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Article

Biomechanical Performance between Single and Double Lag Screw Trochanteric Gamma Nail used to Stabilize Femoral Neck Fracture: A Finite Element Study

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Abstract. This study was conducted to compare a biomechanical performance between trochanteric gamma nail with single lag screw and double lag screw in the treatment of femoral neck fracture and femoral neck fracture without lesser trochanter. A 3D model of Thai femur was reconstructed from computed tomography spiral scanner whereas a trochanteric gamma nail was reconstructed with the data obtained from 3D laser scanner. A virtual insertion of the nail and femur was done by computer aided design (CAD) software before imported to finite element analysis. The FE models were analysed in the early stage of fracture. Von Mises stress of implant and elastic strain of fracture were observed for each case. The results showed that a double lag screw provided a better biomechanical performance in femoral neck fracture, especially in femoral neck fracture without lesser trochanter. According to the results, a double lag screw had a lower von Mises stress value on the implant compared to a single lag screw. The elastic strain showed a low value in all double lag screw cases, indicated that a double lag screw produced higher fracture stability.

Keywords: Trochanteric gamma nail, double lag screw, femoral neck fractures, finite element analysis.

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1. Introduction

Hip fracture is commonly found in elderly patients with osteoporosis. Due to the rising of aging population worldwide, the incidence of hip fracture is increasing rapidly. The complications related to hip fracture are very concerned in finding the proper implant to manage a fracture. Hip fracture requires internal fixation treatment method [1]. Extramedullary fixators, e.g., dynamic hip screw, have a good clinical outcome for stable fracture, however, they involve soft tissue invasive [2] and may encounter clinical complications such as screw cut out [3]. Intramedullary fixators, e.g., gamma nail, proximal femoral nail, have been proven to be more effective, especially in their biomechanical performance, including a reducing of bending moment stress, and better load sharing [4], In addition, intramedullary fixators also present good biological advantages such as less blood loss and shorter operation time [5].

Currently, Trochanteric Gamma Nail (TGN) is widely used as an intramedullary fixator for fracture in proximal region. The implants are available with a single and dual lag screw design [6]. Although a single lag screw intramedullary nail has been widely used to treat unstable femoral fracture, there are also some clinical complications related to this type of implant including: screw cut out, implant failure, femoral shaft fracture etc. [7]. A double lag screw was designed to minimize these complications. Several researches used double lag screw to treat their cohort patients which resulted a good clinical outcome [8, 9]. Comparing with single lag screw, a double lag screw provides less complication rate and lower incidence of screw cut out. However, there still have some researches that found no differences in clinical outcomes between both types of the implant [7]. In order to support the clinical works and better understand an implant-related complication, a biomechanical study by means of Finite Element (FE) analysis has been constructed. Wu et al. [10] performed a comparative study of single lag screw (PFNA II) and double lag screw (A2FN) for subtrochanteric fracture. Hsu et al. [11] compared dynamic hip screw, gamma nail and double lag screw nail in three types of fracture. Helwig et al. [12] used finite element analysis to study mechanical behavior of four difference implants (three of single lag screw and one of double lag screw) in trochanteric fracture. Brown et al. [13] investigated a biomechanical performance of double lag screw system under bending and torsion loading. Nevertheless, there are few investigations that directly compare a biomechanical performance of single and double lag screw in the treatment of femoral neck fracture.

