KANSAS JOURNAL of MEDICINE

Brief Report

Use of Electrocautery to Facilitate Suture Passage Through the Greater Trochanter of the Femur: A Biomechanical Study

Jackson R. Staggers, M.D.[1,2], Alexander C.M. Chong, MSAE, MSME[1,2], Kevin A. Dahl, M.D.[1,2], Bruce E. Piatt, M.D.[1,2]

[1]Stanford Orthopedics and Sports Medicine-Sanford Health, Fargo, ND

[2]University of North Dakota, School of Medicine and Health Sciences, Grand Forks, ND

Received July 20, 2023; Accepted for publication Dec. 21, 2023; Published online Dec. 31, 2023
https://doi.org/10.17161/kjm.vol16.21132

ABSTRACT

Introduction. The specific aims of this study were to evaluate (1) the axial force reduction of suture passage utilizing electrocautery when applied to the greater trochanter of the femur, (2) the temperature change caused while using electrocautery for suture passage, and (3) the failure loads and failure modes utilizing this technique.

Methods. Five matched pairs of fresh-frozen femurs were used and classified into two groups: with electrocautery on needle (study group) and without electrocautery on needle (control group). Two bicortical, osseous tunnels were made around the insertion of the gluteus medius tendon. Each specimen was sequentially tested in a needle penetration test and a single load-to-failure test. A #5 Ethibond suture with a straight needle was used.

Results. Electrocautery reduced the peak axial force for bone penetration in 40% (near cortex) and 70% (far cortex) of the trials, and no significant difference was detected between groups or between two osseous tunnels. The average peak force was significantly higher for the far cortex for both groups and for both osseous tunnels compared to the near cortex. There was no significant change in temperature of the tunnel site with electrocautery. Ninety percent of the samples experienced bone tunnel failure for the study group compared to 70% in the control group. The average ultimate failure load for the study group was lower compared with the control group, but this finding was not statistically significant (range: 6%-15%).

Conclusions. Suture passage using electrocautery may not significantly decrease the peak force needed to pass a needle directly through the greater trochanter. ***Kans J Med 2023;16:316-320***

INTRODUCTION

Surgical repair of the hip abductor tendon is a common orthopaedic procedure that is usually performed during primary repair of an acute or chronic tear in isolation or, more commonly, during total hip arthroplasty.[1,2] There are numerous approaches described to gain access to the hip in primary and revision hip arthroplasty, including anterolateral and direct lateral approaches that intentionally release abductor insertions about the hip and necessitate repair at the conclusion of the procedure.[3] Though less common, inadvertent injury to the hip abductor tendons may occur during an anterior or posterior approach which would also require repair. Abductor repair involves direct re-attachment of the tendon to the greater trochanter of the femur through a bone tunnel using a heavy needle, drill, burr, awl, or tunnel device.[4-8] These techniques require additional equipment and implants, which not only add operative set up time and cost to a surgical case, but also contribute to increased difficulty during revision cases from implants littering the surgical field. Because of rising healthcare costs, surgeons must consider the costs associated with an implant relative to potentially equivalent, less costly, and/or implant-free methods.

One technique for repairing a hip abductor tendon to the bone is by simply passing suture needles directly through bone using the mechanical advantage from a needle driver.[4,6] Bone tunnels created by needle are more efficient, more cost effective, and provide an equivalent outcome in comparison to techniques that require implants or specialized tools.[4,5] However, passing suture needles directly through the greater trochanter often is difficult or impossible depending on the bone quality and cortical thickness.[9,10] This can be dangerous for both the patient and the surgeon. Techniques that decrease the peak axial force required to pass the needle gives the surgeon greater control over the needle/needle driver and decrease iatrogenic injury risk. The literature has described the use of electrocautery as a technique to expedite the passage of a suture needle through bone, eliminating the need for a drill or burr. This method aims to save time, conserve operative resources, and reduce associated risks. Previous biomechanical studies using this technique have identified a 36% - 48% average reduction in peak axial force to pass a suture needle through bone.[6,11] This technique, in theory, has multiple benefits including improved safety and efficiency, reduced surgical equipment use, creation of smaller bone conduits, decreased cost, and decreased potential for bone injury. Though there are a few studies to support its safety and efficacy in the shoulder,[6,11] there are no studies that evaluate its use in the greater trochanter (such as during abductor, capsular, or short external rotator repair about the hip). The specific aims of this cadaveric biomechanical study were to evaluate (1) the axial force reduction of suture passage with the use of electrocautery when applied to the greater trochanter of the femur, (2) the temperature change caused while using electrocautery for suture passage, and (3) the failure loads and failure modes of this technique. The authors hypothesized that utilizing electrocautery on a needle provides a significant decrease in the force required for suture passage through the bone.

