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Volumetric Considerations for Valving Long-Arm Casts: The Utility of the Cast Spacer

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Take-Home Points

- Valving a long-arm cast results in decreased cast pressures.
- Univalving can produce a 60% reduction in cast pressure.
- Bivalving produces a 75% reduction in cast pressure.
- Release of the underlying cast padding produces an additional pressure reduction.
- Adding a cast spacer to a univalved cast obtains similar pressure reduction to a bivalved cast.

Complications following closed reduction and casting of pediatric forearm fractures are rare, but they do occur. Arguably the most devastating of these complications is the risk of developing compartment syndrome or Volkmann contracture secondary to injury-associated swelling under a circumferential cast.[1-4] The peak in swelling can develop from 4 to 24 hours following the initial cast application,[5] and as such, medical providers may not be able to identify it early because most children are discharged following closed reductions. For this reason, many providers implement prophylactic measures to minimize pressure-related complications.

A popular method for reducing pressure accumulation within a cast is to valve, or cut, the cast. Previous investigations have shown that cast valving results in significant reductions in cast pressure.[2,6-9] Bivalving a circumferential cast results in significantly greater reductions in cast pressure when compared with univalve techniques;[6,7,9] however, bivalving has also been shown to result in significant impairment in the structural integrity of the cast.[10] An additional method to facilitate cast pressure reduction without impairing the structural integrity of the cast that accompanies a bivalve is to incorporate a cast spacer with a univalve technique to hold the split cast open.[11] Although this method is commonly used in clinical practice, its ability to mitigate cast pressures has not previously been investigated.

The goal of this study is to investigate the influence of incorporating cast spacers with valved long-arm casts. We hypothesized that cast spacers would provide a greater pressure reduction for both univalved and bivalved casts when compared with the use of an elastic wrap. Additionally, we proposed that by incorporating a cast spacer with a univalved cast, we could attain pressure reduction equivalent to that of a bivalved cast secured with an elastic wrap.

Materials and Methods

Upon receiving approval from the Institutional Review Board, experimental testing began with the application of 30 total casts performed on uninjured adult human volunteers. Pressure readings were provided with the use of a bladder from a pediatric blood pressure cuff (Welch Allyn Inc), as previously described.[6] The bladder was placed on the volar aspect of the volunteer’s forearm, held in place with a 3-in diameter cotton stockinet (3M). Cotton cast padding (Webril-Kendall) was applied, 3 in wide and 2 layers thick, and a long-arm cast was applied, 2 layers thick with 3-in wide fiberglass casting material (Scotchcast Plus Casting Tape; 3M).

Once the cast was applied and allowed to set, the blood pressure bladder was inflated to 100 mm Hg. After inflation, forearm cast circumference was measured at 2 set points, assessed at points 2 cm distal to the elbow flexor crease and 10 cm distal to the previous point (**Figure 1**). Using these data, we calculated estimated cast volume using the volumetric equation for a frustum. Following this point, casts were split into 2 experimental groups, univalve or bivalve, with 15 casts comprising each group. The univalve group consisted of a single cut along the dorsum of the extremity, and the bivalve group incorporated a second cut to the volar extremity. Cast valving was performed using an oscillating cast saw (Cast Vac; Stryker Instruments), with care taken to ensure the continuity of the underlying cast padding.

Following valving, casts were secured via 3 separate techniques: overwrap with a 3-in elastic wrap (Econo Wrap; Vitality Medical), application of two 10-mm and 15-mm cast spacers (CastWedge; DM Systems) (**Figure 2**). After securement, cast pressures were recorded, and circumference measurements were performed at the 2 previously identified points. The cast padding was then cut at the valve site and secured via the 3 listed techniques. Cast pressure and circumference measurements were performed at set time points (**Figure 3**). Changes in cast pressure were recorded in terms of the amount of change from the initial cast placement to account for differences in the size of volunteers’ forearms. Volumetric calculations were performed only for the spacer subgroups owing to the added material in the elastic wrap group. Estimated cast volume was calculated using the equation for volume of a frustum (**Figure 4**).

