

(Original Articles)

A Biomechanical Study Area of Cannulated Screw Fixation for Femoral Neck Fracture in Cadaveric

Yuttapong Wajeesing MD.

Department of Orthopaedic Surgery, Bhumibol Adulyadej Hospital, Bangkok, Thailand

Correspondence to : Kicks_off@hotmail.com

Objective : To study the area of cannulated screw in femoral neck whether it will cause the biomechanical effect to femoral neck in terms of strength and stability or not and to consider the procedure to position the screws with multiple screw fixation method to gain appropriate placement and stable strength according to principle of biomechanics.

Material and methods : 24 cadaveric femurs were brought to do an osteotomy at the center of the femoral neck with 60 degree to the horizontal (Pauwel II) by using Image J photo analyzing program to calculate the cross-sectional area of femoral neck and defined screw placement in the form of an inverted triangle in three different positions by dividing the screw area of femoral neck in 3 different areas which were the area A, B and C. Reduction and fixation done with Cannulated screw No. 6.0. The femur was tested with mechanical test (Instron series IX) to analyze Axial stiffness, Axial load to failure, Axial Failure Displacement and Axial failure energy. This data was collected and interpreted.

Results : Femoral neck fracture fixation by using a multiple screw fixation method with cannulated screw, was divided screw area in femoral neck into 3 areas which are area A (4.19 cm.²), area B (2.64 cm.²) and area C (1.35 cm.²). It found that area A which was the most covered areas in femur had a better biomechanical effect than area B and C which were less covered area in femur, respectively. Biomechanical effect in area B was better than area C in Axial stiffness, Axial load to failure, Axial failure displacement and Axial failure energy and there was a statistically significant difference.

Conclusion : The result of femoral neck fracture fixation by using a multiple screw fixation method with a cannulated screw which its placement was in the form of an inverted triangle showed that the more screw placement covers the femoral neck area the more it causes a biomechanical effect and the most stability after the operation.

Keywords : *Area of cannulated screw, biomechanics, Femoral neck fracture*

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การศึกษาทางชีวกลศาสตร์พื้นที่ของสกรูที่ยึดตรึงคอกระดูกต้นขาหัก ในกระดูกต้นขา

ยุทธพงศ์ วรสิทธิ์ พบ.

กองออร์โธปิดิกส์ รพ.ภูมิพลอดุลยเดช พอ.

ความเป็นมา : ในคอกระดูกต้นขาหักชนิดไม่เลื่อน (Femoral neck fracture Garden type 1, 2) และคอกระดูกต้นขาหัก ในผู้ที่อายุน้อย นั้น วิธีการรักษาคือการยึดตรึงกระดูกที่หักด้วย Cannulated screw (Cannulated Screw Fixation) โดยการใช้ screw 3 ตัว วางตำแหน่งเป็นรูปแบบสามเหลี่ยมหัวกลับเพื่อทำการยึดตรึงกระดูก ซึ่งวิธีดังกล่าวนี้จะส่งผลทางด้านชีวกลศาสตร์ โดยทำให้คอกระดูกต้นขาที่ได้รับบาดเจ็บด้วยสกรูนั้นสามารถรับและทนต่อต่อแรงที่มากระทำรวมทั้งมีความแข็งแรงมั่นคง มากที่สุดเมื่อเทียบกับการยึดตรึงด้วยสกรูในรูปแบบอื่น ๆ ถึงอย่างไรก็ตามยังไม่มีการศึกษาในเรื่องของพื้นที่ของสกรูในคอกระดูก ต้นขานั้นมีผลต่อทางชีวกลศาสตร์หรือไม่ ดังนั้น ผู้วิจัยจึงทำการวิจัยขึ้น โดยจะทำการศึกษาในกระดูกต้นขาของอาจารย์ใหญ่ (Cadaveric)

