



รายงานวิจัยฉบับสมบูรณ์

โครงการ การศึกษาตำแหน่ง และแนวการยิงลวดยึดตรึง
กระดูกไหปลาร้าส่วนปลายในศพ

**An Accuracy of Pin Insertion Point for Distal
Clavicle Fixation: A Cadaveric Study**

หัวหน้าโครงการ ผศ.นพ.เอกกมล ธรรมโรจน์
นักวิจัยที่ปรึกษา รศ.นพ.วิระชัย ไควสุวรรณ

ภาควิชาออร์โธปิดิกส์ คณะแพทยศาสตร์
มหาวิทยาลัยขอนแก่น

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สนับสนุนโดยสำนักงานกองทุนสนับสนุนการวิจัย
(ความเห็นในรายงานนี้เป็นของผู้วิจัย สกว.ไม่จำเป็นต้องเห็นด้วยเสมอไป)

คำนำ

นับเนื่องจนถึงปัจจุบันอุบัติเหตุจราจรก็ยังเป็นปัญหาสำคัญอันดับต้นๆ ของประเทศไทย และทั่วโลก ยังมีการพัฒนาความเร็วของยานพาหนะและความสะดวกของการเดินทาง อุบัติเหตุจราจรก็ยิ่งเพิ่มขึ้นทุกปี พบว่าอุบัติเหตุจราจรเป็นสาเหตุการเสียชีวิตของประชากรไทยเสมอมา ถ้าไม่เสียชีวิตผู้ป่วยก็มักจะได้รับภยันตรายหลายระบบ ซึ่ง 78% ของผู้ป่วยจากอุบัติเหตุจราจรจะมีภยันตรายทางออร์โธปิดิกส์ และกระดูกหักที่พบบ่อยที่สุดอย่างหนึ่งก็คือ กระดูกไหปลาร้าหัก เป็นที่ยอมรับกันในศัลยแพทย์สาขาศัลยศาสตร์ออร์โธปิดิกส์ว่า ถ้ากระดูกไหปลาร้าส่วนปลายหักต้องรักษาโดยการผ่าตัดยึดตรึงกระดูกเพื่อป้องกันภาวะแทรกซ้อนที่อาจเกิดขึ้นตามมา และวิธีการยึดตรึงกระดูกไหปลาร้าส่วนปลายหักที่ใช้บ่อยที่สุดคือ การใช้ลวดยึดตรึงกระดูกโดยยิงลวดยึดตรึงกระดูกจากกระดูกอะโครเมียมไปยังกระดูกไหปลาร้า เนื่องจากเป็นวิธีที่ได้ผลดี อุปกรณ์มีราคาถูก และสามารถหาได้ง่าย แต่ภาวะแทรกซ้อนจากการยึดตรึงวิธีนี้ก็พบบ่อยมากโดยเฉพาะการยิงลวดยึดตรึงผิดทิศทาง หรือการทำให้เกิดกระดูกหักเพิ่มขึ้นจากการผ่าตัด คณะผู้วิจัยจึงทำวิจัยเพื่อหาคำแนะนำ และแนวทางที่เหมาะสมเพื่อลดภาวะแทรกซ้อนที่อาจเกิดขึ้นกับผู้ป่วย โดยคณะผู้วิจัยขอขอบคุณสำนักงานกองทุนสนับสนุนการวิจัยที่เห็นความสำคัญของปัญหาและได้ให้เงินสนับสนุนโครงการวิจัยนี้ สุดท้ายนี้ผู้วิจัยหวังว่าความรู้ที่ได้จากโครงการวิจัยนี้จะเป็นพื้นฐานความรู้ และข้อมูลสำคัญที่นำมาใช้เพื่อลดภาวะแทรกซ้อนที่อาจเกิดขึ้นกับการรักษาผู้ป่วยกระดูกไหปลาร้าหักต่อไป

เอกกมล ธรรมโรจน์

มกราคม 2547

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กิตติกรรมประกาศ

ผู้วิจัยขอขอบคุณ รศ.นพ.วีระชัย โควสุวรรณ ที่ให้คำปรึกษาเกี่ยวกับระเบียบวิธีวิจัยทั้งหมดในโครงการวิจัย, รศ.พญ.กิมพร ชมะณะรงค์ ที่อำนวยความสะดวกและจัดเตรียมศพดองในการทำวิจัย และสำนักงานกองทุนสนับสนุนการวิจัยที่ให้การสนับสนุนด้านเงินทุนในโครงการวิจัย สุดท้ายผู้วิจัยขอขอบคุณอาจารย์ใหญ่ทุกท่านที่สละร่างกายเพื่อเป็นแหล่งความรู้และวิทยาทานแก่นุชนรุ่นหลัง ซึ่งผู้วิจัยรู้สึกซาบซึ้งและขออนุโมทนาในกุศลจิต โดยจะนำความรู้ที่ได้จากการวิจัยมาเผยแพร่เพื่อเป็นประโยชน์แก่วงการแพทย์ต่อไป

บทคัดย่อ

รหัสโครงการ TRG4580018

ชื่อโครงการ การศึกษาดำแหน่งและแนวการยิงลวดยึดตรึงกระดูกไหปลาร้าส่วนปลายในศพ

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ระยะเวลาโครงการ 1 ปี 6 เดือน

วัตถุประสงค์ โครงการวิจัยนี้มีวัตถุประสงค์ประสงค์เพื่อหาดำแหน่งที่แม่นยำ และแนวการยิงลวดยึดตรึงกระดูกไหปลาร้าส่วนปลายหัก

รูปแบบการวิจัย การศึกษาทดลองในศพดอง

สถานที่ทำวิจัย ห้องปฏิบัติการกายวิภาคศาสตร์

การประเมินหลัก ตำแหน่ง และแนวที่ใช้ในการยิงลวดยึดตรึงกระดูกไหปลาร้าส่วนปลายในศพดอง

ระเบียบวิธีวิจัย โครงการวิจัยนี้ใช้ชิ้นส่วนของศพดองบริเวณไหล่ 32 ตัวอย่าง โดยการเจาะรูที่บริเวณขอบกระดูกด้านหลัง ส่วนกลางของกระดูกไหปลาร้าให้มีขนาดกว้างเพียงพอที่จะทำการยิงลวดยึดตรึงกระดูกขนาด 2 มม. เข้าไปในโพรงกระดูกส่วนปลายของกระดูกไหปลาร้าได้โดยอิสระ เมื่อทำการยิงลวดยึดตรึงกระดูก ขนาด 2 มม. จนทะลุที่ผิวกระดูกด้านบนของกระดูกอะโครเมียม เราจะวัดตำแหน่งที่ลวดยึดตรึงโผล่ขึ้นบริเวณผิวกระดูกอะโครเมียมเป็นสัดส่วน และวัดมุมของลวดยึดตรึงกระดูกโดยเทียบกับเส้นอ้างอิง (เส้นที่ลากจากปุ่มกระดูกไหปลาร้าส่วนปลายด้านใน ไปยังมุมกระดูกด้านหน้าของกระดูกอะโครเมียม) หลังจากนั้นจะถอนลวดยึดตรึงออก แล้วทำการยิงลวดยึดตรึงกระดูกเข้าไปใหม่โดยการสุมยิงแล้วทำการวัดโดยกระบวนการเดิมซ้ำ โดยจะทำการยิงและวัดซ้ำจนกระทั่งกระดูกอะโครเมียมหัก และบันทึกจำนวนครั้งของการยิงซ้ำที่ทำให้กระดูกหัก

ผลการวิจัย ข้อมูลของการยิงลวดยึดตรึงกระดูกจำนวน 304 ครั้งใน 32 ตัวอย่างพบว่า อัตราส่วนของระยะจากขอบหน้าของกระดูกอะโครเมียมหารด้วยความยาวของกระดูกอะโครเมียมเท่ากับ 0.325 ± 0.04 อัตราส่วนของระยะจากขอบด้านนอกของกระดูกอะโครเมียมเท่ากับ 0.397 ± 0.09 ส่วนแนวการยิงลวดยึดตรึงเมื่อเทียบกับเส้นอ้างอิงในระนาบหน้าหลังเท่ากับ 14.59 ± 4.34 และในแนวระดับเท่ากับ 7.69 ± 3.04 จากการวิเคราะห์ระยะปลอดภัยการพบว่ามีอัตราอดของกระดูกอะโครเมียมจากการหักเนื่องจากการยิงซ้ำ 8 และ 10 ครั้งเท่ากับ 0.72 (ช่วงความเชื่อมั่นที่ 95% คือ 0.53-0.84) และ 0.41 (ช่วงความเชื่อมั่นที่ 95% คือ 0.24-0.57) ตามลำดับ

วิจารณ์และสรุป การยิงลวดยึดตรึงกระดูกโดยไม่เปิดแผลเป็นวิธีที่ใช้บ่อยที่สุดในการรักษากระดูกไหปลาร้าส่วนปลายหัก หรือการเคลื่อนหลุดของของระหว่างกระดูกอะโครเมียมและกระดูกไหปลาร้า ผลการวิจัยพบว่าตำแหน่งที่ใช้ในการยิงลวดยึดตรึงกระดูกโดยการวัดเป็น

อัตราส่วนคือ 0.325 ของความยาวของกระดูกอะโครเมียม และ 0.397 ของความกว้างของกระดูกอะโครเมียม ถ้าใช้ลวดยึดตรึงขนาด 2 มม.ในการยึดตรึงไม่ควรยึลวดยึดตรึงซ้ำเกิน 8 ครั้งเพราะอัตราเสี่ยงต่อการเกิดกระดูกอะโครเมียมหักจะเพิ่มสูงอย่างรวดเร็ว

คำสำคัญ การยึลวดยึดตรึงกระดูก, กระดูกไหปลาร้า, ตำแหน่ง

Abstract

Project Code: TRG4580018

Project Title: An Accuracy of Pin Insertion Point for Distal Clavicle Fixation:

A Cadaveric Study

Investigator: Ekamol Thumroj, M.D.

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Project Period: 1 year 6 months

Objective: The purpose of this study is to identify the optimal pin insertion point for distal clavicle fixation.

Design: Cadaveric study.

Setting: Medical school anatomy laboratory.

Main Outcome Measure: Optimal pin insertion point and its direction for distal clavicle fixation in embalmed cadaveric shoulders.

