Under Pressure: The Utility of Spacers in Univalved Fiberglass Casts

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Background: Univalving fiberglass casts after fracture manipulation or extremity surgery reduces the risk of developing compartment syndrome (CS). Previous experiments have demonstrated that univalving decreases intracompartmental pressures (ICPs), but increases the risk for loss of fracture reduction due to altering the mechanical properties of the cast. The purpose of this study was to correlate cast valve width within a univalved cast model to decreasing ICP.

Methods: Saline bags (1 L) were covered with stockinette, Webril, and fiberglass tape then connected to an arterial pressure line monitor. Resting pressure was recorded. A water column was added to simulate 2 groups (n = 5 each) of clinical CS: low pressure CS (LPCS range, 28 to 31 mm Hg) and high pressure CS (HPCS, range, 64 to 68 mm Hg). After the designated pressure was reached, the fiberglass was cut (stockinette and Webril remained intact). Cast spacers were inserted into each univalve and secured with varying widths: position #1 (3 mm wide), #2 (6 mm), #3 (9 mm), and #4 (12 mm). Pressure was recorded after cutting the fiberglass and following each spacer placement.

Results: In LPCS and HPCS groups, after univalve and placement of spacer position #1, pressure dropped by a mean of 52% and 58%, respectively. Spacer #2, decreased the pressure by a mean of 78% and 80%, respectively. Both spacer sizes significantly decreased the underlying pressure in both groups. Spacer #3 and #4 progressively reduced pressure within the cast, but not statistically significantly more than the previous spacer widths.

Conclusions: This experimental model replicates the iatrogenic elevation in interstitial compartment pressure due to rigid cast application, not necessarily a self-sustained true CS. Increasing the univalved cast spread by ≥ 9 mm of the initial cast diameter will reduce pressure to a pre-CS level; however, a spread of only 6 mm can effectively reduce the pressure to < 30 mm Hg depending on the initial elevated ICP. Cutting the Webril and stockinette in our model yielded a pressure decrease of 91% and 94% from the starting experimental pressure in the LPCS and the HPCS groups, respectively.

Clinical Relevance: Although the utility of splitting fiberglass casts has been previously demonstrated, we present evidence highlighting the benefit of spacing the split by at least 6 to 9 mm.

Key Words: intracompartmental pressures, compartment syndrome, cast spacer

(*J Pediatr Orthop* 2017;00:000–000)

Synthetic fiberglass cast materials became available as an alternative to plaster of Paris in the 1980s. The benefits of fiberglass material have been described as lighter weight, greater strength, relative radiolucency, resistant to water, and cleaner to apply.[1–3] Because of to these added benefits, fiberglass casts are frequently utilized to immobilize a fractured limb.[3]

In the acute fracture care setting, applying a circumferential cast can increase intracompartmental pressures (ICPs) potentially leading to compartment syndrome (CS). Cast valving is a commonly practiced technique to reduce pressure associated with limb swelling.[1,4–9] This technique has been shown to significantly decrease the pressure inside a cast model.[1,4] The disadvantage of cast valving has been associated with compromising the biomechanical properties of a fiberglass cast.[10] Although cast valving is commonly practiced, the orthopaedic literature fails to demonstrate a specific valving technique that offers substantial pressure reduction, while maximizing cast integrity. The purpose of this study was to correlate the width of the cast valve, within a univalved cast model, to decreasing ICPs.

METHODS

One-liter IV saline bags were partially emptied (200 to 250 mL) before being casted with a 2-inch stockinette, wrapped in Webril (50% overlap), then casted with 1 entire roll of a 3" fiberglass tape. The stockinette, Webril, and casting material were applied to involve the entire length of the saline bag. The bag was then connected to a pressure transducer (PX260, Edwards Lifesciences Corp., Irvine, CA), which was attached to a patient monitoring system (GE Dash 3000, GE Healthcare, Milwaukee, WI). The resting pressure of the casted saline bag was recorded

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No support or funding was received in collaboration with this work.

The authors declare no conflict of interest.