METHODS

This was a cadaveric biomechanical study. Approval for this study was obtained from our institute research committee, and the cadaveric femur specimens were procured from our institution-approved tissue supplier.

Specimens. Five fresh frozen, non-preserved lower torsi with bilaterally intact femurs were obtained and used (2 female, 3 males, 10 femurs); the mean donor age was 76 ± 8 years (range: 63 – 81 years) and the mean body mass index (BMI) was 19.3 ± 4.9 kg/m^2 (range: 13.9 – 25.7 kg/m^2). All specimens were directly and radiographically inspected and confirmed to be free of fracture, hardware, previous surgery, and other obvious gross pathology or deformity. The hip abductor muscles (gluteus medius, gluteus minimus, and tensor fasciae latae) were grossly

intact in all specimens and there was no obvious hip pathology noted. After thawing each specimen to room temperature, the specimens were dissected proximally to reveal the greater and lesser trochanters of the femurs.

Study Groups. Each pair of femurs of the same cadaver were randomly assigned to two study groups: with electrocautery on needle (study group) or without electrocautery on needle (control group). Every effort was made to replicate the *in vivo* methods of a typical hip abductor repair technique during hip arthroplasty or open hip abductor repair by simulating typical tunnel placement and trajectory. The tunnel sites were cleared of soft tissues, blood, and fluids to provide good electrical conduction through the needle. For the study group, needle penetration testing was accomplished with an electrical current applied to the needle. The electrical power from the electrocautery device (Valleylab FT10 Energy Platform, Medtronic Covidien, Minneapolis, MN) was applied to the needle using the pure "cut" function at a power setting of 50 Watts. This power setting was chosen based on the findings of previous studies and is a commonly used setting.[6,11] For the control group, needle penetration testing was performed similar to the study group except without any electrical current applied to the needle.

Experimental Setup. The experimental setup and test protocol were similar to previously described in the literature for consistency.[6,11] A custom-designed testing apparatus was designed and used to stabilize the specimens and standardize the testing procedure for conducting needle penetration (Figure 1) and failure mode testing (Figure 2a). An electrocautery grounding pad was placed onto the adjacent intact skin and soft tissues of the distal femurs to provide a closed loop for the electrocautery device. A servo-hydraulic materials testing system (Model 8874; Instron, Norwood, MA) with a 1-kN load cell was used for all needle penetration and load-to-failure testing for both groups. Two bicortical osseous tunnels were made similar to the standard open surgical techniques for hip abductor tendon repair (T1 and T2) separated by 1 cm in the vertical and horizontal planes and centered at the midline of the greater trochanter around the insertion of the gluteus medius tendon (Figure 2b). The suture (Loop 1) was passed through proximal osseous tunnels (T1), and the suture (Loop 2) was passed through distal osseous tunnels (T2). Both loops were tied with five square knots.

Figure 1. Needle penetration test experimental setup.