Methods: Thirty-two embalmed cadaveric shoulders were used in this study. We created the hole at the posterior two-third of mid clavicle about 1.5 cm. from conoid tubercle. The hold was created as wide as we can freely retrogradely drilled into the medullary canal of distal clavicle. A 2.0-millimeters Kirschner wire was retrogradely drilled until it penetrated the acromion. We recorded the emerging point of K-wire in ratio scales and the angle of K-wire compared with the reference line, line from superior tubercle of clavicle to anterior angle of acromion. After the data of first drilling was recorded, K-wire was removed and randomly repeatedly drilled in the same specimen until the acromion was fracture. The number of drilling was recorded. The specimens were processed in the same procedures.

Results: The data of 304 drilling-counts of 32 specimens shown that the length of sagittal pin inserting point from anterior border of acromion divided by acromion length were 0.325 ± 0.04 . The length of coronal pin inserting point from distal border of acromion divided by acromial width was 0.397 ± 0.09 . The angles of K-wire compared with reference line were 7.69 ± 3.04 and 14.59 ± 4.34 degree in coronal and horizontal plane respectively. According to the survival analysis, the incidence density was 0.11 (95%CI: 0.072-0.15) samples-counts. The survival rate at 8 and 10 drilling-times were 0.72 (95%CI: 0.53-0.84) and 0.41 (95%CI: 0.24-0.57) respectively.

Discussion and Conclusion: Closed pinning is one of the most common fixation methods, which used for the fracture of distal clavicle and acromioclavicular joint

dislocation. This study suggested that the insertion point for closed pinning in ratio scale of acromial length and width were 0.325 and 0.397 respectively. If the 2.0 millimeters K-wire was used for fixation, it should not be drilled more than 8 times because the risk of acromial fracture was suddenly high.

Key Words: Intramedullary pinning, Clavicle, Insertion point.

Introduction

The clavicle

The shape and configuration of the clavicle not only is important for its function but also provides an explanation for the pattern of fractures encountered in this bone. Although it appears almost straight when viewed from the front, when viewed from above, the clavicle appears as an S-shaped double curve that is concave ventrally on its outer half and convex ventrally on its medial half (Fig. 1, 2). Although some reports have noted differences in the shape and size of the clavicle from a male to a female and from the dominant to the non-dominant arm, others have not found this to be the case as have discounted its clinical significance.

Fig. 1 The right clavicle viewed from the front appears almost straight bone.

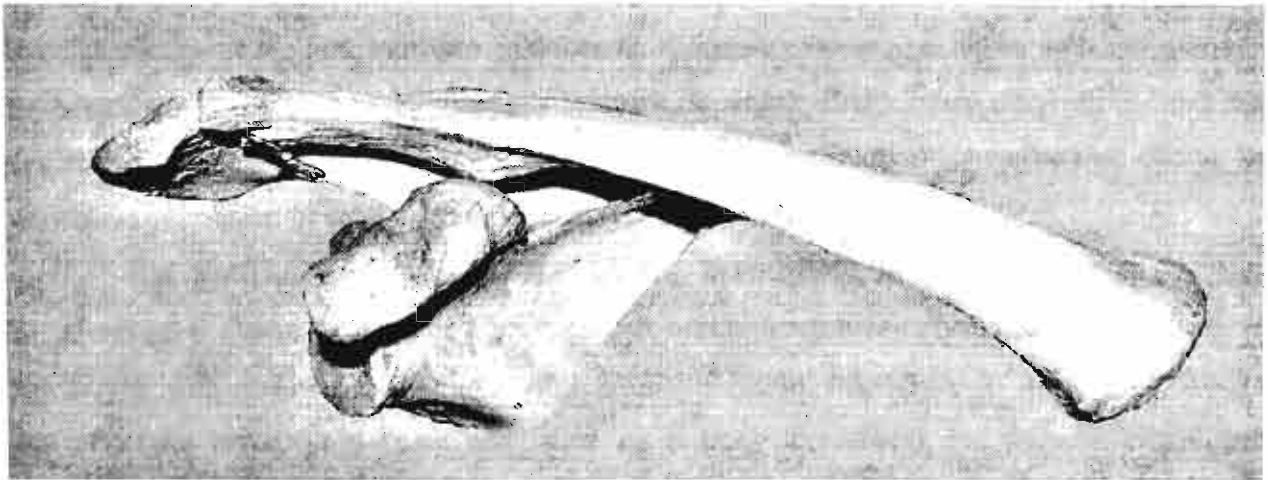


Fig. 2 The left clavicle viewed from above appears an S-shape bone.



It has been found that the outer third of the clavicle exhibited varying degrees of anterior torsion and that changes in torsion might be responsible for altered stresses that lead to changes of primary degenerative disease in the acromioclavicular joint. The cross-section of the clavicle differs in shape along its length, varying from flat along its outer third to prismatic along its inner third. The exact curvature of the clavicle and its thickness, to a high degree, vary according to the attachments of the muscles and the ligaments. The flat outer third is most compatible with pull from muscles and ligaments, whereas the tubular medial third is a shape consistent with axial pressure or pull. The junction between the two cross-sections varies as to its precise location in the middle third of the clavicle.

The tubular one third of the clavicle, which is thicker in cross-section, offers protection for the important neurovascular structures that pass beneath the medial one third of the clavicle. The intimate relationship between these structures and the clavicle assumes great importance both acute fracture, in which direct injury may occur, and the unusual fracture sequelae of malunion, nonunion or production of excessive callus, in which compression of these structures may lead to late symptoms.

The clavicle, by serving as a bony link from thorax to the shoulder girdle (Fig. 3), provides a stable linkage of the arm trunk mechanism and contributes significantly to the power and stability of the arm and shoulder girdle, especially in movement above the shoulder level. This bone also acts as a bony framework for muscle origin and insertion. The upper third of the trapezius inserts on the superior surface of the outer third of the clavicle, opposite the site of origin of the clavicular head of the deltoid along its anterior edge. The clavicle also acts as a skeletal protection for adjacent neurovascular structure and for the superior aspect of the lung. The subclavian and axillary vessels, the brachial plexus, and the lung are directly behind the medial third of the clavicle.

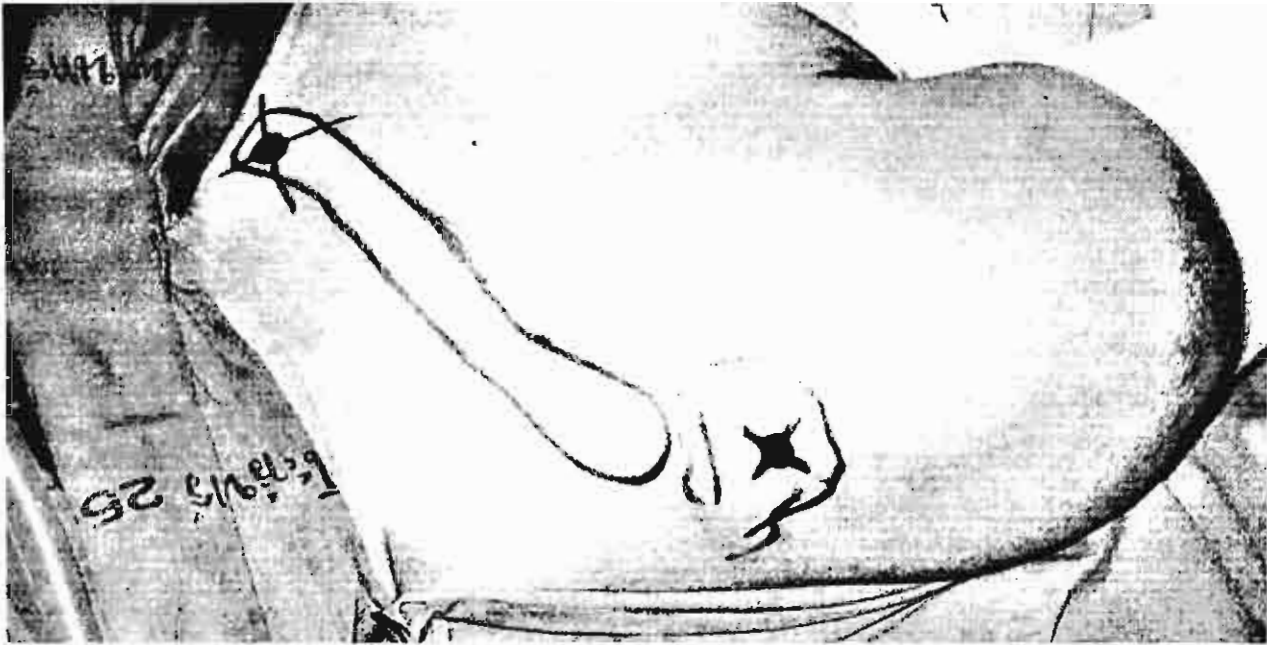
Fig. 3 The right clavicle, by serving as a bony link from thorax to the shoulder girdle, provides a stable linkage of the arm and trunk.



Clinical aspects of clavicular fracture

The clavicle is entirely subcutaneous and thus is easily accessible to inspection and palpation. (Fig. 4) This fact may account for its inclusion in some of the earliest descriptions of injuries of the human skeleton and their treatment. Because the clavicle is subcutaneous along its entire length, the only structures that cross it are the supraclavicular nerves. In most individuals, it is possible to grasp the bone and manipulate it, which can be helpful in producing crepitus if an acute fracture is suspected.

Fig. 4 The clavicle is entirely subcutaneous and it is easily accessible to inspection and palpation.



Fracture of the clavicle is usually not difficult to recognize and typically unite uneventfully with many different methods of treatment. Nevertheless, the frequency with which this injury is seen and the difficulty in managing the early and late complications of this fracture attest to its importance such as pin loosening (Fig. 5.) or misdirection of pin (Fig. 6.). Its clinical relevance is underscored when one considers that the clavicle is the most common fracture site occurs in childhood⁴. It has been estimated that 1 of 20 fractures involves the clavicle¹¹ and that fracture of the clavicle may constitute as much as 44% of shoulder girdle injuries. The incidence of fractures of the clavicle in adults appears to be increasing owing to several factors, including the occurrence of many more high-velocity vehicular injuries and the increase in popularity of contact sports. The mechanism of injury of fractures of the clavicle in adults has been widely reported to consist of either direct or indirect force. It has generally been assumed that the most common mechanism of fractures in adults is a fall onto the outstretched hand. Fracture of clavicle distal to the coracoclavicular ligaments; occur from a fall on the lateral shoulders, drawing the shoulder and scapulars downward.