We used a 2-cast type (univalve and bivalve) by 4 securement subgroups (initial, elastic wrap, 10-mm spacer, and 15-mm spacer) design, with cast type serving as a between-subject measure and securement serving as a within-subject variable. An a priori power analysis showed that a minimum sample size of 15 subjects per condition should provide sufficient power of .80 and alpha set at .05, for a total of 30 casts. Statistical analyses were performed using IBM SPSS Statistics software version 21 (IBM). Experimental groups were analyzed using mixed-design analysis of variance (ANOVA). Post hoc comparisons between valving groups and cast securement were performed using Scheffe's test to control for type II errors. Change in cast volume between the initial cast and cast spacers groups was compared using paired Student's t tests. Statistical significance was predetermined as $P < .05$.

Results

A summary of collected data for cast pressure and volume is detailed in **Table 1**, subdividing the variables on the basis of cast type and type of securement. Recorded pressures of the different subgroups are depicted in **Figures 5** and **6** according to type of securement (initial, elastic wrap, 10-mm spacer, or 15-mm spacer). Results of the mixed-design ANOVA demonstrated significant differences between the initial cast pressure and univalve and bivalve groups ($P < .05$). There was a main effect for bivalve having lower pressure overall (F [1, 1)] = 3321.51, $P < .001$). There was also a main effect indicating that pressure was different for each type of securement (elastic wrap, 10-mm spacer, 15-mm spacer) (F [1, 28] = 538.54, $P <. 01$). Post hoc testing confirmed pressure decreased significantly, in descending order from elastic wrap, to 10-mm spacers, to 15-mm spacers ($P < .05$).

The summary of volumetric changes is listed in **Table 2**. The decrease in pressure correlated with an associated increase in cast volume, as demonstrated in **Figure 7**. The degree of increase in cast volume was more pronounced in the bivalve group ($P < .001$). The volume increased in the 15-mm group compared with the 10-mm group for both groups ($P < .001$) and increased for each spacer group with the release of the underlying padding ($P < .05$).

Analysis of the planned comparisons demonstrated no significant difference between the bivalve with elastic wrap and univalve with 10-mm spacer subgroups (t [28] = 1.85, $P = .075$, $d = .68$). In comparing the bivalve with elastic wrap group with the univalve and 15-mm spacer subgroup, the univalve group showed significantly lower pressures [t [28] = 6.32, $P < .001$, $d = .2.31$).

Discussion

Valving of circumferential casting is a well-established technique to minimize potential pressure-related complications. Previous studies have demonstrated that univalving techniques produce a 65% reduction in cast pressure, whereas bivalving produces an 80% decrease.[6,7,9] Our results showed comparable pressure reductions of 75% with bivalving and 60% with univalving. The type of cast padding has been shown to have a significant effect on the cast pressure, favoring lower pressures with cotton padding over synthetic and waterproof padding, which, when released, can provide an additional 10% pressure reduction.[6,7]

Although bivalving techniques are superior in pressure reduction, the reduction comes at the cost of the cast's structural integrity. Crickard and colleagues[10] performed a biomechanical assessment of the structural integrity by 3-point bending of casts following univalve and bivalve compared with an intact cast. The authors found that valving resulted in a significant decrease in the casts' bending stiffness and load to failure, with bivalved casts demonstrating a significantly lower load to failure than univalved casts. One technique that has been used to enhance the pressure reduction in univalved casting techniques is the application of a cast spacer. Rang and colleagues[11] recommended this technique as part of a graded cast-splitting approach for the treatment of children's fractures. This technique was applied to fractures with only modest anticipated swelling, which accounted for approximately 95% of casts applied in their children's hospital. Our results support the use of cast spacers, demonstrating significant reduction in cast pressure in both univalve and bivalve techniques. Additionally, we found that a univalved cast with a 10-mm cast spacer provided pressure reduction similar to that of a bivalved cast.