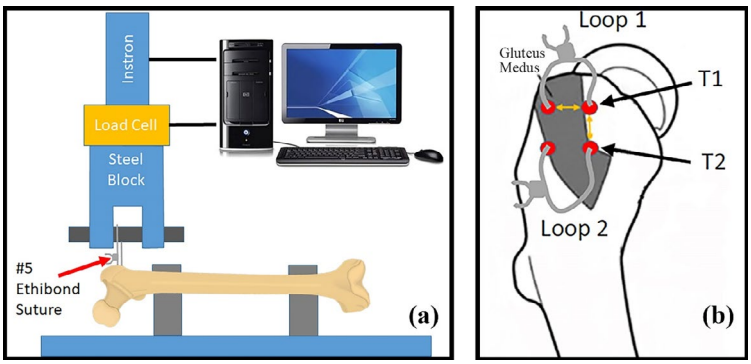

Figure 2. Failure mode test experimental setup. (a) Single load-to-failure mode test experimental setup, and (b) needle passage locations in the greater trochanter. The two osseous tunnels (T1, T2) were separated by 1 cm in vertical and horizontal planes and centered at the midline of the greater trochanter around the insertion of the gluteus medius tendon. Two suture loops (loop 1 and loop 2, as indicated in gray) were tied with five square knots and used for the load-to-failure test.

Test Protocol. Each specimen from both study groups were sequentially tested in two parts. In Part I, a needle penetration test was performed through the greater trochanter to measure peak axial force and temperature change through each cortex of the two tunnels. Peak axial force was defined as the maximum force recorded during needle penetration through each cortex. In Part II, a single load-to-failure test was performed of each suture loop (Loop 1 and Loop 2).

In part I, a #5 Ethibond® suture with a straight needle (Ethibond Excel, D7809, Ethicon Inc., Somerville, NJ) was used. The needle was preloaded to 6 N to provide a well-defined starting point for data collection. The needle was then continuously loaded at a crosshead speed of 1 mm/sec until complete needle penetration occurred through both cortices. Load and displacement data were collected at 100 Hz. For the control group, needle penetration testing was accomplished as described without an electrical current applied through the needle. For the study group, needle penetration testing was conducted the same as the control group, except the tip of the electrocautery pen was used to apply an electrical current to the needle throughout the duration of each trial. The maximum temperature was measured at the needle penetration site using a 12:1 infrared laser thermometer with an accuracy rating of 0.1°C (IR12; Ames Instruments, Calabasas, CA) held at 30.5 cm (1 foot) from the needle.

In Part II, a single load-to-failure test of the suture loops was performed to evaluate the ultimate failure loads and failure modes while using this technique. The suture loops were preloaded to 6 N to provide a well-defined starting point for data collection, and then five preconditioned loading cycles were applied from 6 N to 30 N at 1 Hz to avoid potential errors produced from slack in the loops and stretching of the suture materials. The loops were then continuously loaded at a crosshead speed of 1 mm/sec until complete bone or suture failure occurred. Load and displacement data were collected at 100 Hz, and the mode of failure was recorded. This study defined two modes of failure: 1) suture breakage or knot failure, and 2) bone tunnel failure.

Statistical Analysis. A paired-sample t-test was used to compare notable differences between groups regarding peak force, temperature, and ultimate failure load variables. Frequencies and percentages for other variables were obtained. All statistical testing were analyzed using IBM SPSS statistics software (Version 24.0; IBM Corporation, Armonk, NY), and statistically significant relationships were

defined as those p value less than 0.05.

RESULTS

Part I – Needle Penetration Peak Force Test. For the near cortex, the peak axial force was lower in only four out of ten (40%) trials in the study group compared to the control group (reduction range: 1% - 36%). On average, the peak axial force was higher in the study group compared with the control group for the near cortex of both osseous tunnels (T1: +61%; T2: +16%), although these findings were not significant (T1: p = 0.255; T2: p = 0.805; Table 1). When comparing the two tunnels at the near cortex, the study group showed no significant decrease in peak axial force, registering a 38% reduction compared to the control group (p = 0.542; Table 1).

Table 1. Summary data for needle penetration peak force test.

Cortex	Osseous Tunnel	Study Group (N) (mean ± SD, range)	Control Group (N) (mean ± SD, range)	Study vs Control Group (%)	p value	p value
Near	T1	23 ± 21 (6 – 52)	13 ± 8 (6 – 27)	61	0.255	0.542
	T2	46 ± 21 (20 – 64)	48 ± 34 (12 – 98)	16	0.805	
Far	T1	56 ± 22 (26 – 77)	63 ± 35 (31 – 118)	-2	0.593	0.463
	T2	79 ± 32 (45 – 125)	89 ± 30 (57 – 124)	-1	0.639	

Note: SD, standard deviation.