Fig. 5. The patient suffers from pin loosening after closed reduction and internal fixation with K-wire.

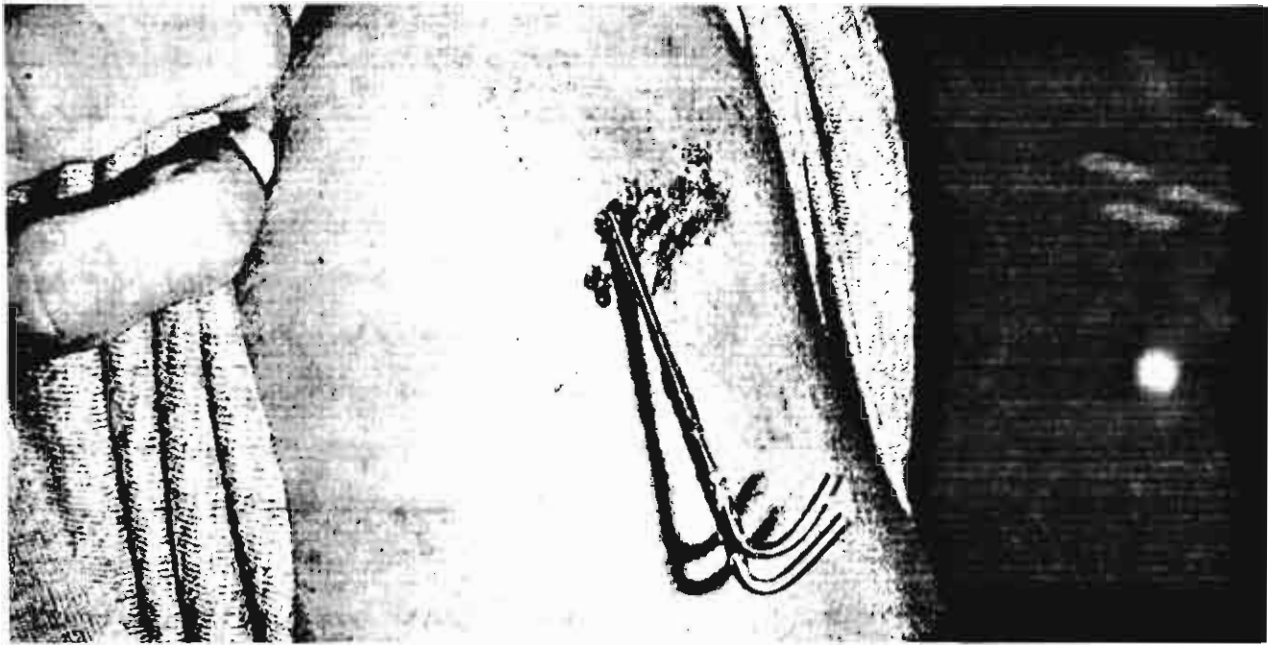


Fig. 6. Post-operative X-ray of Thai male shown fracture of left distal clavicle treated by closed reduction and internal fixation with K-wire. There was intrusion of K-wire into subacromial space.



Generally, most of the clavicle fractures can achieve adequate union with little complication in nonoperative method. However, fracture of the distal third has been associated with a higher percentage of delayed or nonunion.^{1, 5, 12-13} Fracture of the distal third account for 12 to 15% of all clavicular fractures and are subclassified according to the location of the coracoclavicular (CC) ligaments relative to the fracture fragments. Approximately 85% of nonunions of the clavicle occur in the middle third of the bone. Despite this, it appears that fractures of the distal one third of the clavicle are much more susceptible to nonunion than are shaft fractures. In his series on clavicular nonunion, Neer noted that distal clavicular fractures accounted far more than one half of ununited clavicles after closed treatment. He found the reasons for this increased incidence of nonunion to be multifactorial: (1) The fracture is very unstable, and the muscle forces and weight of the arm tend to displaced the fracture fragments; (2) Because these distal clavicular injuries are often the result of severe trauma, these is extensive local soft tissue injury, and there may be associated injuries that may affect generalized biologic and specific fracture healing; and (3) There may be difficulty in securing adequate external immobilization.

Even in those fractures in which union may occur with closed methods, the union time for distal clavicular fracture is often delayed; this healing time, combined with associated degree of soft tissue trauma, may lead to stiffness and prolong disability from disuse. For this reason, Neer advocated early open reduction and internal fixation for this injury.¹²

If surgery for a fractured clavicle is to be undertaken, historically the choices have tended to be between plate fixation (AO) and intramedullary fixation. Most authors prefer intramedullary fixation for acute fractures for the following reasons: (1) there is less exposure of the fracture and therefore a smaller skin incision; (2) little periosteal stripping is needed and therefore there is less interference with the healing potential of fracture; (3) removal of hardware is less problematic and can usually be done with a local anesthetic; and (4) no screw holes remain to act as potential areas of weakness of the bone. For these reasons, intramedullary pinning is still the most common preferred method for many surgeons. In an attempt to insert the various kinds of pin into the medullary canal of distal clavicle is very difficult and may produce complications from the operative procedure. We created the study to identify the optimal pin insertion point for distal clavicle fixation for safest intramedullary pinning of distal clavicle fracture and acromioclavicular joint dislocation.

Objective

The purpose of this study is to identify the optimal pin insertion point for distal clavicle fixation.

Materials and Methods

Thirty-two embalmed cadaveric shoulders attached with the chest wall were used for the present study. The experiment was performed in the same manner for each specimen. Two palpable anatomic landmarks, anterosuperior tuberosity of medial end of clavicle and anterior angle of acromion, were identified on each specimen and used as a reference line. Bone window was created at the distal one-third of clavicle about 1.5 centimeters medial from conoid tuberosity and leaved the anterior cortex of the clavicle intact. Bone window was created as wide as we can freely retrograde drilled into the medullary canal of distal clavicle. A 2.0-millimeters Kirschner wire (K-wire) was retrograde drilled into the medullary canal of distal clavicle through the bone window (Fig. 7, 8). After K-wire emerged though the acromial surface, subacromial space was checked to ensure that no part of K-wire penetrated in this space.

Fig. 7 Schematic diagram of superior view of right acromioclavicular joint shown the location bone window.

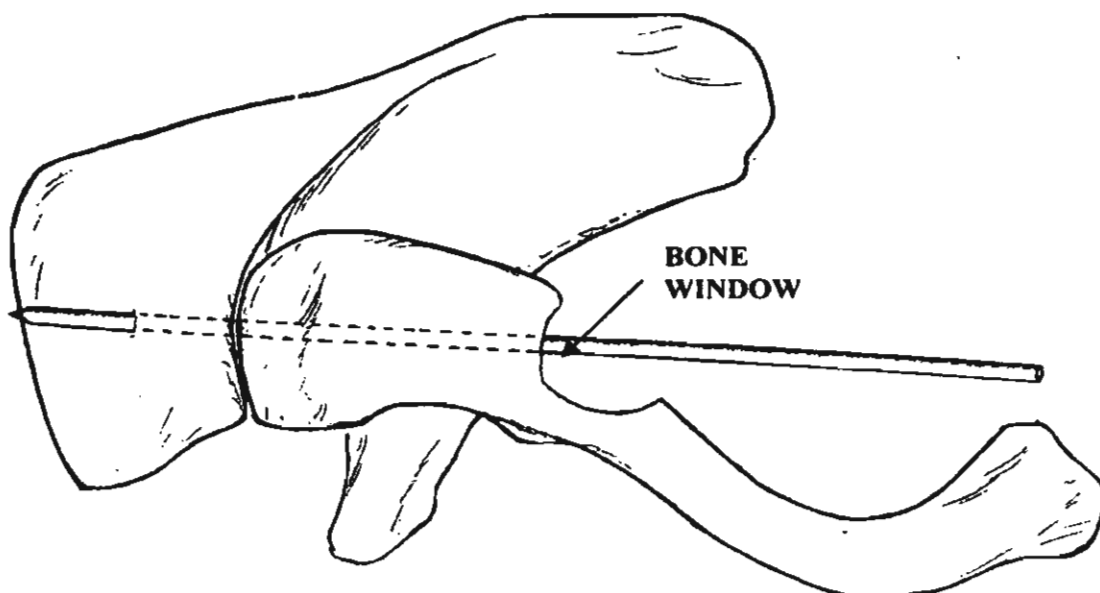
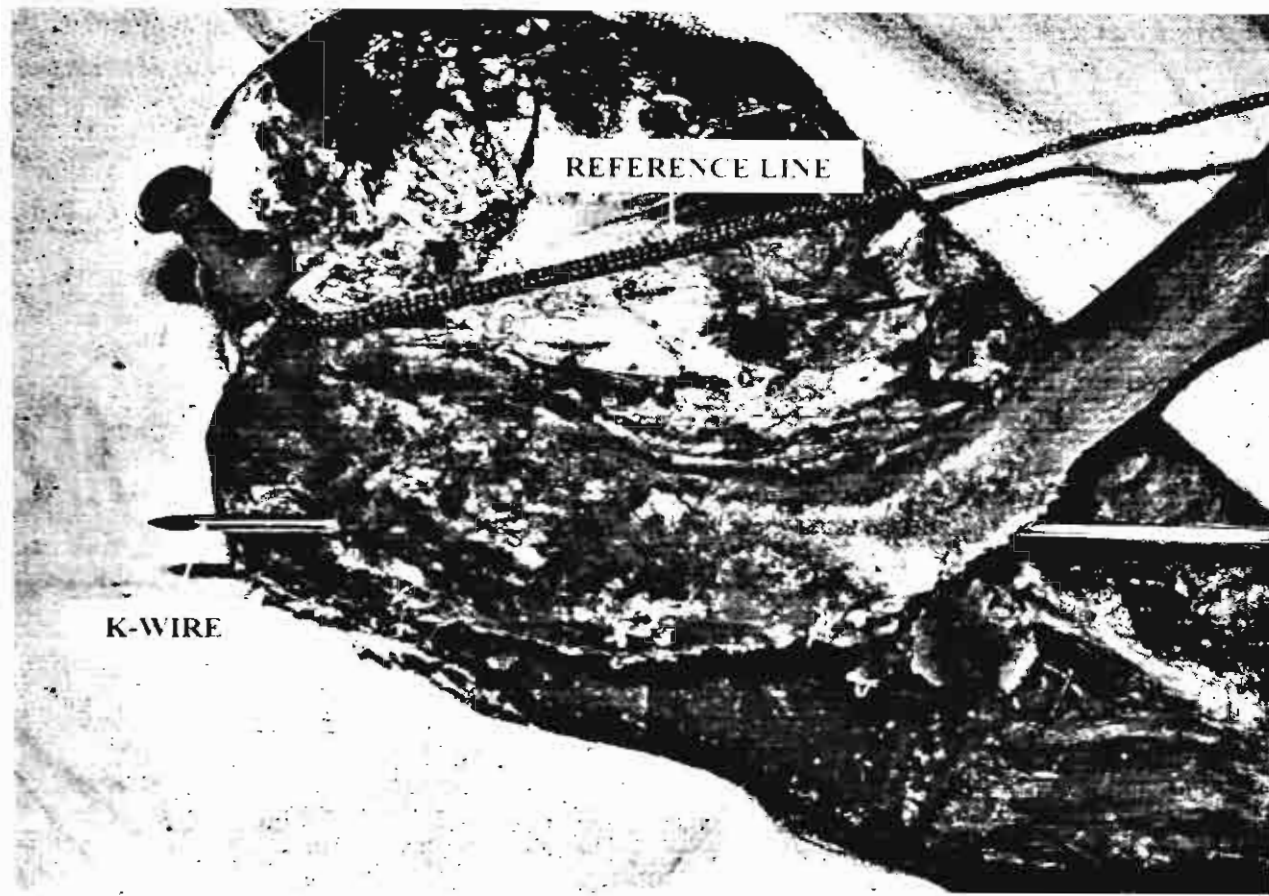
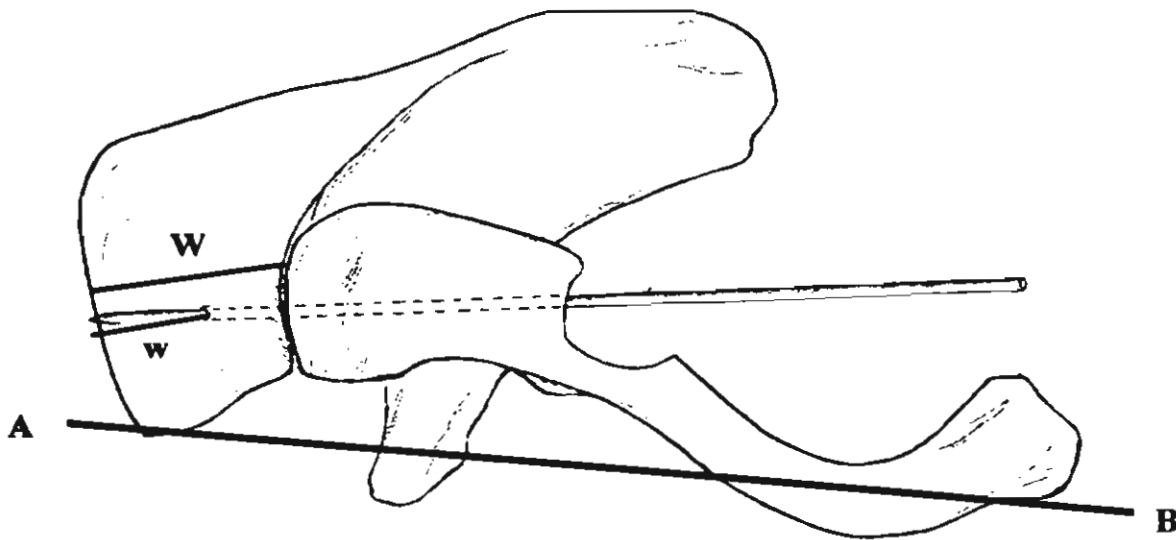


