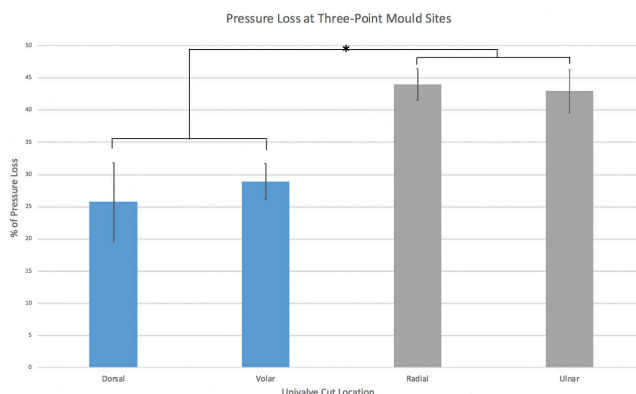

Fig. 4 Averaged percentage of pressure loss across the three-point moulding sites. Casts univalved on the dorsal or volar surface lost 27.3% of pressure compared with casts univalved on the radial or ulnar aspect lost 43.5% of pressure at the three-point moulding sites.

dic surgeons often univalve cut the cast after closed reduction to accommodate swelling.[15] The aim of this study was to determine if the univalve cast cut location differentially effects pressures at the three-point mould sites.

The practice of univalve cutting a cast changes multiple properties of the cast. A biomechanical study applied short-arm plaster casts to mannequin forearms and univalve cut the casts on either the dorsal, volar, ulnar or radial side.[20] The study found that casts cut along the dorsal surface were stronger compared with casts cut on the other areas. Another study explored whether the location of the univalve cut effects how much swelling can occur beneath the casts.[21] Their study aimed to determine if the location of the univalve cut affects how much swelling the forearm can accommodate, which may have clinical implications regarding compartment syndrome. Their study cut casts along the ulnar, radial, dorsal or volar aspects and found that the location of the univalve cut did not

Table 1 Table of forces (N) at each mould point of the three-point mould. Pre-valve and post valve forces are depicted

| Univalve location	Distal dorsal mould					Mid-volar mould					Proximal dorsal mould				
	Pre-valve	SD	Post-valve	SD	Percentage	Pre-valve	SD	Post-valve	SD	Percentage	Pre-valve	SD	Post-valve	SD	Percentage
Dorsal	12.0	2.4	6.1	0.9	49.1	17.6	9.1	18.2	10.1	-3.2	9.1	1.7	6.0	1.5	34.1
Volar	11.7	2.1	8.3	1.3	29.0	13.2	4.2	9.8	2.3	26.0	7.7	1.4	4.9	0.8	35.5
Radial	10.1	1.6	4.9	0.6	51.9	16.6	8.5	10.4	5.5	37.5	8.1	1.9	4.6	0.9	43.8
Ulnar	10.2	2.3	4.9	0.8	51.7	12.2	2.9	8.9	1.9	27.1	7.8	1.6	3.7	0.4	52.8
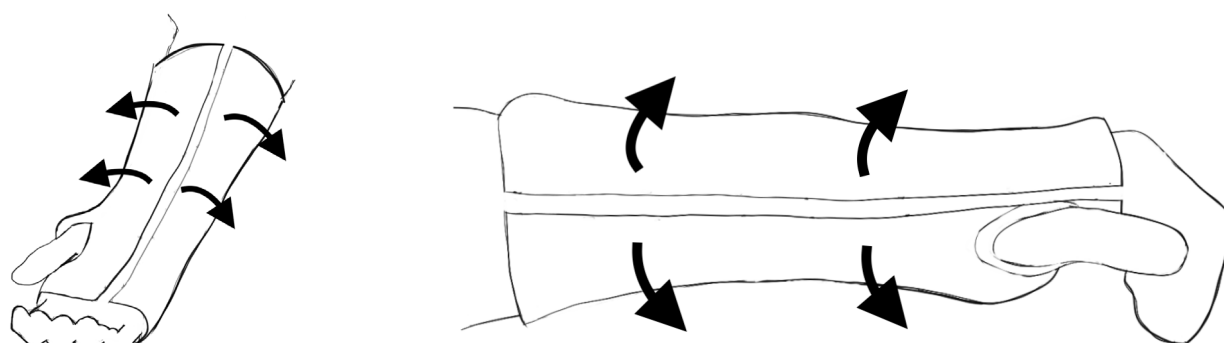
Fig. 5 Illustration of a cast with a univalve cut. The black arrows represents the direction of cast expansion following the univalve cut and spread: **a)** depicts a univalve cut on the volar surface. This shows how the cast expansion occurs perpendicular to the force of the three-point mould; **b)** depicts a univalve cut on the radial border. This shows how cast expansion occurring in the same plane as the three-point mould directly counteracting the forces of the three-point mould.