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DOI: 10.1097/BPO.0000000000000961

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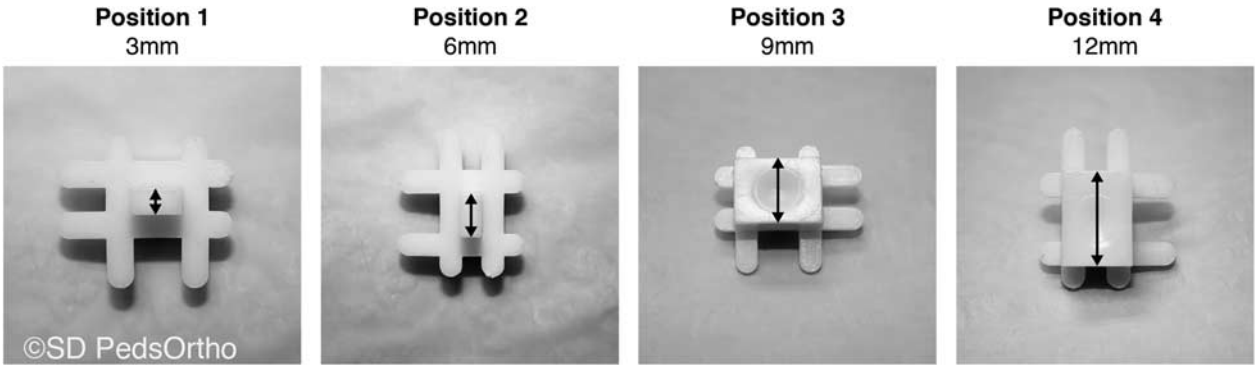

FIGURE 1. Cast spacer positions. Figure reproduced with permission from San Diego Pediatric Orthopedics (© SD PedsOrtho).

before applying the desired starting pressure. To increase the pressure within the saline bag, a water column was connected to the closed system with a Y-connector. Water was then slowly added to the column to titrate up to the desired starting pressure. Once this pressure was reached, the pressure was recorded and the cast was univalved with a cast saw (940 Cast Cutter, Stryker, Kalamazoo, MI).

The study was devised into 2 separate groups, the high pressure compartment syndrome (HPCS) (starting pressure, 64 to 68 mm Hg) and low pressure compartment syndrome (LPCS) (starting pressure, 28 to 31 mm Hg). Five trials (casts) were performed in each group. The HPCS study group was completed first. After the cast was univalved, the pressure was recorded with the Webril and stockinette still intact. Two commercially available cast spacers, Ortho-J Inc. (Tifton, GA) were then placed within the univalve 4 inches from both ends of the cast. The commercially available cast spacer used has 4 available positions to maintain the space of the valve (#1 = 3 mm, #2 = 6 mm, #3 = 9 mm, and #4 = 12 mm; Fig. 1). The cast spacer was initially positioned in the #1 position and the pressure was then recorded. The same technique was performed with the cast spacer in position #2, #3, and #4. After the pressure was recorded in the #4 position, the Webril and stockinette was then cut. The pressure was again recorded with no spacers placed. The LPCS group was studied in the same manner as the HPCS.

Between group comparisons at individual time points was done utilizing a Mann-Whitney *U* test. Evaluation of difference in changes over time (resting, initial CS, and varying spacer positions 1 through 4) was completed with repeated measures analysis of variance to assess the interaction of group and time. Analyses were conducted utilizing SPSS version 12 (SPSS Inc., Chicago, IL).

RESULTS

The 5 trials conducted for the HPCS had a mean starting pressure of 66.2 mm Hg ranging 64 to 68 mm Hg. After the fiberglass was univalved, the pressure dropped on average 74% of the starting pressure. The mean pressure after univalving the cast was 18.6 mm Hg (13 to 24 mm Hg). The average space after univalving the cast was 4 to 5 mm. Spacers in the #1 position (3 mm) were then placed within the valve and the pressure increased by a mean of 27.6 mm Hg (21 to 32 mm Hg) relative to the measured pressure after univalving the cast. This pressure increase was likely due to the need to actually decrease the space of the valve to accommodate and hold a 3 mm (#1) spacer which was less than the initial space of 4 to 5 mm created by the univalve cut alone. Placing the #1 spacer did however decrease the pressure on average 58% when compared with the starting pressure.

The standard compartment syndrome group (LPCS) had a mean starting pressure of 30 mm Hg (28 to 30 mm Hg). After univalving the casts, the pressure was reduced by a mean of 72% of the starting pressure with an average pressure of 7.8 mm Hg (4 to 11 mm Hg). Spacer position #1 was placed and again there was a slight increase in pressure since the valve width after univalving the cast was wider than the #1 spacer. The pressure did however decrease a mean of 52% of the starting pressure with an average of 14.2 mm Hg (12 to 16 mm Hg). The absolute pressure measurements in both the LPCS and the HPCS groups and the percent decrease relative to the starting pressure are summarized in Table 1.

