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Cast Wedging: A "Forgotten" Yet Predictable Method for Correcting Fracture Deformity

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Many cast wedging techniques have been discussed in the literature; however, to our knowledge, these techniques have not been experimentally validated. This paper illustrates a technique and measurement methodology for reproducible wedging and validates the geometric approach to predict the correct wedge size. Fracture deformities of saw bone models were created and placed in casts. These were used to represent in-vivo fractures of both distal and mid-shaft radius fractures, as well as distal and mid-shaft tibia fractures. Cast wedge correction was performed to correct the deformities. Fifteen specimens were observed with the goal to obtain a post-wedge angulation of less than 5 degrees. Of the 15 fractures casted, 66% achieved this goal. It was found that 80% of the apex posterior type displacement did not achieve satisfactory correction. Eliminating the apex posterior type fractures resulted in a 90% success rate of acceptable alignment. In the orthopaedic literature, there are various techniques for predicting the wedge size, but there are few studies which present either clinical or experimental data to support their method. This study validates the technique of geometric analysis for fracture reduction using cast wedging. The results indicate that angulation can be corrected to less than 5 degrees for fractures with isolated varus, valgus, or apex anterior deformities with 90% success. Alternative methods should be considered for apex posterior type deformities.

Cast wedging is a technique traditionally used in pediatric orthopaedics to correct fracture malalignment. It is a technique that has been utilized less frequently in the recent years given the advances in surgical management of fractures. However, indications for cast wedging commonly present themselves especially in the pediatric population. Many wedging techniques have been discussed in the literature, but to our knowledge, these techniques have not been experimentally validated[1-5]. Previous authors have advocated opening wedges, closing wedges, as well as a combination of each of these approaches. This paper will illustrate the technique and methodology for a reproducible wedging procedure and validate this geometric correction technique by performing a series of experiments to reduce angular deformity in long bones.

Methods

Study Design

We used saw bone models that resembled an in-vivo fracture model (Sawbones,Vashon, Washington).The saw bone models were termed the "soft tissue arm" and "soft tissue leg" models. Individual models were used to represent four of the most common types of fractures for which wedging is used clinically. These include a fracture of the distal and mid-shaft radius, as well as those of the distal and mid-shaft tibia. These fractures were created on separate models and casted in their respective deformed positions for assessment. One model of each direction of displacement was created for each fracture location. Multiple trials of each were not performed due to supply limitations of the saw bone models. After radiographic assessment of the fractures, a geometric analysis was performed. Cast wedge correction of a single plane deformity was performed with each trial. As such, each correction in both the coronal and sagittal planes were performed separately. The degree deformity (pre-wedge), wedge size (cm), and residual deformity following correction (post-wedge) were noted.

Technique of Wedging

A 5 step technique was conducted to achieve our measurements on the cast wedging model (Figure 1). First, the amount of induced deformity in each plane was determined by measuring the angle of deformity (Step 1). Next, the center of rotational alignment (CORA) must be determined. This is the apex at which the angulation occurs and the axis of rotation of the fracture. This point may differ in simplicity given the type of fracture pattern. The CORA is determined by drawing a longitudinal line down the axis of each major bone fragment. The CORA is the point at which these lines intersect (Step 2). A standardized horizontal straight line is then drawn through the CORA that is perpendicular to the largest segment of the long bone. This will be used as the reference line for which the angular correction will be made (Step 3). Using the same fracture deformity angle that was determined in Step 1, a new line is drawn at that same angle from the horizontal reference line (Step 4). The vertex of the angle should be peripheral at the level of the cast. The angle formed by these intersecting lines represents the angular deformity. At our institution, we prefer utilizing the opening wedge technique as opposed to a closing wedge. A measurement is then made at the periphery of the cast on the