For the far cortex, the peak axial force was lower in seven out of the ten (70%) trials in the study group compared to the control group (reduction range: 11% - 51%). On average, the peak axial force was lower in the study group compared with the control group for the far cortex of both osseous tunnels (T1: -2%; T2: -1%), but these findings were also not significant (T1: p = 0.593; T2: p = 0.639). When comparing the two tunnels at the far cortex, there was no significant decrease in peak axial force in the study group of -2% compared to the control group (p = 0.463; Table 1). When comparing the peak axial force of the near and far cortex, the average peak force was significantly higher in the far cortex (range: 73% - 368%) for both study groups and for both osseous tunnels in all except one case (Table 2). In that one case, the far cortex still had a 73% higher peak force at the far cortex compared to the near cortex, although it did not reach statistical significance.

Table 2. Comparison of average needle penetration peak force (N) for near and far cortex.

Osseous Tunnel	Group	Near Cortex (N) (mean ± SD)	Far Cortex (N) (mean ± SD)	Near to Far Cortex (%)	P value
T1	Study	23 ± 21	56 ± 22	142	0.007*
	Control	13 ± 8	63 ± 35	368	0.017*
T2	Study	46 ± 21	79 ± 32	73	0.163
	Control	48 ± 34	89 ± 30	86	0.002*
T1 + T2	Study	35 ± 23	68 ± 76	96	0.008*
	Control	31 ± 30	76 ± 34	147	<0.001*

Note: SD, standard deviation.
*Significant rise in needle penetration peak force between cortices.

In the study group, there was a mean increase of 0.2°C ± 0.4°C (range: 0.0°C – 1.3°C) at the bone tunnel site with the use of electrocautery. This change in temperature difference between the two groups was not statistically significant (p = 0.435).

Part II – Load-to-Failure Test. During load-to-failure testing, 90% of the samples experienced bone tunnel failure for the study group compared to 70% in the control group (Table 3), and 50% of the trials in the study group had lower ultimate failure loads compared with the control group (reduction range: 17% - 69%; Table 3). There was no statistically significant difference detected in the ultimate failure load between either the loop tested (Loop 1: p = 0.74; Loop 2: p = 0.62) or between the two study groups (p = 0.51; Table 3). Even though the average ultimate failure load for the study group (T1: 156 N ± 34 N; T2: 169 N ± 85 N; T1 + T2: 163 N ± 61 N) was lower than the control group (T1: 167 N ± 63 N; T2: 200 N ± 76 N; T1 + T2: 183 N ± 68 N; range: 6% - 15%), these findings were not statistically significant (T1: p = 0.738, T2: p = 0.616, T1 + T2: p = 0.510; Table 3).

Table 3. Summary data for load-to-failure test.

Suture Loop	Specimen Number (lower torso)	Failure Mode		Ultimate Failure Load				
		Study group	Control group	Study group (N)	Control group (N)	Study vs Control group (%)	p value	
Loop 1	1	BT	BT	166	165	1	0.738	0.510
	2	BT	BT	100	156	-36*		
	3	BT	S	188	254	-26*		
	4	BT	BT	151	181	-17*		
	5	BT	BT	176	78	126		
Loop 2	1	BT	S	78	254	-69*	0.616	
	2	BT	BT	124	106	17		
	3	S	BT	279	223	25		
	4	BT	S	128	281	-54*		
	5	BT	BT	238	136	75		

Note: BT, bone tunnel failure. S, suture breakage or knot failure.
*Significant reduction in ultimate failure load between groups.