วัสดุและวิธีการ : นำ Cadaver ที่เป็นกระดูกต้นขามาทั้งหมด 24 ชิ้น ทำ osteotomy ตำแหน่งกึ่งกลางของคอกระดูกต้นขาทำมุม 60 degree to horizontal (Pauwel II) ใช้โปรแกรมวิเคราะห์รูปภาพ Image J ในการคำนวณพื้นที่ในแนวหน้าตัดของ คอกระดูกต้นขาและ กำหนดการวางตำแหน่งของ screw เป็นรูปแบบสามเหลี่ยมหัวกลับ ที่แตกต่างกันออกเป็น 3 พื้นที่ ได้แก่พื้นที่ A, B และ C ทำการ reduction และ Fixation ด้วย Cannulated screw No 6.0 แล้วนำมาทดสอบด้วยเครื่อง mechanical test (Instron series IX) เพื่อหา Axial stiffness, Axial load to failure, Axial Failure Displacement, Axial failure energy เก็บบันทึกข้อมูลและแปลผล

ผลการศึกษา : การยึดตรึงคอกระดูกต้นขาหักด้วยวิธี multiple screw fixation ด้วย cannulated screw นั้น จากการ แบ่งพื้นที่ของสกรู ในคอกระดูกต้นขาออกเป็น 3 พื้นที่คือพื้นที่ A (4.19 ตร.ซม.) พื้นที่ B (2.64 ตร.ซม.) และพื้นที่ C (1.35 ตร.ซม.) พบว่าพื้นที่ A ซึ่งมีพื้นที่ ครอบคลุมกระดูกต้นขามากที่สุดนั้น ให้ผลทางชีวกลศาสตร์ (Biomechanics) ที่ดีกว่าพื้นที่ B และ C ซึ่งมีพื้นที่ครอบคลุมคอกระดูกต้นขา ที่น้อยกว่าลงมาตามลำดับ และพื้นที่ B นั้นก็มีผลทางชีวกลศาสตร์ที่ดีกว่าพื้นที่ C ทั้ง Axial stiffness, Axial load to failure, Axial failure displacement และ Axial failure energy ตามลำดับ โดยมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ

สรุป : ในการยึดตรึงคอกระดูกต้นขาหักด้วยวิธี multiple screw fixation ด้วย cannulated screw โดยวิธีการวาง ตำแหน่งสกรูให้เป็นรูป สามเหลี่ยมหัวกลับนั้น ควรวางตำแหน่งของสกรูให้มีพื้นที่ครอบคลุมคอกระดูกต้นขาให้มากที่สุด เพื่อให้ได้ ผลทางด้านชีวกลศาสตร์ (Biomechanics) ที่ดีและมีความมั่นคงแข็งแรงมากที่สุดตามภายหลังจากการ fixation

คำสำคัญ : ชีวกลศาสตร์, พื้นที่ของสกรูที่ยึดตรึงคอกระดูกต้นขาหัก

Introduction

Femoral neck fracture Garden type 1, 2 and Femoral neck fracture in young patients, the treatment is a Cannulated screw (Cannulated Screw Fixation) by fixing 3 screws to hold the bones together⁽¹⁻⁵⁾. There are many studies which concluded that the screw placement in the form of an inverted triangle in three positions are inferior screw along calcar, posterior/superior screw and anterior/superior screw⁽⁶⁻¹⁰⁾. It caused biomechanical effect by causing femoral neck, which was fixed by screw could endure and tolerate any forces, including stability as much as possible comparing with the screw fixation in other forms and positioning the distance between the screws should be

extended around femoral neck and made the most of it. Nevertheless, there is no study about the screw area of femoral neck whether it can affect in biomechanical way or not. Thus, the researcher aims to know how the screw placement to extend around the femoral neck as much as possible, as mentioned previously. When the screw area of the femoral neck is considered by determining different areas, whether it will cause the biomechanical effect to femoral neck in terms of strength and stability or not by studying in the femoral neck of Cadaver.