When the pressure readings from the high CS group and the standard CS groups were combined, each subsequent spacer position pressure was significantly different from the previous with the Webril intact ($P = 0.001$) and Webril and stockinette cut ($P = 0.007$). However, the clinical difference between the pressure readings of spacer position #3 and #4 was minimal.

DISCUSSION

Immobilizing limbs in fiberglass casts has provided many benefits to orthopaedic patients.[1–4] The complications that can arise from fiberglass casts are few and mostly benign, however a known severe complication is CS. The sequelae of CS are variable and can be devastating and disabling to the patient.[1]

Valving fiberglass casts has been a practiced technique to prevent the development of CS in an acutely

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TABLE 1. Pressure Reduction After Univalving the Cast and Spacer Placement Comparing the LPCS and HPCS Groups

Univalve/Spacer Position	Average Measured Pressure (Range) (mm Hg)		*P*	Average Pressure Reduction (%) Group 1 (LPCS)	Average Pressure Reduction (%) Group 2 (HPCS)
	LPCS Group	HPCS Group			
Cast before univalve	30 (28-31)	66.2 (64-68)	**< 0.001**	NA	NA
Univalve only without a spacer	7.8 (4-11)	18.6 (13-24)	**0.002**	72	74
Position 1 (3 mm)	14.2 (12-16)	27.6 (21-32)	**0.008**	52	58
Position 2 (6 mm)	6.4 (4-9)	13.2 (8-17)	**0.016**	78	80
Position 3 (9 mm)	5.2 (3-8)	9.2 (6-11)	**0.032**	83	86
Position 4 (12 mm)	5.4 (3-8)	8.2 (5-10)	0.056	82	88
Webril and stockinette cut	2.6 (2-5)	5 (3-11)	0.099	91	94

Bold values are statistical significant with $P < 0.05$.
HPCS indicates high pressure compartment syndrome; LPCS, low pressure compartment syndrome; NA, not applicable.

inflamed limb.[1] The disadvantage of cast valving is loss of fracture reduction and/or inadequately immobilizing a limb, therefore the cast integrity can be compromised.[1–4]

Crickard et al investigated the biomechanical integrity of univalved and bivalved cast models.[10] In their study they created a 3-point bending apparatus to mechanically test cylindrical casts with a univalve, bivalve, and no valve. They found that cast valving significantly decreased the bending stiffness by 28% and load to failure of fiberglass casts. However, univalved casts have a higher load to failure and bending stiffness than bivalved casts, therefore the cast integrity appears to be superior with univalved casts. To our knowledge, the bending stiffness of a univalved cast with the presence of cast spacers has not yet been studied. Placing rigid spacers within the valve and maintaining a specified width may offer improved bending stiffness and load to failure, however this theory presents another potential area for further research.

It has become our custom in clinical practice to univalve the cast and place cast spacers, which are held in place with circumferentially applied tape for the immediate postoperative and/or postreduction period. Cast repair is typically done by removing the spacers, closing the univalve and overwrapping the cast at ~7 to 10 days. The original cast is typically preserved and converted back to a solid cylindrical cast, thereby conserving material. Cutting the Webril and stockinette in our model yielded a pressure decrease of 91% and 94% from the starting experimental pressure in the LPCS and the HPCS groups, respectively. Despite these findings cutting the Webril and stockinette is not routinely done at our facility since the soft material will bunch after the cast is repaired, and may lead to skin complications. In clinical instances when the need to cut the cast and Webril is considered a splint is typically utilized in lieu of a cast.

Ziano et al[11] hypothesized that just cutting the cast could eliminate all clinically relevant pressure. Their study investigated skin surface pressures on patients placed in short-arm fiberglass casts. The study model increased the pressure within the cast by infusing air within an emptied saline bag placed within the fiberglass cast. They investigated 3 test groups which included the following steps: first, alleviating skin surface pressures by initially bivalving the cast and Ace wrap; second, bivalving the cast, spreading, and Ace wrap; and third, bivalving the cast, spreading, cutting the Webril, and then placing Ace wrap. They found that the last technique could eliminate all relevant skin surface pressures; however, Ace wrapping after the cast was valved noticeably increased the skin surface pressure.[11] We also noted this increase in pressure after cutting the cast and then inserting the spacers at their smallest width (3 mm). Cast bivalving is an excellent technique to decrease the risk of developing CS; however, the balance between cast integrity and pressure reduction is likely compromised.[10]