Fig. 8. A 2.0 millimeters Kirschner wire was retrogradely drilled through the bone window and it emerged at superior surface of acromian in embalmed cadaveric shoulder.



The emerging point of the K-wire on the superior surface of acromian was recorded as ratio scale both in sagittal and coronal plane to decrease the effect of size variation of the specimens. The emerging point of the K-wire in coronal plane was recorded as coronal portal insertion ratio (CPIR), distance from medial border of acromian to emerging point (w) divided by the width of acromian in mid-portion (W) as Fig. 9. The emerging point of K-wire in sagittal plane was recorded as sagittal portal insertion ratio (SPIR), distance from anterior border of acromian to emerging point (l) divided by the acromial length in the mid-portion (L) as Fig. 10.

Fig. 9 Schematic diagram of superior view of right acromioclavicular joint shown the reference line, line AB, and measurement of coronal portal insertion ratio (CPIR), length of "w" divided by length of "W". The measurement of horizontal pin angle (HPA), angle between the Kirschner wire and reference line in horizontal plane.



The directions of K-wire in relation to the reference line, line AB (Fig. 9.), were recorded both in coronal and horizontal plane as a coronal pin angle (CPA) and horizontal pin angle (HPA) respectively (Fig. 11, 12, 9).

Fig. 10 Schematic diagram of superior view of right acromioclavicular joint shown the measurement of sagittal portal insertion ratio (SPIR), length of "I" divided by length of "L".

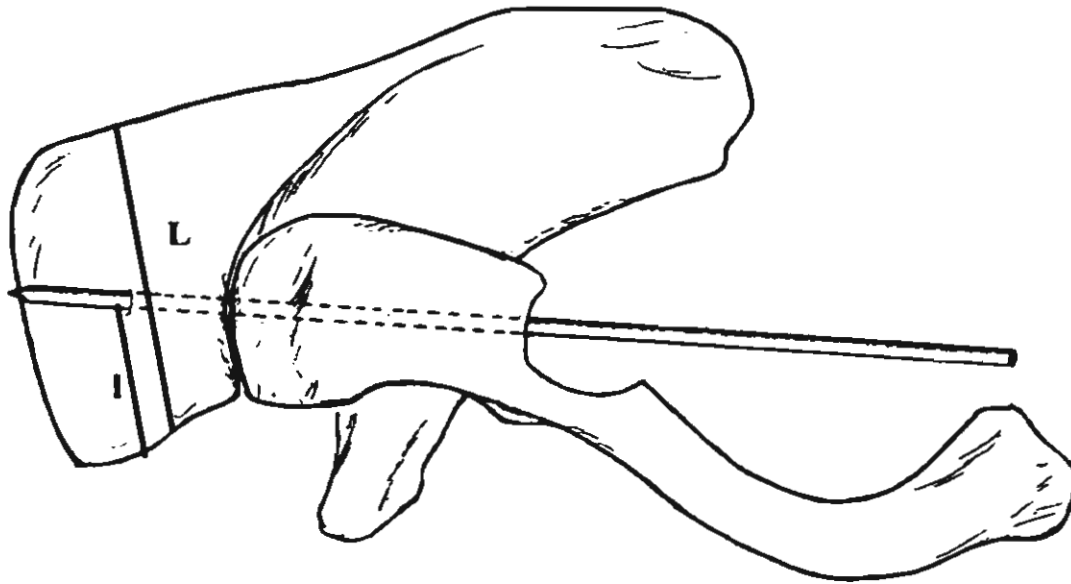


Fig. 11 Schematic diagram of anterior view of right acromioclavicular joint shown the reference line, line AB, and measurement of coronal pin angle (CPA), angle between the Kirschner wire and reference line in coronal plane.

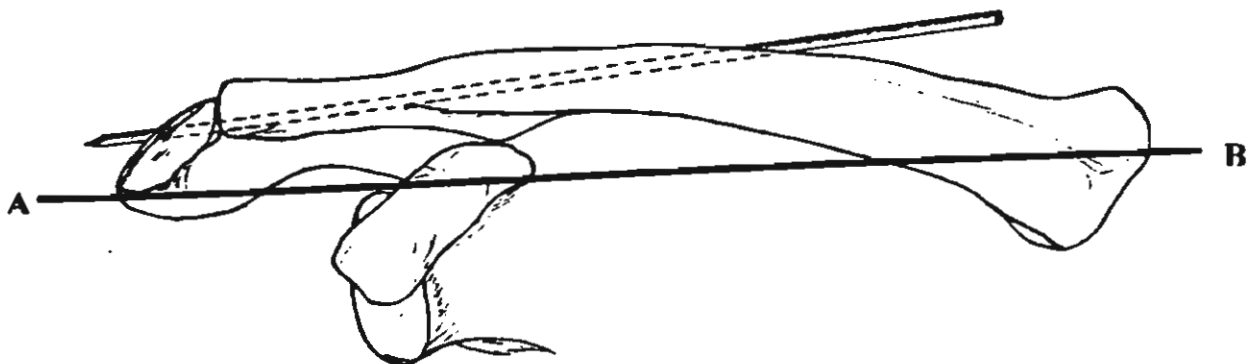
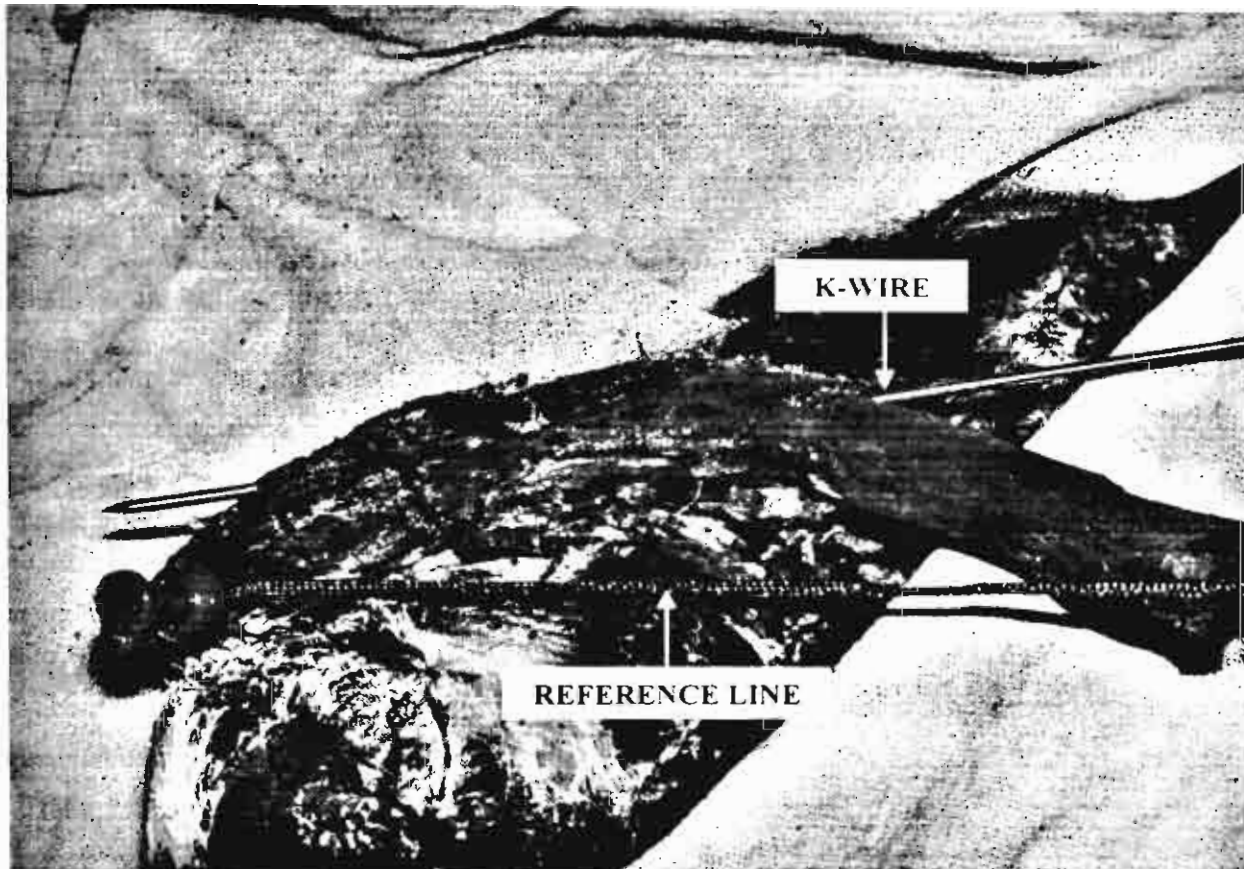