DISCUSSION

Utilizing electrocautery to facilitate the passage of a suture needle through bone has been described in the literature as an alternate technique to save time, operative resources, and cost.[6,11] This is the first known published cadaveric biomechanical study to simulate *in vivo* conditions for osseous bone tunnel creation through the greater trochanter utilizing this technique and provides biomechanical data with direct and immediate clinical implications. Despite prior studies supporting the use of electrocautery for suture passage in the shoulder,[6,11] the current study reveals that this technique does not significantly reduce the peak force required to pass a needle directly through the greater trochanter. This study also concluded there was no significant increase in temperature

with the use of electrocautery. There was no statistically significant difference detected in the ultimate failure load or failure mechanism of the bone tunnels between with and without electrocautery on needle repair techniques, despite concerns about the effect of electrical current passing through bone.

A biomechanical study performed by Littlefield et al.[6] identified a 48% average reduction in peak axial force to pass a suture needle through bone using this technique. Their experimental model consisted of 96 trials (72 with electrocautery and 24 without electrocautery) where a needle was passed repeatedly through a cadaveric humeral head. A humeral head was selected for biomechanical testing due to its suitability for consistent thickness and density, which is ideal for testing purposes. However, it's essential to note that this may not precisely mirror real clinical scenarios where this technique might be applied. Our previous study[11] published the first cadaveric biomechanical study that evaluated this technique applied to rotator cuff repair. The findings from that study concluded that suture passage using electrocautery significantly reduces the peak force required to pass a needle directly through the greater tuberosity. The goal with the present study aimed to address this gap in the literature to determine if electrocautery suture passage is a useful technique when applied to osseous bone tunnel creation through the greater trochanter.

The results of this study showed that electrocautery decreased the peak axial force to pass through only 40% of the trials through the near cortex of the greater trochanter (reduction range: 1%-36%), and through 70% of trials through the far cortex (reduction range: 11%-51%). Interestingly, 60% of the trials through the near cortex and 30% of the trials through the far cortex showed an increase in peak axial force with the use of electrocautery. This is in contrast to the Littlefield et al.[6] and Staggers et al.[11] studies that seemed to show a consistent and predictable decrease in peak axial force when using electrocautery. There are multiple possible explanations for this finding. Singh et al.[12] found that the electrical properties of bone to depend highly on variables such as water content, temperature, electrical frequency, power of hydrogen (pH), and direction of current, which are likely different between these two studies. Additionally, this study hypothesized that most of the variability in current testing was secondary to variable thickness in cortical bone surrounding the greater trochanter. While this variability makes it challenging to obtain consistent data, it also more accurately reflects real world conditions. As a result, this variable thickness in cortical density would make it difficult consistently to rely on this technique to pass suture through bone during osseous bone tunnel creation through the greater trochanter.

Another observation of this study was the significant increase in peak force to penetrate the far cortex when compared to the near cortex. This is likely due to the cumulative friction force or hoop stress from the near cortex acting on the needle as it passes into the far cortex. As the needle passes through each cortex of bone, there is an increase in the contact surface area of the bone on the needle, which increases resistance. This is important in hip abductor repair because using suture tunnels requires bicortical fixation through a transosseous tunnel technique. A surgeon may have difficulty or fail to pass a suture needle bicortically by hand even using the mechanical advantage from a needle driver and electrocautery. The peak axial force required to pass suture in this study exceeded upwards of 125 N of force even with electrocautery. This is a considerable amount of force, which could result in failure to pass the needle, slippage, injury, or needle breakage.

One of the potential drawbacks of using electrocautery to facilitate suture needle passage through bone was the possibility of burning the bone and affecting the structural integrity of the bony tunnel.[6] This study found that the tunnel integrity was not affected by this technique, as there was no evidence of burned tissues and the mean change of the maximum temperature was less than 2°C between the two groups. Additionally, there was no significant difference in the ultimate load to failure testing between study and control groups. This study concludes that differences in bone tunnel strength were more dependent on bone density, cortical thickness, patient age, and tunnel placement.