The theory behind the application of cast spacers is that a split fiberglass cast will not remain open unless held in position.[11] Holding the cast open is less of a restraint to pressure reduction in bivalving techniques, because the split cast no longer has the contralateral intact hinge point to resist cast opening, demonstrated in the compromise in structural integrity seen with this technique.[10] By maintaining the split cast in an opened position, the effective volume of the cast is increased, which allows for the reduction in cast pressure. This is demonstrated in our results indicating an increase in estimated cast volume with an associated incremental reduction in cast pressure with the application of incrementally sized cast spacers. Although this technique does have the potential for skin irritation caused by cast expansion, as well as local swelling at the cast window location, it is a cost-effective treatment method compared with overwrapping a bivalved cast, $1.55 for 1 cast spacer vs an estimated $200 for a forearm cast application.

This study is not without its limitations. Our model does not account for the soft tissue injury associated with forearm fractures. However, by using human volunteers, we were able to include the viscoelastic properties that are omitted with nonliving models, and our results do align with those of previous investigations regarding pressure change following valving. We did not incorporate a 3-point molding technique commonly used with reduction and casting of acute forearm fractures, owing to the lack of a standardized method for applying the mold to healthy volunteers. Although molding is necessary for most fractures in which valving is considered, we believe our data still provide valuable information. Additionally, valving of circumferential casts has not been shown, prospectively, to result in a reduction of cast-related compartment syndrome, maintenance of reduction, or need for surgery.[12,13] However, these results are reflective of reliable patients who completed the requisite follow-up care necessary for inclusion in a randomized controlled trial and may be applicable to unreliable patients or patient situations, a setting in which the compromise in cast structural integrity may be unacceptable.

Conclusion

We demonstrated that incorporating cast spacers into valved long-arm casts provides pressure reduction comparable to that achieved with the use of an elastic wrap. The addition of a 10-mm cast spacer to a univalved long-arm cast provides pressure reduction equivalent to that of a bivalved cast secured with an elastic wrap. A univalved cast secured with a cast spacer is a viable option for treatment of displaced pediatric forearm fractures, without compromising the cast’s structural integrity as required with bivalved techniques.

This paper will be judged for the Resident Writer’s Award.

Key Info

Figures/Tables

Figures / Tables:

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Figure 1. Depiction of standardized points for circumference assessment with proximal mark indicating a 2 cm distal to elbow flexor crease and second mark measured 10 cm distally.

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Figure 2. Clinical image of fiberglass long-arm cast following univalve with placement of two 10-mm cast spacers.

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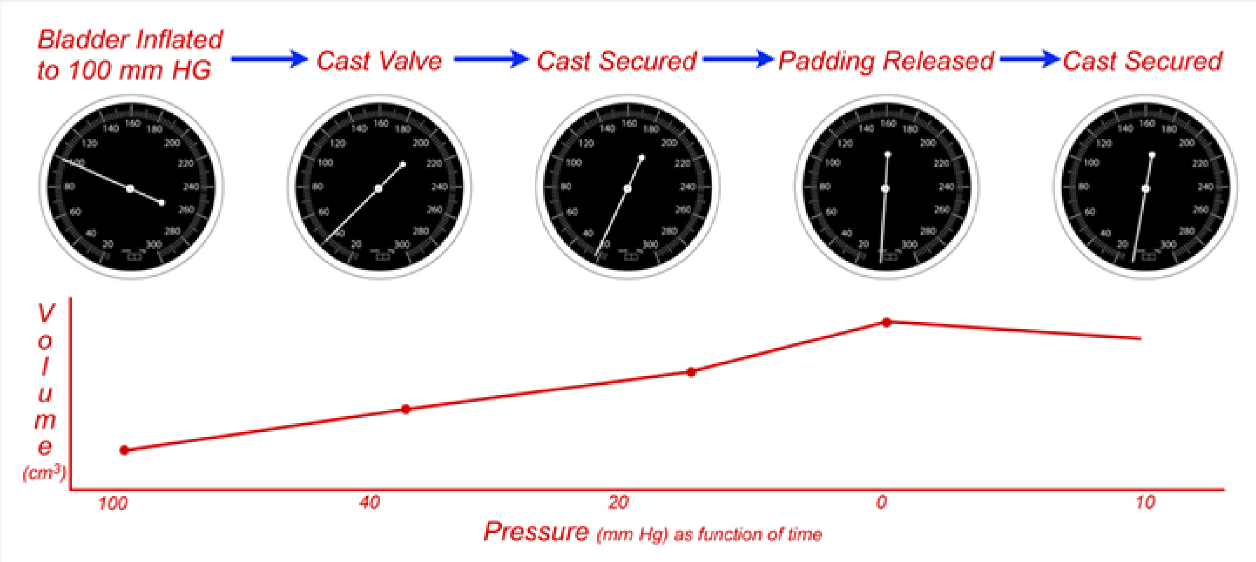