Fig. 12 cadaveric specimen of anterior view of right acromioclavicular joint shown the reference line, line AB, and measurement of coronal pin angle (CPA), angle between the Kirschner wire and reference line in coronal plane.



After the first recorded, K-wire was removed and then randomly retrograde drilled though the bone window again. The emerging point was recorded in the same manner. The cadaveric specimen was repeatedly drilled until the acromial fracture occurs. The number of drilling until the acromial fracture occurs was recorded for each specimen.

The area available for intramedullary pinning of distal clavicle without deviation of K-wire out of the medullary canal to damage the surrounding structure was called the "safe portal". The safe portal of intramedullary pinning and its directions were determined.

The drilling-counts which penetrated into subacromial space were excluded for determining the safe portal and its direction but it's were included to determine the survival times of repeated drilling.

Results

Safe portal and its directions

The data of 304 drilling-counts of 32 specimens were included to determine the safe portal and its directions (Table 1). The 14 drilling-counts were excluded because there were the part of K-wire penetrates though subacromial space. The average CPIR was 0.397 ± 0.09 . The average SPIR was 0.325 ± 0.04 . The CPA and HPA were 7.69 ± 3.04 and 14.59 ± 4.34 degree respectively. The effect of K-wire angles in fracture events and no fracture events were compared by using paired t-test. The means CPA in fracture events (TABLE 3) was significantly higher than no fracture events ($P < 0.05$) but there was no significant different of HPA (TABLE 3) between these two groups ($P = 0.10$).

TABLE 1. Portal insertion ratio and its directions

	Means $\pm$ SD
CPIR	0.397 ± 0.09
SPIR	0.325 ± 0.04
CPA (degree)	7.690 ± 3.04
HPA (degree)	14.59 ± 4.34

CPIR, coronal portal insertion ratio; SPIR, sagittal portal insertion ratio; CPA, coronal pin angle; HPA, horizontal pin angle.

TABLE 2 The horizontal pin angle (HPA) in fracture events and no fracture events were compared by using paired t-test.

Group	N	Mean	Standard Deviations	SEM
Fracture events	32	15.12	3.661	0.647
No fracture events	32	10.67	3.462	0.612

Difference 4.453 4.858 0.8587

95% confidence interval for difference: 2.702 to 6.204

t = 5.186 with 31 degrees of freedom; P = 0.000

TABLE 3 The coronal pin angle (CPA) in fracture events and no fracture events were compared by using paired t-test.

Group	N	Mean	Standard Deviation	SEM
Fracture events	32	8.375	2.24	0.396
No fracture events	32	7.625	0.77	0.136

Difference 0.75 2.509 0.4436

95% confidence interval for difference: -0.1547 to 1.655

t = 1.691 with 31 degrees of freedom; P = 0.101

Survival times for repeated drilling

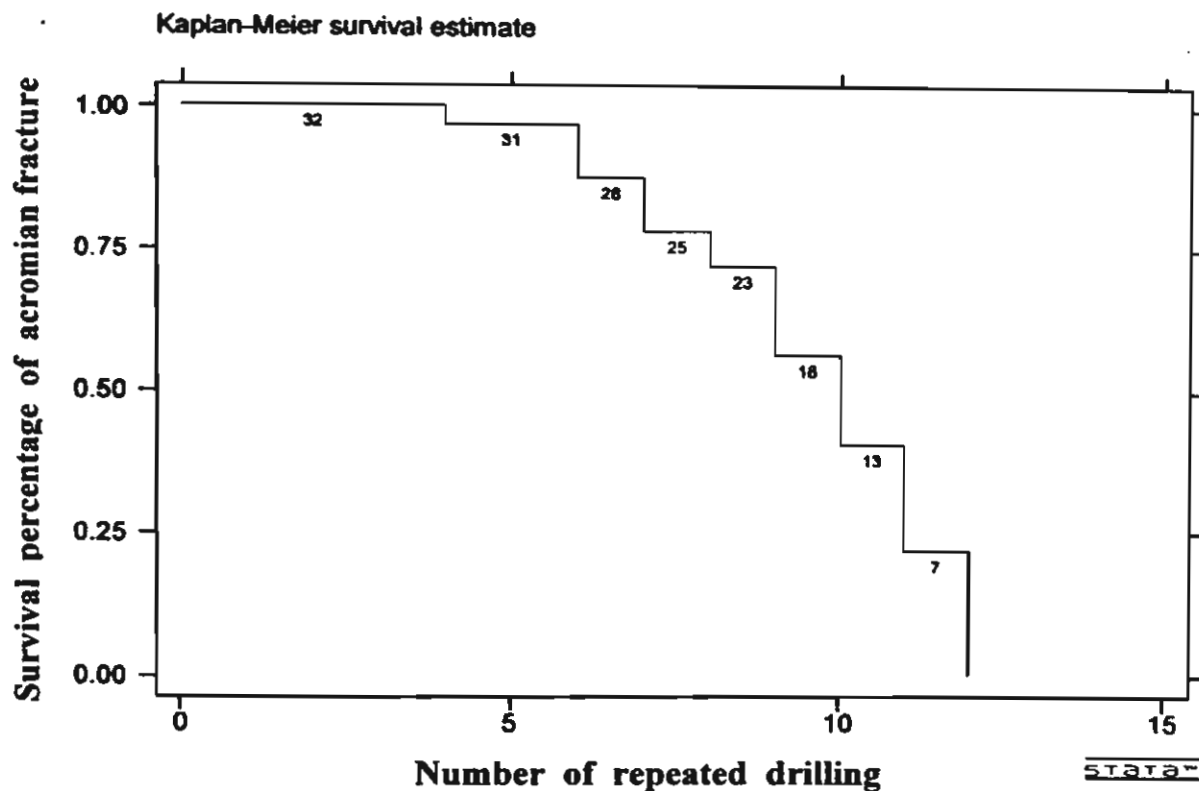
The numbers of 318 repeated drillings were counted for survival times. The average number of repeated drilling of K-wire until the acromial fracture occur was 9.8 drilling-times, range from 4 to 12 drilling-times. According to survival analysis, the incidence density was 0.11 (95%CI: 0.72-0.15) sample-counts. The survival rate at 4, 6, 8, and 10 drilling-times were 0.97 (0.89-0.99), 0.88 (0.70-0.95), 0.72 (0.53-0.84), and 0.40 (0.24-0.57) respectively (Table 4). No acromial fracture occurred in less than 4 drilling-times. Acromial fractures occurred after 4 drilling-times and until 12 drilling-times. All acromial fractures occurred at the superomedial part of acromial which articulated with the distal end of clavicle. The survival rate was suddenly decreased from 8 to 10 drilling-times (Fig. 13).

TABLE 4 Survival rate and number of repeated drilling

No. of repeated drilling	Survival rate	Standard error	95% CI
4	0.968	0.030	0.798-0.995
6	0.875	0.058	0.700-0.951
8	0.718	0.079	0.529-0.842
10	0.406	0.086	0.238-0.567
12	0.000	-	-

CI, confidence interval.

Fig. 13 Graph of the survival percentage and their corresponding number of repeated drilling. The line show the decreasing of survival rate with the increasing of number of repeated drill.



Discussions

In adults with clavicular fractures, the goal of treatment (as with other fractures) is to achieve healing of bone with minimal morbidity, loss of motion, and residual deformity. Although distal clavicular fractures may heal quite well without surgical treatment because of the deforming forces and high incidence of nonunion, many authors continue to recommend primary open reduction and internal fixation, either with an intramedullary pin or some method of dynamic fixation to bring the proximal clavicular segment to the distal

As early as the late 1920s, more than 200 different treatment methods has already been described for fractures of the clavicle. The exact method of treatment of the fractured clavicle depends on several factors, including the age and medical condition of the patient, the location of the fracture, and associated injuries.

In acute treatment of distal clavicular fractures as well as high degree acromioclavicular separations. Open or closed reduction with internal fixation. A number of techniques has been described for treatment of clavicular fractures with internal fixation. These technique have included circlage sutures, intramedullary devices (Steinmann pin, K-wire, Knowles pin, Kuntsches nails, or Rush pin), or plate fixation. Although a variety of encircling wires, pins, and sutures binding the proximal fragment to the coracoid process have been described, most authors preferred the intramedullary fixation. Plate fixation is often impractical because of the small distal fragment. It appears that some types of intramedullary device not prone to migration might offer the safest method of treatment for distal fractures of clavicle.

Intramedullary pinning of distal clavicle with various types of instrument still to be the most preferred method for distal clavicle fixation. The difficulty is how to define the safe portal and its directions. The acromian is thin and flat bone. The clavicle is curve, oval, and subcutaneous along its entire length and there are important neurovascular structures pass beneath it. Moreover, there are the angulation between these bones and some motion of acromioclavicular joint. The deviation of intramedullary pin out of the clavicle can penetrate though skin or damage to neurovascular structures.

