Effect of Patient-Surgeon Orientation on Plunge Depth During Plate Fixation of Clavicle Fractures

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ABSTRACT

Background: Operative management of clavicle fractures indicated for open reduction internal fixation poses significant risk to critical anatomic structures. The associated risks to the underlying neurovascular structures during clavicle fixation as a result of plunge depth for patients in the supine position in comparison to patients in the beach-chair position is currently unknown. The purpose of this study was to compare plunge depth measurements between the supine and beach-chair positions during plate fixation of clavicle fractures.

Methods: The participant population at this single institution was comprised of residents, fellows, and fellowship-trained, attending orthopaedic surgeons. The participants drilled three bicortical holes into the bone model. The arm was then adjusted and positioned at 45° to simulate beach-chair positioning. The participant drilled three additional holes into the bone model. After allowing each clay mold to harden, the clay was removed, and the plunge depth was measured with a depth gauge by two independent researchers with a standard depth gauge.

Results: A total of 9 attending surgeons, 9 fellows, and 12 residents participated in this study. Including all levels of training, it was found that the beach-chair position had an average plunge depth of 2.9 mm, which was lower than the average supine position plunge depth of 3.2 mm. This difference was not found to be significant (P = 0.116).

Conclusions: We found no significant difference in plunge depth measurements during clavicle fixation in the supine versus beach-chair position. However, the importance of safely executing clavicle fracture fixation is critical to prevent avoidable morbidity and potential mortality of orthopaedic patients. The plunge depths recorded, if produced from a larger sample, should motivate deep reflection of the current liberal indications of clavicle fracture fixation.

Keywords: Clavicle Fracture, ORIF, Trauma

INTRODUCTION

Clavicle fractures typically occur in young, active individuals and account for about 3.0% of all fractures. Approximately 80.0% of clavicle fractures occur in the middle third of the clavicle. Due to this relationship, there is a considerable risk to the clavicle's critical anatomical structures when these fractures are treated with open reduction internal fixation (ORIF).[1,2] Robinson et al[3] reported a 4.8 mm distance between the subclavian vein and the clavicle, with a standard deviation of 2.6 mm from the medial clavicle.

Safely drilling for bicortical fixation is of paramount importance during the operative treatment of clavicle fractures. One of the most fundamental skills of an orthopaedic surgeon is minimizing the depth of drill-bit penetration when drilling for bicortical fixation. Drill-bit penetration through the far cortex is terminologically described as "plunging" or "past-pointing."[4-6] A greater depth of plunging poses an increased risk of surgical complications, such as injury to neurovascular structures like the subclavian vein, subclavian artery, brachial plexus, and lung parenchyma.[3,7]

Clavicle fracture fixation is performed with the patient in either the supine or beach-chair position or with the head of the bed between the two positions. To our knowledge, the effects and associated risks of plunge depths on the underlying neurovascular structures during clavicle fracture fixation relative to patient positioning are currently unknown. We believe that plunging is more likely to occur when patients are positioned in the beach-chair position because this position requires surgeons to extend their arms away from their center of mass, resulting in a longer lever arm during drilling.

The purpose of this study was to evaluate potential differences in plunge depth measurements during clavicle fracture fixation according to patient-surgeon positioning and level of surgical training. We hypothesized that one-third of the plunge depths would exceed

the previously reported distance of 4.8 mm between the far cortex of the clavicle and the closest neurovascular structure, regardless of patient-surgeon positioning and level of training.

METHODS

After obtaining Institutional Review Board approval (HRPP #HSC-MS-18-0620), participant recruitment occurred from January to August 2019. The participant population at this institution was comprised of residents, fellows, and fellowship-trained, attending orthopaedic surgeons. Demographic information collected for each subject included level of training (resident year, fellow, and attending) and the approximate number of clavicle ORIF procedures performed.