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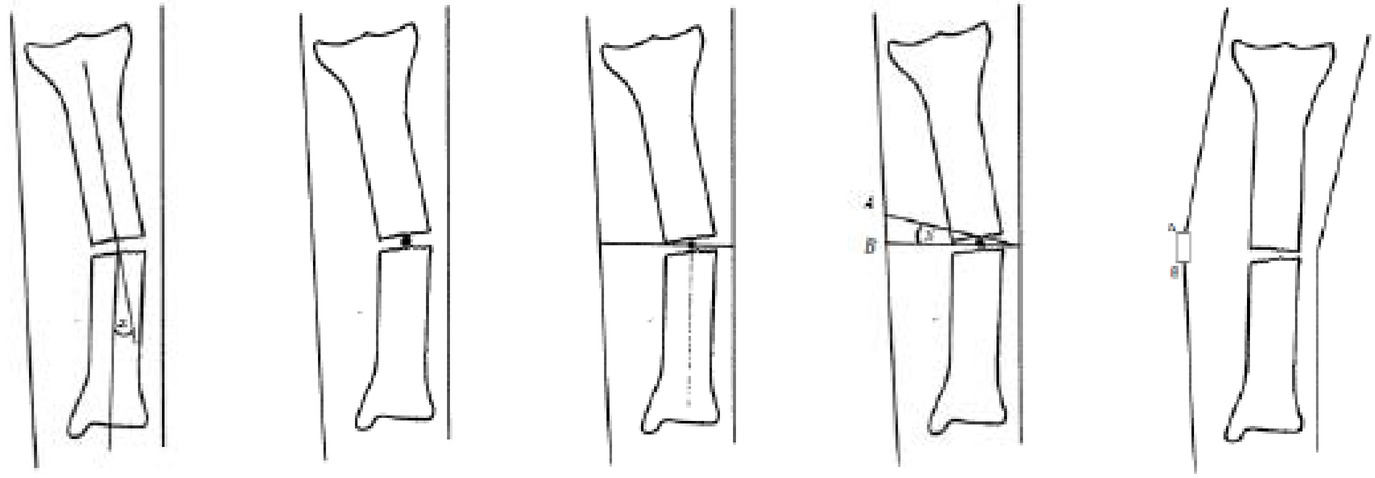

Step 1: Draw a longitudinal line through the center of each bone segment. These lines are used to find the angular deformity of fracture, represented by angle x.

Step 2: The point at which these two longitudinal lines intersect is the center of rotational alignment (CORA).

Step 3: A horizontal reference line is drawn through the CORA that is perpendicular to the long bone. This will serve as a reference line for the correction.

Step 4: Using the fracture deformity angle that was determined in Step 1, a new line is drawn at this same angle (x) from the horizontal reference line. The distance from A to B is then measured. This represents the size of the wedge necessary to achieve the anticipated angular correction.

Step 5: A cast saw is then used to cut ¾ of the circumference of the cast, leaving ¼ intact as a hinge. The appropriately sized wedge is inserted and the reduction is confirmed by new radiographs. Cotton is then packed gently into the gaps of the cast to fill the voids, and the cast is overwrapped with new plaster or fiberglass material.

Figure 1. Five-step technique for cast wedging.

concave side to determine the size of the wedge necessary to achieve the anticipated angular correction.

The same procedure is then repeated for the same fracture in the orthogonal radiographic view so that both sagittal and coronal deformity may be corrected separately. At this point, the size of the needed spacer can be more accurately determined. A cast saw is used to cut the cast three-quarters of its circumference, leaving the apical one-quarter intact to be used as a hinge (Step 5). This cut should be made at the level of the CORA which may be found radiographically using paperclips. A cast spreader is then used to spread the cast as the wedge is inserted. Post-reduction films are obtained and compared with pre-reduction films in the event that further adjustments need to occur. Once reduction is sufficient, cotton packing is used to gently fill the gaps formed by the wedging, and the cast should be overwrapped with casting material. An in-vivo example of cast wedging being used to correct deformity in a distal tibia fracture can be seen in Figure 2.

Statistical Analysis

The goal of the study was to determine if geometric analysis for fracture reduction using cast wedging was sufficient to predict a wedge that would realign fractures within 5 degrees of anatomic alignment. The relationship between pre-wedge deformity angle and corrective wedge size was examined by simple linear regression. For post-wedge degree, the absolute values were used to perform data analysis. One sample t-test was used to test whether the post-wedge degree is different from the 5 degrees of anatomic alignment.

Results

The correlation coefficient between the pre-wedge angle and the size of the wedge was 0.917, indicating that as the size of the deformity increases, the corresponding wedge size also increases.

In this study, a total of 15 specimens were observed. These included extension, flexion, apex medial, and apex lateral angulations. Four types of fractures were studied in each direction. These fractures included a mid-shaft radius, distal radius, distal tibia, and mid-shaft tibia. One model representing each combination of fracture and angular direction was tested with exception to an apex medially angulated mid-shaft tibia fracture. This data can be viewed in Table I.

The goal of this experiment was to obtain a post-wedge angulation of less than 5 degrees. Of the 15 fractures casted, 10 of these achieved that goal. Of the five that did not, four were the extension deformities of each tested fracture type, and the fifth was an apex laterally displaced distal tibia fracture. Omission of the extension type fractures resulted in 10 out of 11 post-wedge casts accomplishing the 5 degree goal.

Evaluation of post-wedge angles for the 15 samples finds a mean residual angulation of 4 degrees with a 95% confidence interval of 2.66-5.34 ($p = 0.13$). Isolating the extension deformities found a mean residual angulation of 6.75 degrees with 95% confidence interval of 5.23-8.27 ($p = 0.035$). With the omission of extension deformities and when only the apex medial, lateral, and flexion deformities are considered, the mean residual angulation is 3 degrees with a 95% confidence interval of 1.69-4.31 ($p = 0.0067$). This indicates that when

Figure 2. An in-vivo example demonstrating a successful reduction of a distal tibia and fibular fracture using our cast wedging procedure. Image (A) Pre-reduction AP and Image (B) Pre-reduction lateral radiographs. Image (C) Post-wedge AP and Image (D) Post-wedge lateral radiographs.

correcting apex medial, lateral, and flexion deformities individually, cast wedging successfully improved the deformity to a mean angulation of 3 degrees.