Materials and Methods

Twenty four bone of Femurs from Cadaver who donated body at forensic medicine, Bhumibol Adulyadej hospital were used in this study. For inclusion Criteria was Cadaver over 20-yearold and exclusion criteria were there is femur surgery record there is femoral neck fracture record and there is obvious femur deformation. Researcher studied by selecting Cadaver, who donated body at forensic medicine, Bhumibol Adulyadej Hospital, according to inclusion and exclusion criteria so there are 24 of the femur. The bone was cut in the middle of the femoral neck position in Transverse cut perpendicular to neck axis, 60 degrees to the horizontal (Pauwel II).Used Image J photo analyzing program was used to calculate the cross-sectional area of femoral neck and defined screw placement in the form of an inverted triangle in three different positions by dividing the screw area of femoral neck in 3 different areas which were the area A, B and C and using 8 bones per area. Guide pin drill was used according to the defined position.Reduction and fixation done with Cannulated screw No. 6.0 which 5 mm. apart from femoral head. The first screw was fed at inferior calcar which angled with femoral shaft at 130-135 degrees after that fed anterosuperior quadrant and posterosuperior quadrant, respectively.



Figure 1. Show the use of the guide wire drill as specified in the template. After that reduction and inserted the cannulated screw No.6.0 according to the guide wire.

Feeding done in a parallel type by using Fluoroscopy to check the screw position in AP,Lateral. The bone, which was fixed with screws in each defined area was tested with mechanical test (Instron series IX) to analyze Axial stiffness, Axial load to failure, Axial Failure Displacement and Axial failure energy. This data was collected and interpreted.



Figure 2. Shows the position of the three different cannulated screw after the fixation was completed, including area A, B and C

Statistical Analysis

Data was analyzed by using SPSS (Statistical Package of Social Science) version 18 for windows computer package to compare the difference of Axial stiffness, Axial load to failure, Axial Failure Displacement and Axial failure energy in each area by using One-way ANOVA and Post Hoc test and determined statistical significance as $P < 0.05$.

Result

Femoral neck fracture fixation by multiple screw fixation method using cannulated screw, was divided screw area in femoral neck into 3 areas which area A (4.19 cm^2), area B (2.64 cm^2) and area C (1.35 cm^2). After

biomechanical testing by using Biomechanics test and the data was interpreted. It found that Axial stiffness in area A was better than area B and C with statistically significant difference ($P<0.001$) and Axial stiffness in area B was better than area C with statistically significant difference ($P<0.001$). Axial load to failure in area A was better than area B and C with statistically significant difference ($P<0.001$) and Axial load to failure in area B was better than area C with statistically significant difference ($P<0.001$). Axial failure displacement in area A was better than area B and C with statistically significant difference ($P<0.001$) and Axial failure displacement in area B was better than area C with statistically significant difference ($P<0.001$). Axial failure energy in area A was better than area B and C with statistically significant difference ($P<0.001$) and Axial failure energy in area B was better than area C with statistically significant difference ($P<0.001$). (Table 1) From Demographic data, it found that in area A B and C there were samples which were 8 pieces of femur per area, equally. In each area, there were 4 pieces of male femur (50 %) ($P=0.76$) and 4 pieces of female femur (50 %) ($P=0.53$), equally. The gender data of femur in each area, there was no statistically significant difference at all. In part of age of the samples, it found that the average age of samples in area A was 73.75 years old, average age of samples in area B was 71.25 years old and the average age of samples in area C was 73.25 years old. There was no statistically significant difference of femur age in each area. ($P=0.76$) (Table 2)

Table 1. Result of biomechanics in the area of the Cannulated screw that was fixed in the three different Femoral neck areas : areas A, B and C.