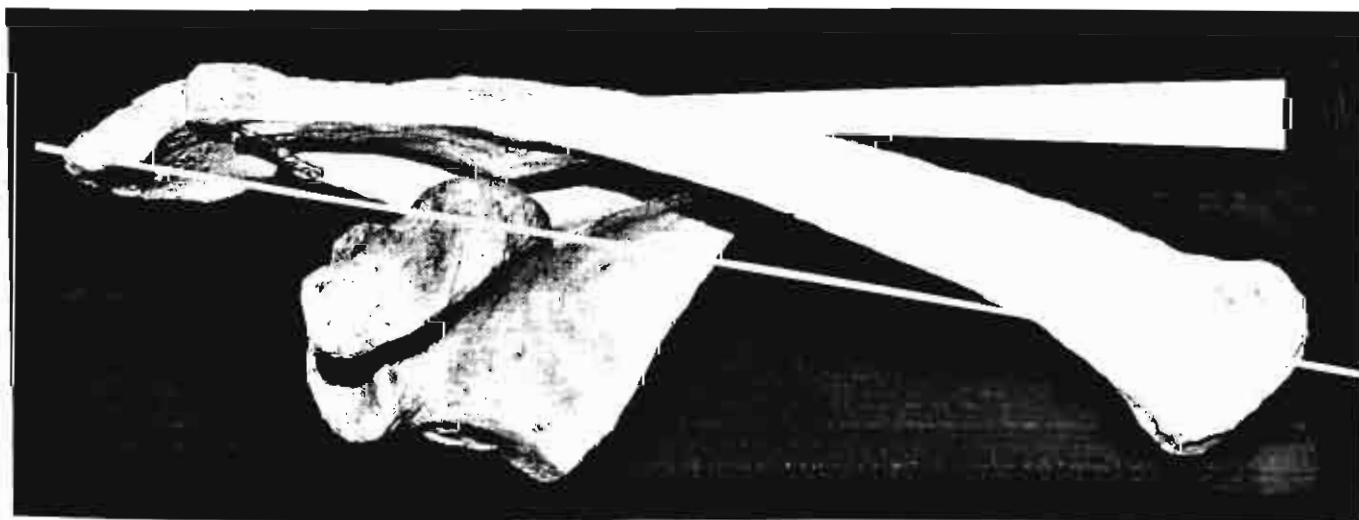
In the operative procedure for intramedullary fixation of distal clavicle, surgeons have to control the pin direction into the medullary canal of distal clavicle to avoid the surrounding soft tissue injury and reinsertion of pin. They usually use fluoroscopy to control the pin direction. Many reinsertions of pin can produce iatrogenic fractures of acromian or clavicle.

Identifying the optimum entry point and its directions for intramedullary pinning of distal clavicle fixation has several clinical implications with respect to reduce the risk of acromial fracture from repeated drilling and avoid the neurovascular injury from misdirection of pin. The identification of safe portal from this study was 39.7% of acromial width and 32.5% of acromial length when measured from medial and anterior border respectively (Fig. 14). The appropriate directions of the pin were 7.69 and 14.59 degree in relation to reference line in coronal and horizontal planes respectively (Fig. 14, 15). Surgeons should concern about K-wire directions especially in coronal plane because it will increase risk if iatrogenic acromial fracture. These safe portal and its directions will provide the high probability of pin point into the medullary canal of distal clavicle and can be applied for various types of intramedullary pin.

Fig. 14 Schematic diagram show the safe portal (green oval area) and its direction (yellow triangle) relate to reference line in horizontal plane.



Fig. 15 Schematic diagram show the K-wire direction (yellow triangle) relates to reference line in coronal plane.



The second part of the results, the survival rate of repeated drilling at 8 and 10 times were 0.72 and 0.41 respectively. These results suggested that the risk of acromial fracture after repeated drilling more than 8 times was suddenly high. No specimens can tolerate the repeated drilling more than 12 times. All acromians broke at superomedial part which articulates with distal end of clavicle. However, these results have limited clinical implications because there are many types and sizes of pin. Moreover, the intramedullary pinning for distal clavicular fracture or acromioclavicular joint dislocation usually inserts antegradely. In our experience, there are another types of iatrogenic fracture when we antegradely fix the distal clavicle such as fracture of distal end of clavicle. The results in this part can only be applied for a 2.0 millimeters K-wire fixation and it should be concerned that the antegradely insert may created many types of iatrogenic fracture. These require further study.

In this study, we design the data collection in ratio scale to decrease the effect of size variation of each specimen. The other factors that can contribute the effect to our experiment are the motion of acromioclavicular joint and sternoclavicular joint unless in the embalmed cadaver. These factors provide the wide standard variation of the data of safe portal and its directions.

Conclusions

Base on this study, we recommend that the safe portal insertion point for distal clavicle fixation should be 39.7% of acromial width and 32.5% of acromial length. The directions of pin are 7.69 and 14.59 degree in relation to reference line in coronal and horizontal planes respectively. If 2.0 millimeters K-wire was used for fixation, it should not be repeatedly drilled more than 8 times because the risk of iatrogenic fracture is suddenly high.

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Appendix

An Accuracy of Pin Insertion Point for Distal Clavicle Fixation: A Cadaveric Study

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Device status:

The device that is the subject of this manuscript is FDA-approved.

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An Accuracy of Pin Insertion Point for Distal Clavicle Fixation: A Cadaveric Study

Abstract

Objective: The purpose of this study is to identify the optimal pin insertion point for distal clavicle fixation.

Design: Cadaveric study.

Setting: Medical school anatomy laboratory.

Main Outcome Measure: Optimal pin insertion point and its direction for distal clavicle fixation in embalmed cadaveric shoulders.

Methods: Thirty-two embalmed cadaveric shoulders were used in this study. We created the hole at the posterior two-third of mid clavicle about 1.5 cm. from conoid tubercle. The hold was created as wide as we can freely retrogradely drilled into the medullary canal of distal clavicle. A 2.0-millimeters Kirschner wire was retrogradely drilled until it penetrated the acromion. We recorded the emerging point of K-wire in ratio scales and the angle of K-wire compared with the reference line, line from superior tubercle of clavicle to anterior angle of acromion. After the data of first drilling was recorded, K-wire was removed and randomly repeatedly drilled in the same specimen until the acromion was fracture. The number of drilling was recorded. The specimens were processed in the same procedures.

Results: The data of 304 drilling-counts of 32 specimens shown that the length of sagittal pin inserting point from anterior border of acromion divided by acromion length were 0.325 ± 0.04 . The length of coronal pin inserting point from distal border of acromion divided by acromial width was 0.397 ± 0.09 . The angles of K-wire compared with reference line were 7.69 ± 3.04 and 14.59 ± 4.34 degree in coronal and horizontal plane respectively. According to the survival analysis, the incidence density was 0.11 (95%CI: 0.072-0.15) samples-counts. The survival rate at 8 and 10 drilling-times were 0.72 (95%CI: 0.53-0.84) and 0.41 (95%CI: 0.24-0.57) respectively.

Discussion and Conclusion: Closed pinning is one of the most common fixation methods, which used for the fracture of distal clavicle and acromioclavicular joint dislocation. This study suggested that the insertion point for closed pinning in ratio scale of acromial length and width were 0.325 and 0.397 respectively. If the 2.0 millimeters K-wire was used for fixation, it should not be drilled more than 8 times because the risk of acromial fracture was suddenly high.

Key Words: Intramedullary pinning, Clavicle, Insertion point.

Introduction

Fracture of clavicle is the most common fracture occurs in childhood (4). It has been estimated that 1 of 20 fractures involves the clavicle (11) and that fracture of the clavicle may constitute as much as 44% of shoulder girdle injuries (15). However, only some types of distal clavicular fracture and acromioclavicular joint dislocation were considered to be an indication for internal fixation. A number of techniques have been described for treatment of distal clavicle fracture. These techniques have include cerclage sutures (3), intramedullary devices (Steinmann pin, K-wire, Knowles pin, Perry pin, modified Hagie pins, or Rush pin) or plate fixation (2, 6-8, 16).

Intramedullary pinning is still the most common preferred method for many surgeons. In an attempt to insert the various kinds of pin into the medullary canal of distal clavicle is very difficult and may produce complications from the operative procedure. The purpose of this study was to evaluate the direction and the optimal pin insertion point and its directions for safest intramedullary pinning of distal clavicle.

Materials and Methods

Thirty-two embalmed cadaveric shoulders attached with the chest wall were used for the present study. The experiment was performed in the same manner for each specimen. Two palpable anatomic landmarks, anterosuperior tuberosity of medial end of clavicle and anterior angle of acromion, were identified on each specimen and used as a reference line. Bone window was created at the distal one-third of clavicle about 1.5 centimeters medial from conoid tuberosity and leaved the anterior cortex of the clavicle intact. Bone window was created as wide as we can freely retrograde drilled into the medullary canal of distal clavicle. A 2.0-millimeters Kirschner wire (K-wire) was retrograde drilled into the medullary canal of distal clavicle through the bone window (Fig.1). After K-wire emerged though the acromial surface, subacromial space was checked to ensure that no part of K-wire penetrated in this space.

The emerging point of the K-wire on the superior surface of acromion was recorded as ratio scale both in sagittal and coronal plane to decrease the effect of size variation of the specimens. The emerging point of the K-wire in coronal plane was recorded as coronal portal insertion ratio (CPIR), distance from medial border of acromion to emerging point (w) divided by the width of acromion in mid-portion (W) as Fig. 2. The emerging point of K-wire in sagittal plane was recorded as sagittal portal insertion ratio (SPIR), distance from anterior border of acromion to emerging point (l) divided by the acromial length in the mid-portion (L) as Fig. 3.

The directions of K-wire in relation to the reference line, line AB (Fig. 2.), were recorded both in coronal and horizontal plane as a coronal pin angle (CPA) and horizontal pin angle (HPA) respectively (Fig. 4, 2).

After the first recorded, K-wire was removed and then randomly retrograde drilled though the bone window again. The emerging point was recorded in the same manner. The cadaveric specimen was repeatedly drilled until the acromial fracture occurs. The number of drilling until the acromial fracture occurs was recorded for each specimen.