Discussion

When fracture reduction is incompletely obtained in a cast, for certain fractures, wedging may be considered as a viable technique to correct deformity and avoid surgical intervention. There are three types of wedging: opening, closing, and a combination of opening and closed wedging. At our institution we prefer to use opening wedge casting exclusively thereby avoiding the risks that accompany closing wedges. Closing wedge casts have the potential for both the pinching of the skin and the accumulation of cast padding at the wedge site which may cause skin breakdown. Additionally, closing wedges also may produce fracture shortening and reduce the volume of the cast, which can theoretically result in compartment syndrome[6].

There have been multiple techniques proposed for predicting the size of a wedge. Bebbington, Lewis, and Savage suggested a technique that involves tracing the angle of displacement onto the cast itself using a marking pen[1]. The line is meant to represent the fracture fragments. Wedges are then inserted until the bent line becomes straight. Guastavino[5] and Husted[3] each introduced formulae that could be used to predict the amount of wedging; Husted's method even accounted for radiographic magnification.

With digital radiography and embedded protractor tools, we feel that our method of wedging is easier to use than those previously mentioned and is an accurate predictor of the wedge size necessary to achieve proper reduction. Examination of our experimentally determined data indicates that single plane deformities can be corrected with our technique with greater than 90% accuracy (within 5 degrees of anatomic) unless there is extension deformity. Our goal was to reduce each fracture to a post-wedge angle of less than 5 degrees. This goal was achieved in most of the fractures with medial, lateral, and flexion deformities. However, in all four cases representing an extension deformity, this correction goal was not reached. In the tibial fractures, it is believed that this failure to reduce extension deformities is a result of the quantity of soft tissue on the posterior leg. The gastroc-soleus

TABLE I. Summary of data collected showing the pre-wedge angulation, the calculated size of the wedge placed and the resultant uniplanar post-wedge angulation for each fracture model. Negative values refer to degrees of overcorrection.

	Pre-wedge Angular Deformity	Wedge Size (cm)	Post-wedge Angular Deformity	Within 5 Degree Correction Goal
Mid Shaft Radius				
Apex Medial	9	1.4	2	Yes
Apex Lateral	13	2.9	−4	Yes
Extension	24	4.2	−8	No
Flexion	24	3.7	0	Yes
Distal Radius				
Apex Medial	20	3.7	1	Yes
Apex Lateral	15	2.9	2	Yes
Extension	7	1.8	−6	No
Flexion	29	4.8	4	Yes
Distal Tibia				
Apex Medial	21	3.6	5	Yes
Apex Lateral	10	2.2	6	No
Extension	23	4	−6	No
Flexion	45	10	5	Yes
Mid Shaft Tibia				
Apex Lateral	21	4.9	3	Yes
Extension	34	4.3	7	No
Flexion	29	7.7	1	Yes

complex consists of a large muscle belly that is thought to have cushioned the pressure from the cast being wedged. This likely prevented adequate correction of the fracture deformity. With the exclusion of those extension deformities, it was found that the remaining fracture patterns corrected to a mean post-wedge angular displacement of 3 degrees. Additionally, 90% of this subgroup was successfully reduced to less than 5 degrees residual angulation. The results demonstrated wedging to be effective for all fracture types tested with the exception of those with an extension deformity.

There are three major limitations of this study. The first is that the power of the experimental model is limited. Due to a limited supply of saw bones, only one trial of each fracture deformity was tested. This increases the probability of type 2 (beta) error. The next limitation of this study is the inability to correlate the plasticity of the artificial saw bone limbs to that of an actual human limb. Periosteum and soft tissue interposition within a fracture site are two very significant *in vivo* obstacles to fracture reduction. These were not present on our models, allowing for a more consistent fracture pattern. Although this eliminated variables in our experimental design, it does make the applicability of the technique more difficult in an actual clinical case. The last limitation is that there was not effective examination of multiplanar deformities. Many long bone fractures are displaced in both the coronal and sagittal planes. Although there are reliable strategies for multiplanar correction of fractures using wedging, this was not adequately examined in this experimental design.

Conclusions

This study validates the technique of geometric analysis for fracture reduction using cast wedging. The results indicate that angulation can be corrected to less than 5 degrees for fractures with apex medial, lateral, and flexion deformities with 90% success. Alternative methods should be considered for extension type deformities. While this is not a new or novel technique, this study should remind the physician that this technique can be a useful non-operative way of fracture realignment in the early stages of fracture healing.

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