Prevention of Excessive Medialisation of Trochanteric Fracture by a Buttress Screw: A Novel Method and Finite Element Analysis

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This paper proposes a novel method of using an antero-posterior buttress screw at the distal fragment just below the fracture site in conjunction with the sliding hip screw (SHS) to resist excessive femoral medialisation. A virtual assessment of the effectiveness of this new method was performed using the finite element analysis. The results indicate that the use of a sliding hip screw (SHS) combined with a buttress screw can help resist femoral medialisation better than using an SHS with no buttress screw. The von Mises equivalent stress (EQV) was found to be in a safe range, which indicates increased integrity of the lateral wall with the addition of the buttress screw.

Keywords: *Trochanter, Fractures, Hip screw, Dynamic hip screw, Medialization*

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Excessive medialisation of the distal fragment relative to the proximal part is an important factor that leads to the failure of fracture fixation using a sliding hip screw (SHS) for trochanteric fractures(1). Factors that contribute to femoral medialisation include: fracture pattern, comminution of medial cortex, integrity of lateral wall, and obliquity of the lag screw placement(2-5). Excessive medialisation of the distal fragment will cause the contact fracture surface to diminish and would delay bone healing. The lag screw will be fully collapsed and later behave as a fixed angle device, subsequently resulting in cutout of the lag screw(1,4,5). Femoral medialisation has been reported to be minimal with the use of the proximal femoral nailing system. This is due to the resistance effect of the nail portion located in the intramedullary canal. This resistance effect makes the use of a proximal femoral nail over the sliding hip screw in various unstable types of trochanteric fractures favorable(6,7).

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SHS is advised for use on stable fractures only. In cases with an insufficiency of lateral wall, the only method that is recommended to resist femoral medialisation is one that adds the trochanteric stabilization plate (TSP) to the SHS. This method requires more extensive surgical exposure and an expensive device(8). To mitigate this problem with a simpler and cost-effective method, the authors herewith propose the insertion of a buttress screw in an antero-posterior direction at the location, just below the barrel of the SHS, to resist femoral medialisation. Finite element analysis was performed to identify the effectiveness of this method.

Material and Method

Finite element models

A cadaveric femur was scanned with a Philips spiral computed tomography (CT) scanner. The scan was performed with 3.0 millimeter slice thickness. After scanning, a set of CT images was imported into medical image processing software (Mimics, Materialise NV, Belgium) to reconstruct a three-dimensional model of the femur. All components of the SHS employed in this study were scanned with an ATOS II optical laser scanner for purposes of mapping three-dimensional geometry. The side plate of the SHS had a 135-degree neck shaft angle relative to the sleeve. The length of the side plate was 90 millimeters; whereas, the sleeve portion was 35 millimeters in length. The SHS device has four distal locking transverse screws. The lag screw was 8 millimeters in diameter. The side plate of the SHS device was virtually attached to the intact femur and the lag screw was inserted through the femoral head centre. The intertrochanteric fracture modeled in the present study was a two-part fracture. The fracture site was 45 degrees, drawn from above the lesser trochanter to just below the greater trochanter. The AP buttress screw was inserted into the intact femur in an anterior-posterior direction.

A four-node tetrahedron element was used to generate a finite element (FE) model of an intact femur and an SHS. Different regions of the intact femur were assigned differing combinations of material properties. For the SHS and AP buttress screw, the material properties of titanium were given. All material properties used in this study were assumed to be linear, elastic, and isotropic. Table 1 shows the material properties used in the FE analysis.

All contact conditions between bodies to be joined were frictionless. The components in the SHS were allowed relative displacement between them. In addition, the buttress screw was allowed relative displacement to the proximal cortical body. The lag screws and distal locking transverse screw penetrating into the bone structure had no relative displacement.

The biomechanical loads applied to the FE model were derived from the work of Behrens et al[12]. Forces at 25% of the gait cycle (25% gait cycle force was applied?) were applied to the FE model, since the force at this level reaches maximum over the entire gait cycle. Table 2 shows the maximum applied loads. The intact femur was fully constrained at the distal end. Fig. 1 shows the FE model and loading conditions.

Two specific areas of investigation were focused upon in the present study: 1) how the buttress screw affected the overall mechanical performance of the SHS device; and, 2) stress distribution in the lateral cortical wall region. All cases were performed using FE commercial software package (MSC Marc Mentat, MSC Software, Inc., USA). The number of elements and nodes employed in FE analysis were 95,957-101,872 and 25,262-26,810 respectively.

Results

The results focused on the kinematics of fractures, implant strength, and lateral wall integrity in virtual scenarios both with and without the AP buttress screw.