Sawbone models of human radii were chosen for this study because they can be more appropriately contained in the mounting construct and allow for repeatable measurements (Sawbones USA, Pacific Research Laboratories; Vashon, Washington). Molding clay was affixed to the undersurface of each bone model to simulate the physical structures present on the undersurface of the clavicle. The bone and affixed clay were then placed in a bivalved 2.5-inch diameter polyvinyl chloride pipe secured to an adjustable arm on a custom aluminum frame with a 9.5-inch wooden base. This design allowed for the simulation of clavicle fixation in supine and beach-chair positions. The height from the ground to the top of the aluminum frame was 57.5 inches. From the ground to the arm of the platform, the height was 44.0 inches. The base was removable to accommodate for height differences between participants. The arm was adjusted to 10° for the supine position and 45° for the beach-chair position (Figures 1 through 3). A board-certified orthopaedic surgeon selected the height and degree of rotation based on measurements obtained in simulated supine and beach-chair positions in the operating room.

In each simulation, the arm of the completed construct was first positioned at 10° to simulate supine positioning. The participant drilled three holes into

Figure 1. *Aluminum frame to simulate supine (left) and beach-chair (right) positioning.*

Figure 2. *Sawbone model in supine position.*

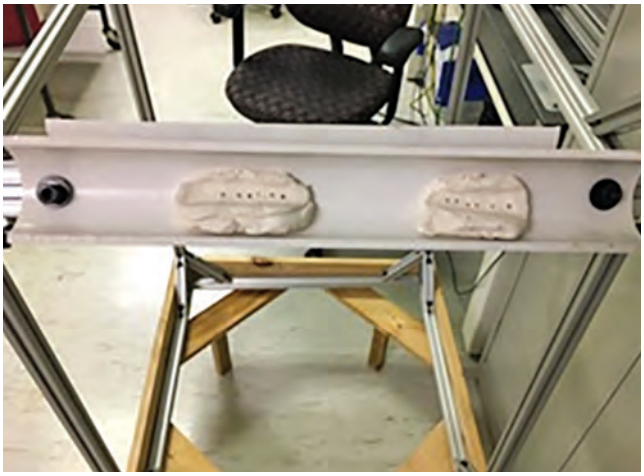

Figure 3. *Sawbone model in beach-chair position.*

the bone model after adjusting their body position, as appropriate, for technical execution. The arm was then adjusted and positioned at 45° to simulate beach-chair positioning. The participant then drilled three additional holes into the same bone model. Participants were not given practice attempts or additional training. A Stryker System 7 drill with a 2.5-mm drill bit was used. A new drill bit was issued after every two participants, along with a charged battery to ensure consistency with respect to drill bit blunting and drill speed. After each clay mold was removed, the plunge depth was measured with a depth gauge by two independent researchers.

RESULTS

A total of 9 attendings, 9 fellows, and 12 residents participated in this study. The average number of ORIF clavicle cases for residents, fellows, and attending surgeons was 7, 15, and 74, respectively. Including all levels of training, it was found that the beach-chair position had an average plunge depth of 2.9 mm, which was lower than the average supine position plunge depth of 3.2 mm. This difference was not found to be significant (P = 0.116). The range of plunge depth by attending surgeons was 1 to 6 mm in the supine position and 1 to 6 mm in the beach-chair position. The range of plunge depth by orthopaedic fellows was 1 to 5 mm in the supine position and 1 to 4 mm in the beach-chair position. For residents, the plunge depth range was 0 to 8 mm in the supine position and 1 to 6 mm in the beach-chair position. The differences between groups were not statistically significant. Attending surgeons and fellows had measured depths greater than or equal to 3 mm significantly (P < 0.05) more often than the residents (Tables 1 and 2).

DISCUSSION

The purpose of this study was to compare plunge depth measurements between supine and beach-chair positions during clavicle fracture fixation and to simultaneously evaluate differences in plunge depths based on the surgeon's level of training. The importance of drill control and the consequences of plunging is well known to the orthopaedic surgeon. However, to our knowledge, the effect of patient positioning on plunge depth during clavicle fracture fixation has not been described. We hypothesized that a significantly lower plunge depth would occur when this procedure is performed in the supine position when compared to the beach-chair position. Although the opposite was true, the difference was not statistically significant, which we believe is due to a combination of factors. First, the surgeon is drilling nearly colinear to the direction of gravity, allowing them to appreciate the breach in the far cortex more effectively than with the patient in the supine position, where drilling is nearly perpendicular to the direction of gravity. Second, perpendicular drilling allows for more friction, potentially preventing the surgeon from appreciating the breach in the far cortex, which may result in a deeper plunge depth.