This study has several limitations to recognize. First, this study utilized fresh frozen cadaveric specimens, and freeze and thaw cycles of specimens over the study period could have compromised the structural quality of the cortical bone. However, every effort was made to minimize the number of freeze/thaw cycles that the specimens endured. Second, a potential confounding variable is the bone quality of the cadaveric specimens. No medical history of the cadavers was provided, though radiographic evaluation did not show abnormalities indicating osteoporosis such as increased radiolucency or cortical thinning. The authors recognize that bone mineral density evaluation was not performed in the current study and could be considered in future studies. This cadaveric study provided no information about long-term outcomes or healing biology, and the utility of this technique may differ from in vivo situation where blood, surrounding soft tissues, and other variables could affect results. This study used straight needles through perpendicular trajectories to the cortical bone, which differs from common surgical practice that often utilizes curved needles on angled trajectories. This is due to limitations of our servo-hydraulic testing system, which required linear trajectories perpendicular to the cortical bone. This study only performed a single load-to-failure test, but the leading source of failure in orthopaedic repairs has been recognized as cyclic loading. Further evaluations including actual hip abductor or analogue tissue, increased sample size with accounting for variations in bone quality, use of curved needles to simulate real clinical scenarios, and in a larger randomized controlled study is required to support the findings of this study.

CONCLUSIONS

Suture passage using electrocautery does not significantly decrease the peak force needed to pass a needle directly through the greater trochanter. This finding contradicts previous biomechanical studies showing the technique's clinical efficacy in the shoulder,[6,11] and therefore is not a reliable technique to utilize during osseous bone tunnel creation through the greater trochanter. This study hypothesized the decrease in efficacy was due to the increased variability in cortical bone thickness surrounding the greater trochanter. Clinicians should recognize these

limitations and be cautious when utilizing this technique for repairing hip abductor tendons to the greater trochanter, though there may be other clinical situations this technique might be useful.

REFERENCES

[1] Kenanidis E, Kyriakopoulos G, Kaila R, Christofilopoulos P. Lesions of the abductors in the hip. EFORT Open Rev 2020; 5(8):464-476. PMID: 32953132.
[2] Zhu MF, Musson DS, Cornish J, Young SW, Munro JT. Hip abductor tendon tears: Where are we now? Hip Int 2020; 30(5):500-512. PMID: 32513090.
[3] Moretti VM, Post ZD. Surgical approaches for total hip arthroplasty. Indian J Orthop 2017; 51(4):368-376. PMID: 28790465.
[4] Cole BJ, Sayegh ET, Yanke AB, Chalmers PN, Frank RM. Fixation of soft tissue to bone: Techniques and fundamentals. J Am Acad Orthop Surg 2016; 24(2):83-95. PMID: 26752738.
[5] Ebert JR, Bucher TA, Ball SV, Janes GC. A review of surgical repair methods and patient outcomes for gluteal tendon tears. Hip Int 2015; 25(1):15-23. PMID: 25198307.
[6] Littlefield ZL, Lehtonen EJ, McKissack HM, et al. The utility of electrocautery for suture passage through bone: A biomechanical study. J Orthop Res 2020; 38(5):954-960. PMID: 31746476.
[7] Lachiewicz PF. Abductor tendon tears of the hip: Evaluation and management. J Am Acad Orthop Surg 2011; 19(7):385-391. PMID: 21724917.
[8] Davies JF, Davies DM. Surgical technique for the repair of tears to the gluteus medius and minimus tendons of the hip. JBJS Essent Surg Tech 2014; 4(2):e11. PMID: 30775118.
[9] Treece GM, Gee AH. Independent measurement of femoral cortical thickness and cortical bone density using clinical CT. Med Image Anal 2015; 20(1):249-264. PMID: 25541355.
[10] Donnelly E, Meredith DS, Nguyen JT, Boskey AL. Bone tissue composition varies across anatomic sites in the proximal femur and the iliac crest. J Orthop Res 2012; 30(5):700-6. PMID: 22034199.
[11] Staggers JR, Chong ACM, Piatt BE. Use of electrocautery devices for suture passage through the greater tuberosity: A biomechanical study. J Shoulder Elbow Surg 2023; 32(3):512-518. PMID: 36283564.
[12] Singh S, Saha S. Electrical properties of bone. A review. Clin Orthop Relat Res 1984; (186):249-271. PMID: 6373088.

Keywords: electrocoagulation; femur; suture techniques; biomechanical phenomena.