Biomechanics and Kinematics

The biomechanics and kinematics of fracture were observed by displacement of objects in the FE domain. As shown in Fig. 2, the maximum displacement

Table 1. Material properties[9-11]

Region	Elastic modulus (MPa)	Poission's ratio
Cortical bone	17,000	0.28
Cancellous bone	600	0.30
SHS device	110,000	0.33
Buttress screw	110,000	0.33

Table 2. Applied loads

Component	Force			Act Point (See Fig. 1)
	X	Y	Z	
Hip contact	451.4	225.7	-1,806	P0
Abductor	-468	0	694	P1
Tensor fascia latae	117	158.8	-75.2	P1
Vastus lateralis	8.4	108	-543	P2
Vastus medialis	8.4	-33.4	-167	P3

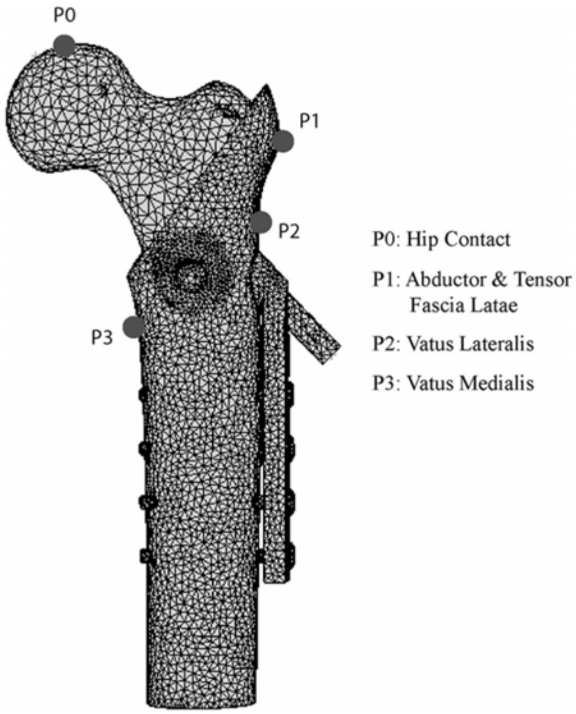

Fig. 1 The finite element model.

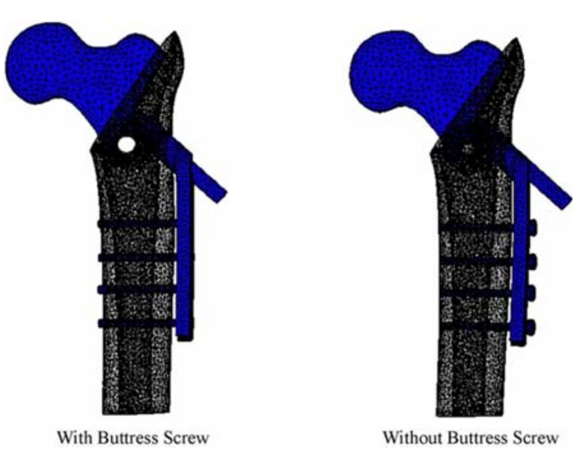

Fig. 2 Biomechanics and Kinematics of fracture with and without AP buttress screw.

of proximal fracture was at the position of the AP buttress screw in the reinforcement case. Without the AP buttress screw, the migration of the proximal femur could continue deep inside the distal fragment.

Stress distribution

As shown in Fig. 3, the SHS case without AP buttress screw reinforcement produced high von Mises equivalent (EQV) stress. The maximum EQV stress

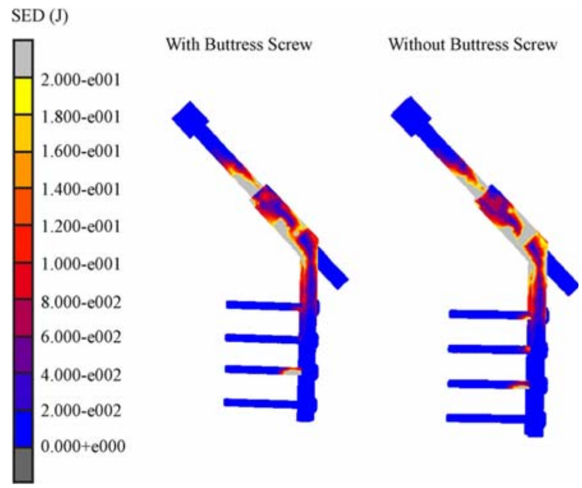

Fig. 3 EQV stress exhibited in SHS.

occurred at the contact area between the lag screw and the barrel of the sliding plate, with a value of 699 MPa. When the AP buttress screw was added, EQV stress was reduced to 602 MPa-a 14% reduction. However, the area exhibiting maximum EQV stress was unchanged. In addition, EQV stress at the contact point between the proximal fracture and the AP buttress screw was not high. As for the EQV stress at the lateral wall, the level of EQV stress was found to be lower when the AP buttress screw was used, as shown in Fig. 4.