Figure 3. Illustration of time points for data collection.

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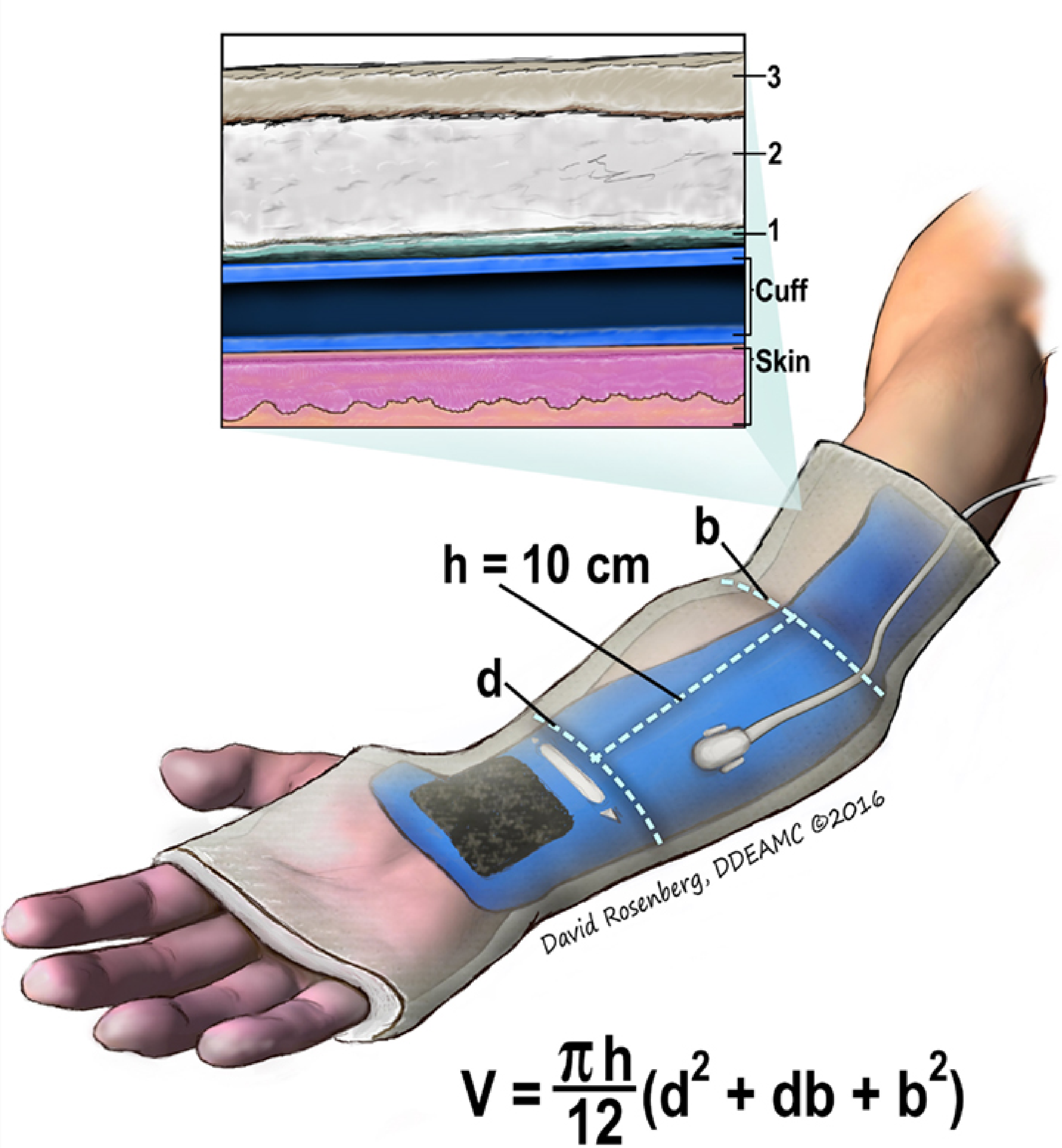

Figure 4. Illustration depicting the method for calculation of estimated cast volume.