As far as we are aware, our study is the first to investigate the pressure reduction of univalving a cast utilizing commercially available cast spacers. Our study demonstrates a proposed technique of minimizing the risk of developing CS while attempting to maintain maximum cast integrity. We found that placing a 6-mm cast spacer (#2 position) within the univalve provides the greatest decrease in pressure in comparison with the previous position. The purpose of the spacer is to maintain a specified width to ensure an anticipated pressure reduction. Cutting a cast without increased pressure within the cast will not normally cause the cast to spread in a clinical setting. Within our lab setting, we likely saw a pressure reduction of 74% after cutting the cast since the pressure was increased within the cast before before valving the cast. Increasing the cast width to 9 mm (#3 position) further decreases the pressure but not significantly, and perhaps at greater cost to the cast integrity. In addition, increasing the width with another 3 mm (#4 position 12 mm) can also decrease the pressure, but with minimal measureable difference.

The commercially available spacers purchased at our facility are available at Ortho-J Inc. (Kast Spreader). At the time of this writing, an individual spacer cost was $1.19. In clinical practice, we typically utilize 2 spacers for a short-arm cast and 3 to 4 spacers for a short-leg and/or long-arm and long-leg cast. Therefore, the financial impact to utilize these spacers for initial immobilization is roughly $2.38 to $4.76. It is also important to note that reuse of these spacers is possible once swelling has resided and the spacers are removed from the valved cast.

A weakness of this study is that it does not investigate the clinical representation of a patient's comfort

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level after placing each spacer position. A direct correlation to the clinical utility of valving a cast and maintaining the valve with spacers is difficult to make due both to the model itself (eg, having only a single fluid pressure compartment, and not accounting for dynamic pressure increases) and due to not addressing concurrent changes in fracture reduction/stability. On the basis of this experimental model we do not know how the cast spacers would affect the reduction in intra-ICP in a multicompartmental limb, or if the position of the valve in relation to the injured compartment would affect the results. We believe however that valving a cast is aimed at alleviating external pressure and not directly pressure within a specific compartment within a limb.

Another limitation of our study was that following the change from spacer position 3 to 4 the drop in pressure in both experimental groups was not found to be significant. This may be attributable to the small change in pressure that was measured and the number of 5 experimental trials being underpowered. A sample size of 5 was chosen as similar studies have used n = 5 to 6 samples.[12] A post hoc, balanced 1-way analysis of variance power calculation was performed. The trials with spacers in positions 1 to 3 were found to be adequately powered at $\beta \geq 0.80$. For the trials using a spacer in position 4 (12 mm) 12 trials would have been needed to detect a significant decrease in pressure.

This study also does not investigate the mechanical loss of cast integrity while increasing the space of a univalved cast. However, previous studies have suggested that cast integrity will decrease while increasing the circumference of the cast.[10] In our experimental model simply cutting the cast (univalving) without using cast spacers reduced the pressure 74% of the starting pressure, creating a cast gap of about 5 mm. Further study of the effect of a univalve with and without a cast spacer is needed to elucidate the biomechanical effects of this practice. Therefore, we currently recommend utilizing the #2 spacer position (6 mm space) in acutely injured limbs where anticipated limb swelling is mild to moderate. The #3 spacer position (9 mm space) should be utilized if moderate swelling is anticipated. Moreover, the Webril and stockinette (if present) should be cut in the setting of suspected CS because it can contribute to higher retained pressure under the cast; but, the cast should never by compressed to match a smaller width spacer, if the pressure in the limb has already declared the need for a greater circumference. Clinical judgment should be used on each patient on how to valve a cylindrical fiberglass cast; however, we feel that our suggested technique will help decrease the risk of CS while maintaining cast integrity. Although univalving a cast without a spacer is an option our concern is that the variability of the width of the valve could adversely affect cast integrity and may not dissipate pressure as intended. The utility of spacers is thought to help maintain cast integrity as the cast can be held at a set point following a univalve as well as set an intended width depending upon the clinical scenario. Taping the cast closed after placing a univalve actually increased the pressure within our experimental model.

Increasing the spread of the univalved cast by 9 mm or more of the initial cast diameter will reduce pressure to a pre-CS steady-state pressure; however, a spread of only 6 mm can effectively reduce the pressure to < 30 mm Hg (absolute CS) depending on the compartment pressure being observed. A cast spacer of 6 mm likely equalizes the reduction in pressure while minimizing cast integrity loss. If further pressure reduction is clinically warranted, a 9-mm cast spacer should be used. There appears to be no clinical utility of a 12-mm cast spacer being utilized for compartment pressure relief.

ACKNOWLEDGMENTS

The authors would like to thank Tracey Bastrom, MA for statistical assistance and J.D. Bomar, MPH for assistance with figure preparation.

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