Similar to Clement et al[8] and opposite Stillwell et al,[9] we found no significant difference in our evaluation of plunge depths in relation to the surgeon's level of training. Safe bicortical drilling is a skill that can be rapidly acquired and retained by orthopaedic surgeons early in their career, but even experienced surgeons place the critical structures at risk. The range of plunge depth for all participants at all positions was 0 to 8 mm. Given that the conical tip of the drill bit measures 1 mm, it is understood that plunging of 1 mm is required to completely drill a bicortical path. Although this is the case, Mulder et al[10] reported the relationship of the subclavian vein to be located as close as 0 mm from the clavicular cortex in both intact and fractured clavicles. Theoretically, any plunging past 1 mm from the far cortex places patients at risk.

Sinha et al[11] have suggested superior plates in medial fractures and anterior plates in lateral fractures to avoid the subclavian vessels. However, as with all surgical procedures performed by orthopaedic surgeons, regional anatomy knowledge and expected technical skill are critical to safely expose, reduce, and provide fixation to fractures, regardless of the patient positioning and level of experience.[12]

There were potential limitations in our study. Similar to an operative setting, multiple people were in the room while the participants performed drilling. Thus each participant was aware their performance was being measured and compared to their peers and colleagues, possibly creating biased results. We believe the Hawthorne effect was equal for all groups and played a minimal role in the results. Other limitations included a small number of attending surgeons recruited for the study and that the study did not occur in a surgical setting.

The importance of safely executing clavicle fracture fixation is critical to prevent avoidable morbidity and potential mortality of orthopaedic patients. Our study did not show a statistically significant difference in plunge depths between supine and beach-chair positioning. However, knowing they were being watched and compared to their peers, the participants in this

Table 1. *Supine Position*

Training	Supine Trial Depths Equal or Greater Than 3 mm	Supine Trial Depths Less Than 3 mm	Total, n (%)	*P*-value
Attending/ Fellows, n (%)	41 (75.9)	13 (24.1)	54, (60.0)	*P*<0.05[a]
Residents, n (%)	17 (47.2)	19 (52.8)	36, (40.0)	
TOTAL, n (%)	58 (64.4)	32 (35.6)	90	

[a]Attending's and fellows had measured depths greater than or equal to 3 mm significantly (*P*<0.05) more often than the residents

Table 2. *Beach-Chair Position*

Training	Beach-Chair Trial Depths Greater Than or Equal to 3 mm	Beach-Chair Trial Depths Less Than 3 mm	Total, n (%)	*P*-value
Attending/ Fellows, n (%)	25 (46.3)	29 (53.7)	54 (60.0)	*P* = 0.1998
Residents, n (%)	22 (61.1)	14 (38.9)	36 (40.0)	
TOTAL, n (%)	47 (52.2)	43 (47.7)	90	

study recorded plunge depths that would damage neurovascular structures in the operating room.

In our opinion, clavicle fracture fixation is often mistaken as a simple and safe procedure, and fixation is performed much more liberally than it has been in the past. In a population-based study by Micev et al,[13] they reported an increase of 337.0% from 2005 to 2010 with only a 15.0% increase in the number of patients presenting with clavicle fractures in the emergency department for the same period of time at ambulatory surgical centers.

The potential significance of past-pointing and the importance of minimizing plunge depth cannot be overstated, regardless of level of training. Considerable damage to subclavian structures is possible as a result of many of the depths recorded in our study. It is well known that technical skill, focus, and awareness is critical during drilling for fracture fixation. If similar plunge depths were reproduced from a larger sample, this should motivate deep reflection on what appears to be increasingly liberal indications for clavicle fracture fixation.

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