affect how the forearm accommodates swelling.[21] One can deduce from this study that no matter where the cast is cut and spread it still allows for approximately the same volumetric expansion. Additional biomechanical studies demonstrated univalved fibreglass casts applied with the stretch-relax technique could better accommodate swelling compared with other casting techniques.[15]

This study showed that univalve cutting a short-arm cast on the dorsal or volar surface retains more pressure at the typical three-point moulding sites when compared with univalve cutting a cast on the radial or ulnar border. Therefore, spreading a cast in the plane perpendicular to the three-point mould maintains more force when compared with spreading a cast in the plane parallel to the three-point mould (Fig. 5). Spreading the cast in the parallel plane directly counteracts the forces of the three-point mould. Since casts maintain more force when cut in the sagittal plane, they should also have a better chance of maintaining fracture reductions. We recommend univalve cutting casts in the sagittal plane of forearm casts.

The most logical limitation is that this study is a biomechanical study which was performed on an arm model. This was not a fracture model. The material properties of the arm model are not the same as human tissue and cannot simulate swelling and other biological factors that

contribute to three-point mould pressure after casting. Furthermore, fracture type and location may make a difference in pressure changes.

This study focused specifically on a particular clinical conundrum: does the location of the univalve cut have a differential effect on pressure at the three-point mould sites? This study demonstrated that the location and act of valving has differential effects on the three-point mould. This discovery opens the door to additional interesting and important studies including how bivalving affects the three-point mould, how casts with more complicated multiplanar moulds and interosseous moulds are affected by valving, the effects of waterproof liners, how plaster casts compare with fibreglass casts and how long arm and long leg casts are affected by the valving process.

Conclusion

The location of the univalve cast cut has differential effects on forces of the typical three-point mould for a dorsally displaced distal radius fracture. Univalve cutting the cast on the volar or dorsal surface retains more force at the three-point mould compared with casts cut on the radial or ulnar border.

COMPLIANCE WITH ETHICAL STANDARDS

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No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OA LICENCE TEXT

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ETHICAL STATEMENT

Ethical approval: This research did not involve human participants or animals. This study was a biomechanical study and was exempt from institutional review board approval.
Informed consent: Informed consent was not needed because this study did not involve patients.

ICMJE CONFLICT OF INTEREST STATEMENT

SLF reports payments from publishing companies for editing paediatric trauma textbooks, outside the submitted work.
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AUTHOR CONTRIBUTIONS

BKM: Study design, Data acquisition, Data analysis, Data interpretation, Draft and critical revision of the manuscript.
KHP: Study design, Data acquisition, Data analysis, Draft and critical revision of the manuscript.
SY: Study design, Data acquisition, Data analysis, Data interpretation, Draft and critical revision of the manuscript.
NAS: Data analysis, Data interpretation, Draft and critical revision of the manuscript.
LR: Study design, Data interpretation, Draft and critical revision of the manuscript.
CMP: Study design, Data analysis, Data interpretation, Draft and critical revision of the manuscript.
SLF: Study design, Data analysis, Data interpretation, Draft and critical revision of the manuscript.

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