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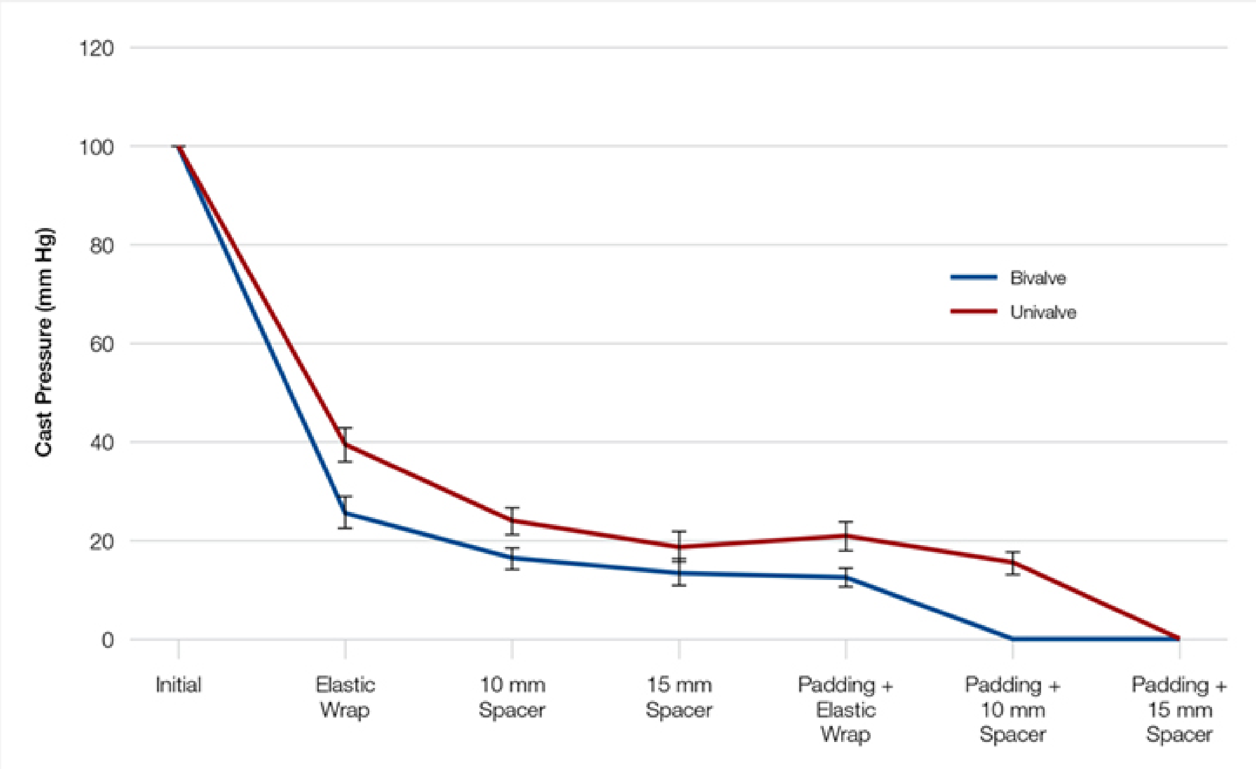

Figure 5. Graphic representation of pressure measurements at each study time point according to cast type (univalve or bivalve).