Area of screw in the femoral neck	Axial stiffness (N) x (95 %CI)	Axial load to failure (N) x (95 %CI)	Axial failure displacement (mm) x (95 %CI)	Axial failure energy (J) x (95 %CI)	P-value
A	605.37 (601.55-609.19)	862.87 (859.37-866.37)	10.06 (9.99-10.12)	14.83 (14.50-15.16)	< 0.001
B	241.50 (238.67-244.32)	622.62 (620.48-624.76)	12.11 (12.00-12.22)	12.06 (11.95-12.17)	< 0.001
C	150.62 (147.80-153.44)	324.37 (322.48-326.26)	15.15 (14.95-15.35)	10.21 (10.03-10.39)	< 0.001

Discussion

This study showed that researcher, aimed to prove that femoral neck fracture fixation by a multiple screw fixation method whether there is a biomechanical effect from the screw area in femoral neck or not. In previous study, Zdero R. et al. studied about the distance between screws which were used in femoral neck fracture fixation by multiple screw fixation method in femoral prosthesis⁽¹³⁻¹⁴⁾. Screws were positioned in the form of an inverted triangle. The result was shown that position on femoral neck to have a lot of distance between screws caused biomechanical result better than less distance and there was a statistically significant difference. It showed that screw placement covered femur area as much as possible, which caused the biomechanical effect in a good way⁽¹⁵⁾.

In this study, multiple screw area in the femur was divided into 3 different areas and the result showed that area A which was the most covered areas in femur had a better biomechanical effect than are B and C which were less covered area in femur, respectively. Biomechanical effect in area B was better than area C in Axial stiffness, Axial

load to failure, Axial failure displacement and Axial failure energy and there was a statistically significant difference. The result was consistent with previous study, which have been mentioned. It also showed that screw placement, the more it covered femur area, the more biomechanical effect was caused in term of stability⁽¹⁶⁻¹⁷⁾.

Table 2. Demographic data

Sample data	Area of screw in the femoral neck			P-value
	A	B	C	
Male	4 (50 %)	4 (50 %)	4 (50 %)	0.76
Female	4 (50 %)	4 (50 %)	4 (50 %)	0.53
Age ($\bar{x} \pm SD$)	73.75 $\pm$ 2.02	71.25 $\pm$ 1.65	73.25 $\pm$ 1.65	0.33

The result can be used to adapt by the doctor who operated surgical treatment. It also can be used to consider in planning before the operation for a patient who has a femoral neck fracture fixation by using a multiple screw fixation method. Screw placement should cover femur area as much as possible because it affects to stability after the operation and help to reduce the risk of implant failure in the future. From the results of this study, it may lead to further study to develop new methods of screw placement to cover femur area as much as possible and increase in accuracy in the future. The advantage of this study is using human femur which may close to reality more than previous study which used femur model. Nevertheless, in this study there are limitations. First one is bone quality because cadavers for the study are elder's so there are effects on stability of studied femur in term of osteoporosis, congenital disease, medication, etc. before the death. This record cannot be known, but there is a biomechanical measurement for each femur before the experiment by measuring three point bending forces using biomechanical tests to obtain equal stability of femur and experiment to reduce the error of data analyzation. However, there is also limitations of cadaver quantity, research fund and experimental equipment which is additionally designed to analyze three point bending force. With these limitations,

The researcher could not select cadavers which have equal bone quality to experiment. Second limitation is biomechanics test which is in the laboratory cannot analyze tensional stiffness as the previous study. Therefore, tensional stiffness cannot be interpreted. The last limitation is a limited amount of cadaver cause none to experiment for the study.

Conclusion

This study aims to determine suitable areas of multiple screw in femoral neck from Femoral neck fracture fixation by using a multiple screw fixation method with cannulated screw. Screw placement was in the form of an inverted triangle to obtain the biomechanical effect after proper and stabilized fixation. The result showed that the more screw placement covers the femoral neck area the more it causes a biomechanical effect in stability. The

suggestion for femoral neck fracture treatment by using a multiple screw fixation method is to position the screw covering femoral neck as much as possible because it affects to stability after the operation and help to reduce the risk of implant failure afterwards. The result leads to further study in effect for the treatment and expect to cause new technique of screw placement to precisely cover femoral neck as much as possible in the future.

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