The area available for intramedullary pinning of distal clavicle without deviation of K-wire out of the medullary canal to damage the surrounding structure was called the "safe portal". The safe portal of intramedullary pinning and its directions were determined.

The drilling-counts which penetrated into subacromial space were excluded for determining the safe portal and its direction but it's were included to determine the survival times of repeated drilling.

Results

Safe portal and its directions

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Survival times for repeated drilling

The numbers of 318 repeated drillings were counted for survival times. The average number of repeated drilling of K-wire until the acromial fracture occur was 9.8 drilling-times, range from 4 to 12 drilling-times. According to survival analysis, the incidence density was 0.11 (95%CI: 0.72-0.15) sample-counts. The survival rate at 4, 6, 8, and 10 drilling-times were 0.97 (0.89-0.99), 0.88 (0.70-0.95), 0.72 (0.53-0.84), and 0.40 (0.24-0.57) respectively (Table 2). No acromial fracture occurred in less than 4 drilling-times. Acromial fractures occurred after 4 drilling-times and until 12 drilling-times. All acromial fractures occurred at the superomedial part of acromial which articulated with the distal end of clavicle. The survival rate was suddenly decreased from 8 to 10 drilling-times (Fig. 5).

Discussions

Intramedullary pinning of distal clavicle with various types of instrument still to be the most preferred method for distal clavicle fixation. The difficulty is how to define the safe portal and its directions. The acromian is thin and flat bone. The clavicle is curve, oval, and subcutaneous along its entire length and there are important neurovascular structures pass beneath it. Moreover, there are the angulation between these bones and some motion of acromioclavicular joint. The deviation of intramedullary pin out of the clavicle can penetrate though skin or damage to neurovascular structures.

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Identifying the optimum entry point and its directions for intramedullary pinning of distal clavicle fixation has several clinical implications with respect to reduce the risk of acromial fracture from repeated drilling and avoid the neurovascular injury from misdirection of pin. The identification of safe portal from this study was 39.7% of acromial width and 32.5% of acromial length when measured from lateral and anterior border respectively. The appropriate directions of the pin were 7.69 and 14.59 degree in relation to reference line in coronal and horizontal planes respectively. Surgeons should concerned about K-wire directions especially in coronal plane because it will increase risk if iatrogenic acromial fracture. These safe portal

and its directions will provide the high probability of pin point into the medullary canal of distal clavicle and can be applied for various types of intramedullary pin.

The second part of the results, the survival rate of repeated drilling at 8 and 10 times were 0.72 and 0.41 respectively. These results suggested that the risk of acromial fracture after repeated drilling more than 8 times was suddenly high. No specimens can tolerate the repeated drilling more than 12 times. All acromians broke at superomedial part which articulates with distal end of clavicle. However, these results have limited clinical implications because there are many types and sizes of pin. Moreover, the intramedullary pinning for distal clavicular fracture or acromioclavicular joint dislocation usually inserts antegradely. In our experience, there are another types of iatrogenic fracture when we antegradely fix the distal clavicle such as fracture of distal end of clavicle. The results in this part can only be applied for a 2.0 millimeters K-wire fixation and it should be concerned that the antegradely insert may created many types of iatrogenic fracture. These require further study.

In this study, we design the data collection in ratio scale to decrease the effect of size variation of each specimen. The other factors that can contribute the effect to our experiment are the motion of acromioclavicular joint and sternoclavicular joint unless in the embalmed cadaver. These factors provide the wide standard variation of the data of safe portal and its directions.

Conclusions

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TABLE 1. Portal insertion ratio and its directions

	Means $\pm$ SD
CPIR	0.397 $\pm$ 0.09
SPiR	0.325 $\pm$ 0.04
CPA (degree)	7.690 $\pm$ 3.04
HPA (degree)	14.59 $\pm$ 4.34

CPIR, coronal portal insertion ratio; SPiR, sagittal portal insertion ratio; CPA, coronal pin angle; HPA, horizontal pin angle.

TABLE 2. Survival rate and number of repeated drilling

No. of repeated drilling	Survival rate	Standard error	95% CI
4	0.968	0.030	0.798-0.995
6	0.875	0.058	0.700-0.951
8	0.718	0.079	0.529-0.842
10	0.406	0.086	0.238-0.567
12	0.000	-	-

CI, confidence interval.

Fig. 1. A 2.0 millimeters Kirschner wire was retrogradely drilled through the bone window and it emerged at superior surface of acromian in embalmed cadaveric shoulder.

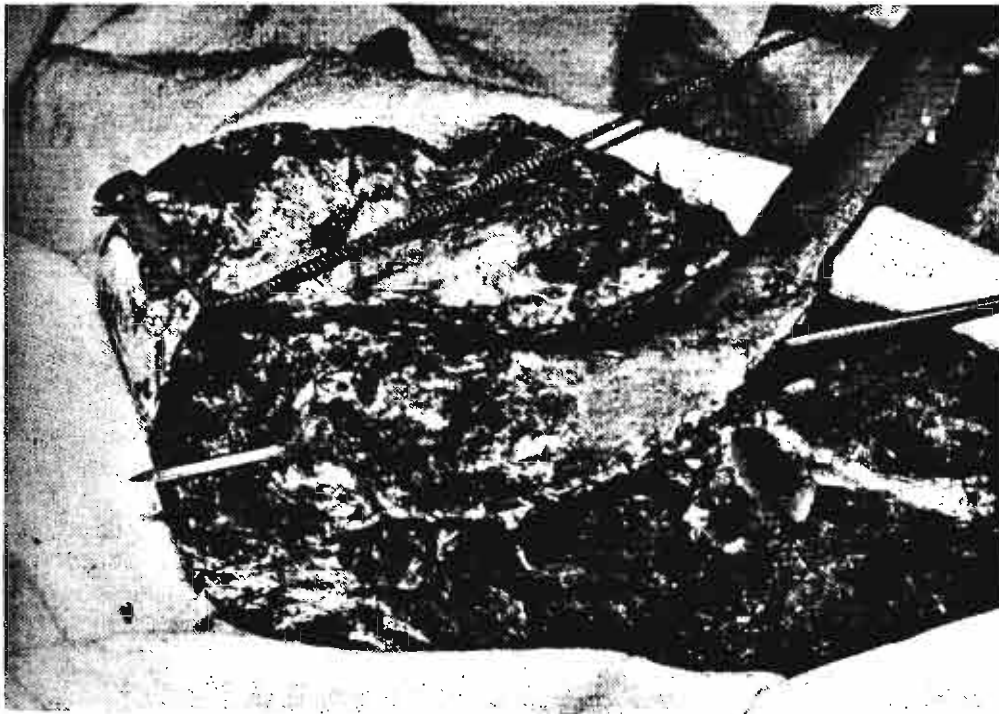


Fig. 2. Schematic diagram of superior view of acromioclavicular joint shown the reference line, line AB, and measurement of coronal portal insertion ratio (CPIR), length of "w" divided by length of "W". The measurement of horizontal pin angle (HPA), angle between the Kirschner wire and reference line in horizontal plane.

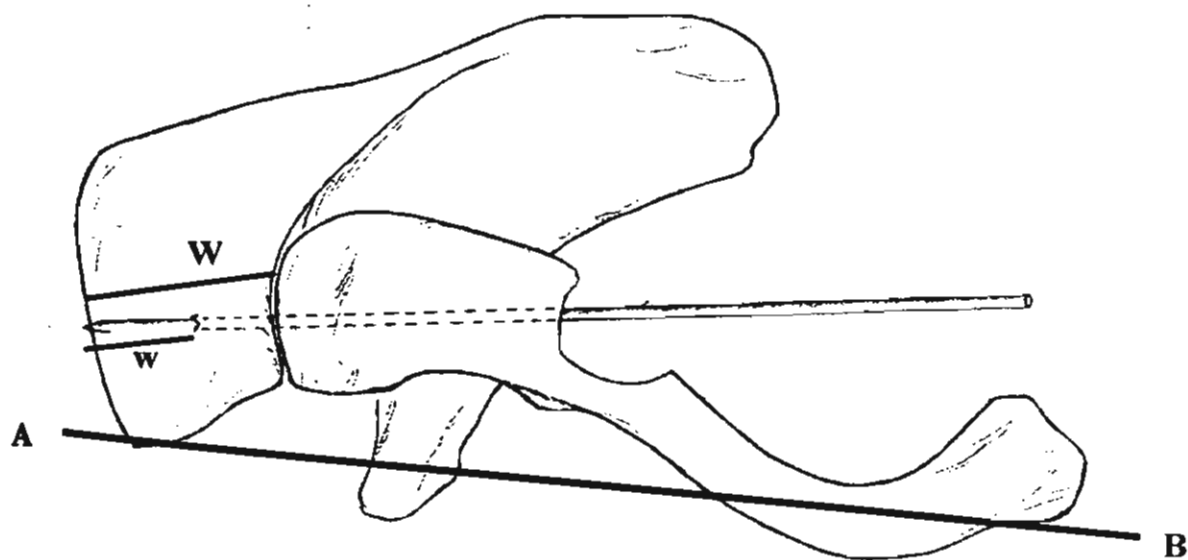


Fig. 3. Schematic diagram of superior view of acromioclavicular joint shown the measurement of sagittal portal insertion ratio (SPIR), length of "I" divided by length of "L".

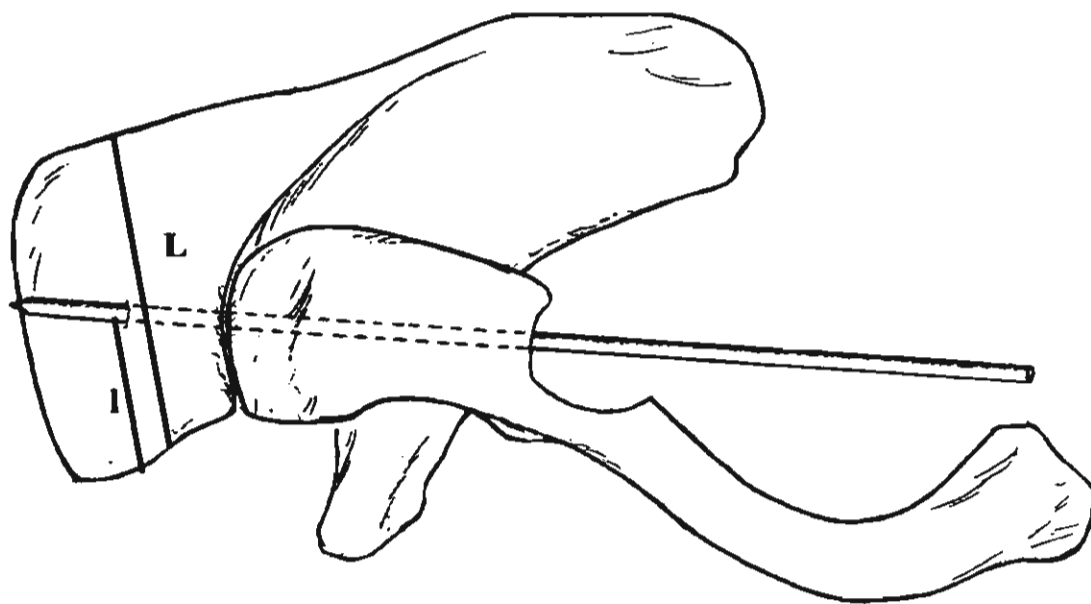


Fig. 4. Schematic diagram of anterior view of acromioclavicular joint shown the reference line, line AB, and measurement of coronal pin angle (CPA), angle between the Kirschner wire and reference line in coronal plane.