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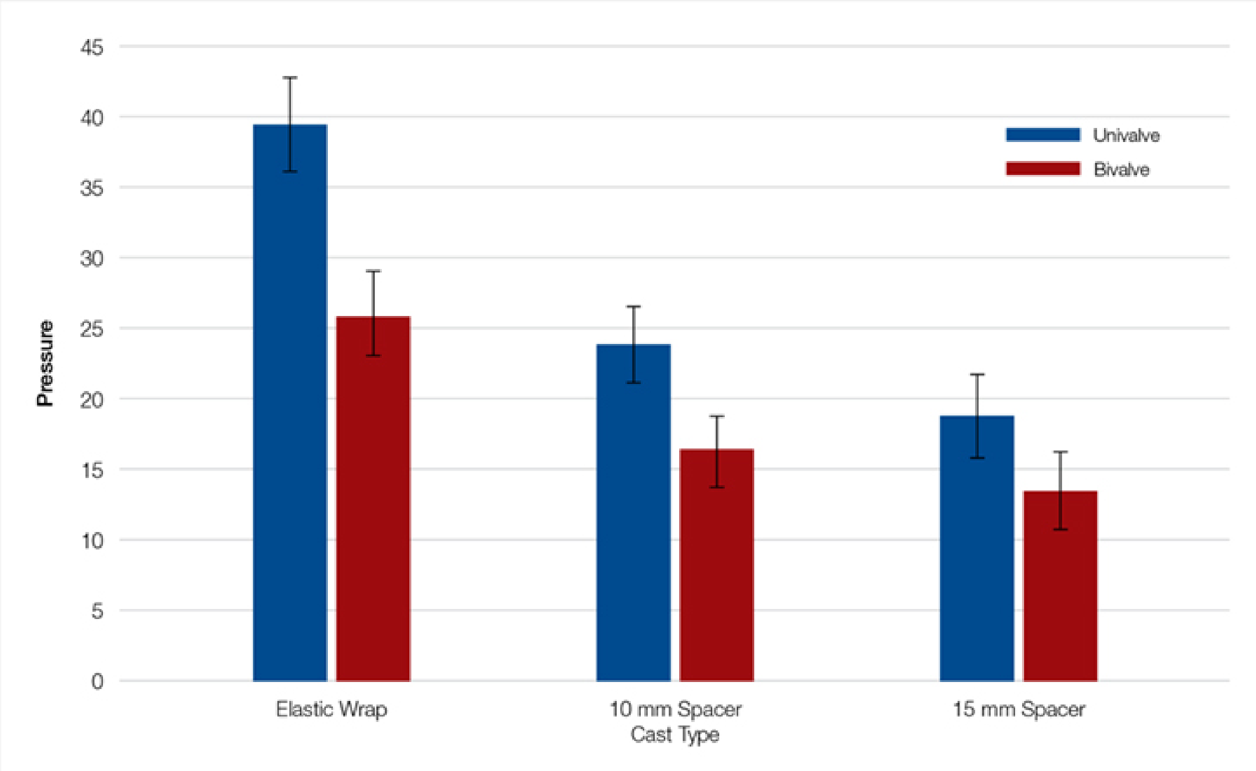

Figure 6. Detailed comparison of valving group according to method of cast securing: elastic wrap vs 10-mm spacer (1) vs 15-mm spacer (2).