Strain energy density

The strain energy density (SED) indicates the risk of bone fracture. As shown in Fig. 6, the results show that the SED inside the lag screw hole were higher than the other parts of cancellous bone. The level of SED in the case of SHS alone was higher than in the case without AP buttress screw reinforcement. Table 3 reports the SED level for both cases.

Discussion

The aim of the present study was to introduce a new method that adds a new component feature to the use of SHS for purposes of overcoming femoral medialisation. The biomechanical feasibility was investigated using FE analysis, which is recognized as producing an accurate result and is widely accepted as a tool for analyzing various biomechanical problems. The idea behind this proposed surgical technique for solving femoral medialisation complications is based on how the mechanism of the SHS works. Since the SHS allows the sliding of proximal femur fracture along the barrel, which compressed to the distal fragment as

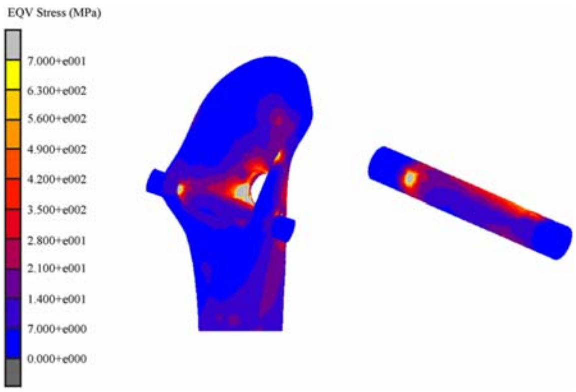

Fig. 4 Von Mises equivalent stress (EQV) exhibited in SHS.

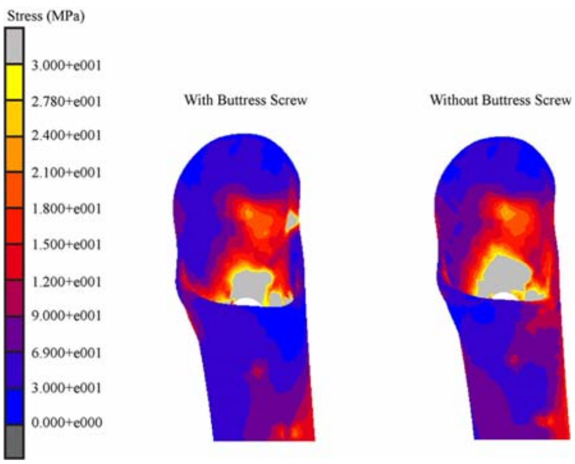

Fig. 5 Bone von Mises equivalent stress.

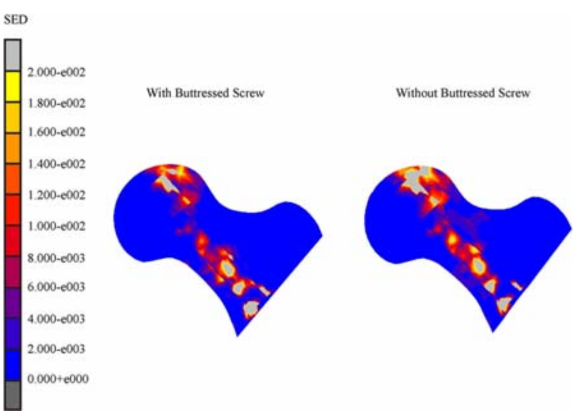

Fig. 6 Cancellous strain energy density.

in one plane, the authors came up with the idea of limiting motion of the proximal femur by the placement of the additional fixation. The implants used in the proposed technique include:

Table 3. SED value in cancellous bone (MPa/1,000)

Case	SED
With buttress screw	181.6
Without buttress screw	284.8

(1) SHS, which functions as a primary support structure that maintains the stability of the fracture after reduction, and

(2) AP buttress screw, which acts as an additional device to resist medialisation.

From the FE result, using SHS alone is not adequately sufficient to protect from femoral medialisation. However, SHS with AP buttress screw resists femoral medialisation effectively. The biomechanics of the complication found in this FE study are supported by the experiments of Park et al[5] who highlighted that sliding of the fracture relates to rotation of the proximal fragment and breakage of the lateral wall. The excessive motion of the lag screw attached to the femoral head, in the barrel was impeded by allowing proximal femur to collide the AP buttress screw. The impact of the proximal femur with the AP buttress screw essentially neutralizes the lateral translation force of the proximal femur.