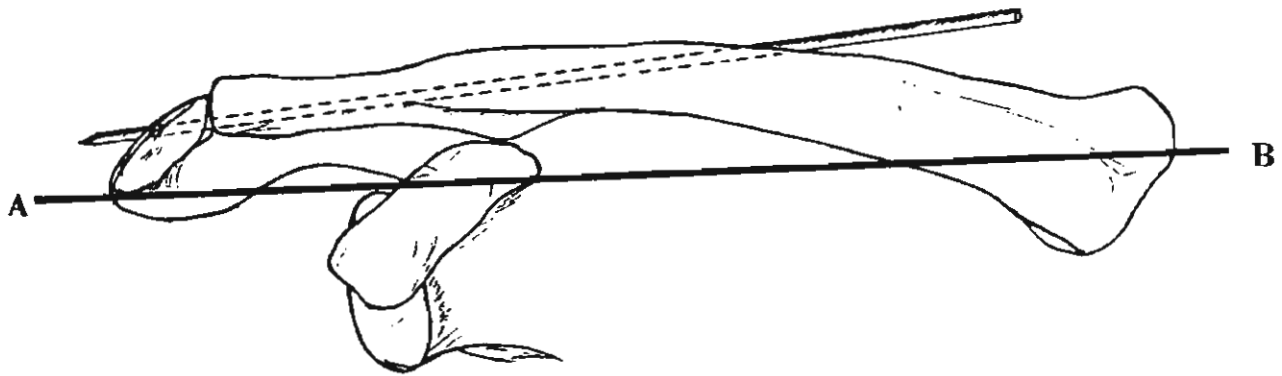
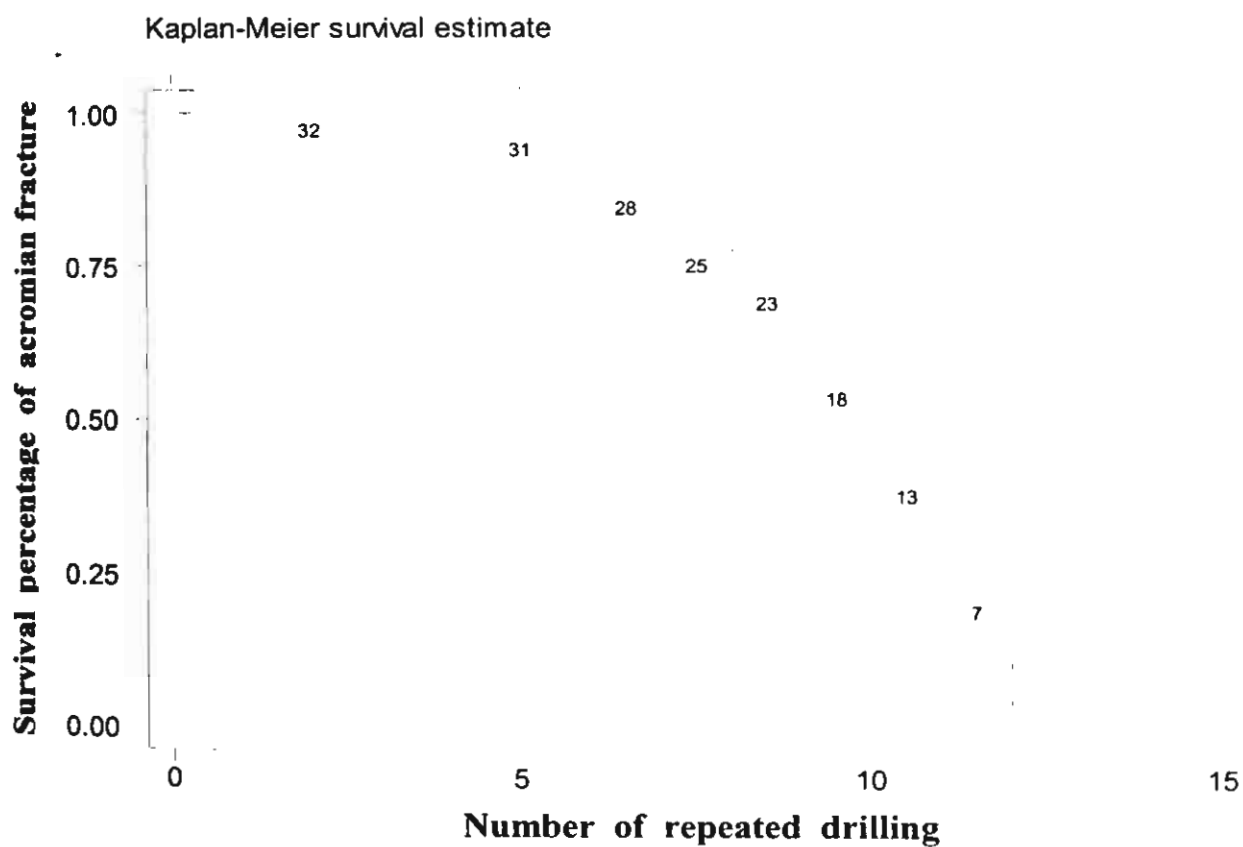


Fig. 5. Graph of the survival percentage and their corresponding number of repeated drilling. The line show the decreasing of survival rate with the increasing of number of repeated drill.



**25th Annual Meeting of
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- ☐ 1. Spine/Pelvis
- ☒ 2. Shoulder/Humerus
- ☐ 3. Elbow/Forearm
- ☐ 4. Wrist/Hand
- ☐ 5. Hip/Femur
- ☐ 6. Knee/Tibia
- ☐ 7. Ankle/Foot
- ☐ 8. Others

µ Section

- ☐ A. Children
- ☒ B. Trauma
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AN ACCURACY OF PIN INSERTING POINT FOR DISTAL CLAVICLE FIXATION: A CADAVERIC STUDY

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Purpose: To study an accuracy of pin inserting point for distal clavicle fixation.

Materials and methods: Thirty-two embalmed cadaveric shoulders were used in this study. We created the hole at the posterior two-third of mid clavicle about 1.5cm. from conoid tubercle. The hole was created as wide as we can freely retrogradely drilled into the medullary canal of distal clavicle. K-wire No. 1.6 was retrogradely drilled until its penetrate the acromion. We recorded the emerging point of K-wire in ratio scales and the angle of K-wire compared with the reference line, superior tubercle of clavicle to anterior angle of acromion. After the data of the first drilled was recorded, K-wire was removed and randomly repeatedly drilled in the same specimen until the acromion was fracture. The number of drilling was recorded. The other specimens were processed in the same procedures.

Results: The data of 304 drilled count of 32 specimens shown that the length of sagittal pin inserting point from anterior border of acromion divided by acromion length were 0.325 $\pm$ 0.044. The length of coronal pin inserting point from distal border of acromion divided by acromial width was 0.397 $\pm$ 0.089. The angles of K-wire compared with reference line were 14.59 $\pm$ 4.34 and 7.69 $\pm$ 3.04 in coronal and transverse plane respectively. According to the survival analysis, the incidence density was 0.11(95%CI: 0.072-0.15) samples-counts. The survival rate at 8 and 10 times-drilled were 0.72(95%CI: 0.53-0.84) and 0.41(95%CI: 0.24-0.57) respectively.

Conclusion: Closed pinning is one of the most common fixation method, which used for the fracture of distal clavicle and A-C joint dislocation. This study suggested that the inserting point for closed pinning in ratio scale of acromial length and width were 0.325 and 0.397 respectively. The angle of the K-wire should be 14.59° and 7.69° compared with the reference line in coronal and transverse plane respectively. The K-wire should not be repeatedly drilled more than 8 times because the risk of acromial fracture was suddenly high.



KHON KAEN UNIVERSITY

This is to certify that

The Project Entitled: An accuracy of pin inserting point for distal clavicle fixation :
A cadaveric study

Researcher: Assistant Professor Ekamol Thumroj , M.D. et al.

Name of Department: Department of Orthopaedics, Faculty of Medicine,
Khon Kaen University

has been reviewed and approved by The Khon Kaen University Ethics Committee
for Human Research based on the Declaration of Helsinki.

Date of Approval: May 15, 2002

Given On January 23, 2004

W. Kosuwon

Associate Professor Weerachai Kosuwon, M.D., M.Sc.
Chairman,
The Khon Kaen University Ethics Committee for Human Research

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Age Group	Percentage of Respondents
18-29	85%
30-49	80%
50-69	75%
70+	70%

	Service, mil.	Standing crop	1974 yield	Std.
20	0.000	0.000	0.775	0.000
5	0.000	0.000	0.7	0.001
8	0.775	0.000	0.000	0.000
10	0.000	0.000	0.200	0.000
12	0.000			

[illegible]

In this study, we design the data collection in eight groups to investigate the effect of the expression of youth questions. The other factors that also contribute the effect is not experiment on the number of questionnaire items and demographic characteristics within the experimental subjects. This design prevents the subtle statistical variation of the data of each subject and its direction.

Based on this study, we speculated that the early postlarval survivor pool in distal olivine basins should be 10.7% of original width and 22.5% of original length. The duration of g_{max} is 1.20 and 14.20 (days) in relation to chlorophyll *a* is constant and temperature plots respectively. Using the 3-6 years used by Quinn, I thought all be approximately 40 years than 6 years because the rate of oligotrophic basins is actually faster.