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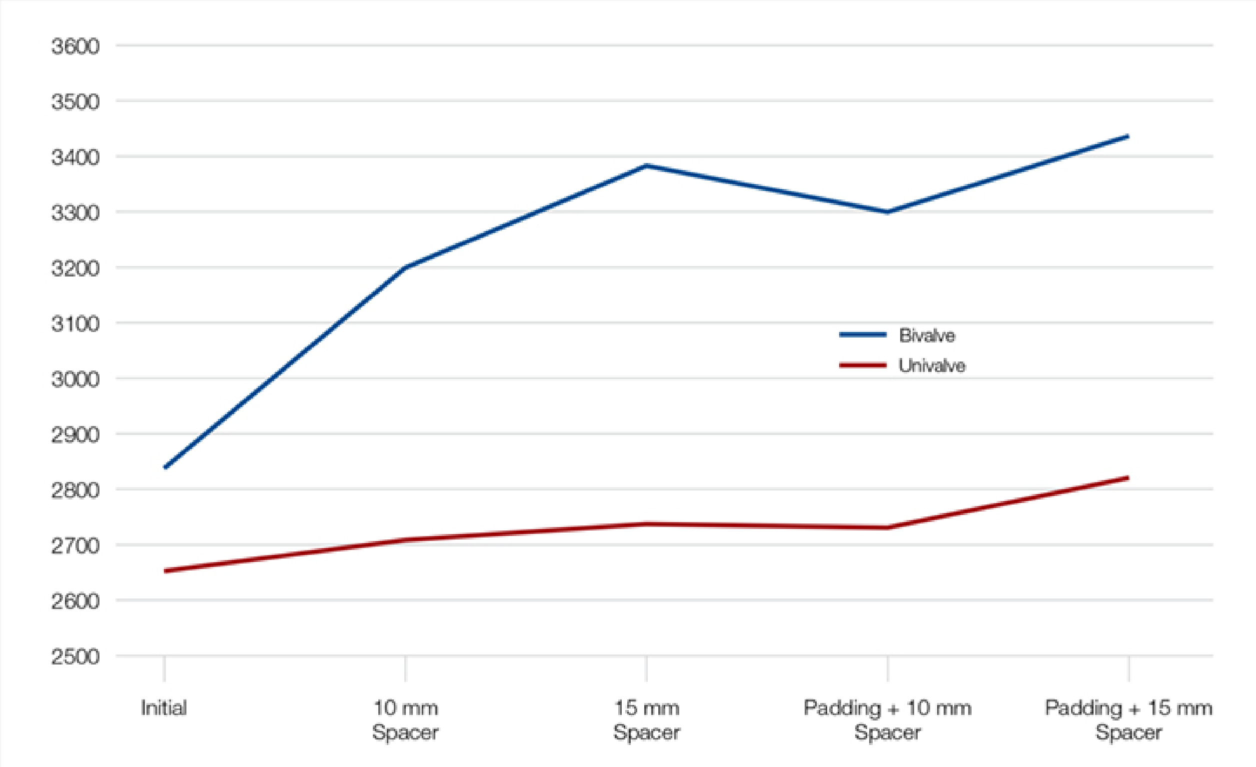

Figure 7. Graph demonstrating change in cast volume, measured in cubic centimeters, at study time points, according to cast type (univalve or bivalve), compared with initial cast volume.

Table 1. Cumulative Data for Two Casting groups at Each Timepoint

Cast	Pressure	Standard Deviation	Volume
Univalve			
Initial	100	---	2654.3
Elastic Wrap	39.47	3.33	---
10-mm Spacer	23.93	2.73	2708.23
15-mm Spacer	18.87	2.94	2734.86
Padding and Elastic Wrap	20.93	2.91	---
Padding and 10-mm Spacer	15.46	2.19	2733.24
Padding and 15-mm Spacer	0	---	2819.27
Bivalve			
Initial	100	---	2839.3
Elastic Wrap	25.9	3.17	---
10-mm Spacer	16.53	2.32	3203.13
15-mm Spacer	13.6	2.74	3380.32
Padding and Elastic Wrap	12.67	1.95	---
Padding and 10-mm Spacer	0	---	3296.55
Padding and 15- mm Spacer	0	---	3438.67

Table 2. Volumetric Data

Cast	Average Volumetric change (cm^3)	Standard Deviation
Univalve		
10-mm Spacer	175.6	65.4
15-mm Spacer	269.4	73.3
Padding and 10-mm Spacer	202.3	62.5
Padding and 15-mm Spacer	294.1	66.9
Bivalve		
10-mm Spacer	363.7	67.2
15-mm Spacer	540.9	85.7
Padding and 10-mm Spacer	457.2	97.9
Padding and 15-mm Spacer	599.3	84.2

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Multimedia

Product Guide

Product Guide

- STRATAFIX™ Symmetric PDS™ Plus Knotless Tissue Control Device
- STRATAFIX™ Spiral Knotless Tissue Control Device
- BioComposite SwiveLock Anchor
- BioComposite SwiveLock C, with White/Black TigerTape™ Loop

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