Biomechanically, the AP buttress screw demonstrated its importance in improving and strengthening the integrity of the fracture. As a result, the strength added by the AP buttress screw is required to resist the force from the proximal femur. The EQV stress level of the AP buttress screw reached the highest level at the contact area with the proximal femur. Since the highest magnitude at the AP buttress screw was not beyond the yield point of materials, it is then deemed safe for resisting the physiological load of a hip joint. The EQV stress of the SHS alone was higher than the case that added the AP buttress screw. Without the AP buttress screw, the SHS had to resist bending and translation forces alone. With the addition and cooperation of the AP buttress screw, those forces are more effectively resisted.

The EQV stress at the lateral cortical wall of a distal fracture is considered being as important as the EQV stress exhibited on implant. Without the insertion of an AP buttress screw, the motion of proximal femur could be limited by the remaining length of the lag screw before the proximal fracture contacts with the lateral cortical wall in distal fragment. When the contact occurs, the proximal femur compresses the lateral cortical wall, which subsequently raises the EQV stress on the lateral cortical wall. This could lead to the collapse of the cortical wall and result in loss of lateral buttresses[5] as well as a lack of screw cutout. The integration of an AP buttress screw as proposed in this study is designed as a buffer to protect the proximal femur to reduce impact to the lateral cortical wall.

SED measures biomechanical change in bone[9], and in the case of SHS fixation alone were found to be higher than with buttress screw. Therefore, there is a higher risk of screw cutout. In addition, the chance of screw cutout depends also on improper lag screw insertion[13-15].

In addition to the proposed technique common alternative techniques for stabilizing trochanteric fractures are:

(1) Proximal femoral nail (PFN) an intramedullary device that is inserted at the center of intramedullary canal that acts as a buttress against medial translation of the proximal fragment. The PFN is very useful, especially in cases where the lateral wall is missing[4].

(2) Trochanteric supporting plate (TSP) a modular extension of the SHS which is designed to increase the integrity of lateral wall to limit medialisation of the proximal fracture.

As proposed in the present work, the AP buttress screw was designed to resist femoral medialisation. As a result, this SHS with AP buttress screw, reinforcement technique is expected to be both effective and efficient. This method will require no surgical extension and the cost for the buttress screw is very minimal. This proposed technique may be a more attractive and cost-effective technique than other techniques that are currently used to stabilize trochanteric fractures.

Conclusion

The present study proposes a new surgical technique that combines the use of both an SHS and an AP buttress screw to overcome femoral medialization in trochanteric fracture. The FE study showed that this proposed technique demonstrated the ability to limit medial translation of the distal fragment. EQV stress in the SHS with AP-buttress screw case was lower than in SHS alone. The level of EQV stress was in the safe range, indicating mechanical integrity. This proposed technique may also reduce the risk of screw cutout, due to low SED values. This proposed method is simpler, less expensive, and easier for surgeons to perform than a procedure involving the TSP.

Potential conflicts of interest

None.

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การป้องกันการเคลื่อนเข้าในของชิ้นหักปลายกระดูกโทรแคนเตอร์หักด้วยสกรูค้ำยัน: การศึกษาด้วยวิธีวิเคราะห์ไฟไนต์เอเลเมนต์

บรรจง มไหสวริยะ, ณัฐพล จันทร์พาณิชย์, ก้องเขต เหรียญสุวรรณ, กฤษณ์ไกรพ์ สิทธิเสรีประทีป

ผู้วิจัยได้เสนอเทคนิคใหม่ในการป้องกัน femoral medialisation ของกระดูกต้นขาหักที่บริเวณ trochanter ภายหลังการยึดตรึงด้วย sliding hip screw (SHS) โดยการใส่สกรูในแนวหน้าหลังที่ชิ้นกระดูกต้นขาส่วนปลาย ห่างจากบริเวณรอยหักเล็กน้อยทำหน้าที่เป็น buttress screw ได้ทำการวิเคราะห์ด้วยวิธี finite element analysis เปรียบเทียบประสิทธิภาพการทำงานของ buttress screw โดยการทดสอบแบบเสมือนจริงพบว่าการใช้ buttress screw ร่วมกับ SHS ช่วยต้านทานการเกิด femoral medialisation ได้ดีกว่าการใช้ SHS โดยลำพัง ผลการศึกษายังพบว่าค่า Equivalent von Mises stress อยู่ในระดับปลอดภัยไม่เกินจุดวิกฤตของสมบัติเชิงกลของกระดูกจึงเชื่อว่าการใช้ buttress screw มีความปลอดภัยไม่ทำให้เกิดความเสี่ยงต่อการแตกของ lateral wall ภายหลังการเจาะใส่ buttress screw