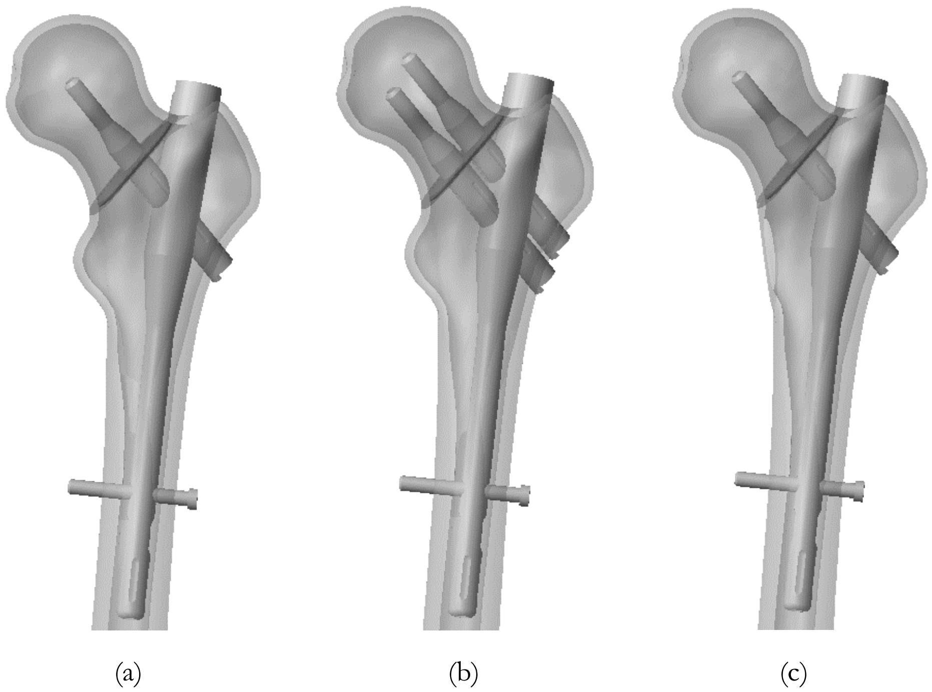
The aim of this study was to compare the biomechanical behavior included stress on the implant and stability of fracture between single lag screw and double lag screw trochanteric gamma nail. Four cases of FE models were designed for investigation, including two types of fracture (neck fracture, and neck fracture without lesser trochanter) and two type of lag screws (single, and double)

2. Method

FE models were developed from computed tomography (CT) data using reverse engineering technique. The FE analysis was performed by the FE software package (MSC Marc Mentat, MSC Software, Inc., USA)

2.1. Finite Element Model

A left Thai femur obtained from corresponding author anatomy data was scanned with a 64-slice spiral computed tomography (CT) scanner. The scan was performed with 0.625 mm slice thickness in all regions. CT images were saved in DICOM file format and then was



(a) (b) (c)

Fig. 1. (a, b) Three-dimensional model of femur with neck fracture treated with single/double lag screw nail. (c) Three-dimensional model of neck fracture with loss of lesser trochanter.

imported to in-house development image processing software. The final three-dimensional model of femur was built using computer aided design (CAD) software (VISI, Vero, UK). In this study, two types of fracture: femoral neck fracture with 2 mm gap at the fracture site (type 1) and femoral neck fracture without lesser trochanter (type 2) were model.

TGN set were acquired the geometry by 3D laser scanner (Sense, 3D System, UK). The nail had a proximal diameter of 16 mm and a distal diameter of 9 mm. The lag screw diameter was 10 mm whereas distal screw diameter was 5 mm. The length of nail was 180 mm. Both implants were virtually inserted into the intramedullary canal by aligning the nail axis to the femoral shaft axis. In addition, the lag screw was aligned to femoral neck axis. Figure 1 shows example of model employed in this study.

Three-dimensional model of the femur and implant were built up from four-node tetrahedral element using automatic mesh generation technique (MSC Patran 2018, MSC Software, Inc., USA). The mesh generation around the hole and screw are denser than other regions. In addition, the element contact surfaces of hole and screw are well aligned.

In order to determine the number of element and node employed in FE analyzes, the convergence test was performed. Four different number of elements between 47,828 to 174,412 were set. In convergence analysis, Equivalent von Mises stress was used for determining optimal number of elements. The least element that does not affect the change in results was applied to all FE cases.

2.2. Material Properties

All materials were assumed to be linear elastic, isotropic and homogeneous. The material at the fracture site in the early stage of fracture was initial connective tissue. Both implants in this study made of stainless steel. Material properties of implant and bone were given in Table 1.

Table 1. Material properties.

Region	Elastic Modulus (MPa)	Poisson's ratio
Cortical	17,000	0.28
Cancellous	1,000	0.30
Fracture	3	0.40
Stainless steel	200,000	0.30

2.3. Boundary Condition

In this study, A single leg stance loading conditions were from the previous work of Chantarapanich et al. [14] Table 2 shows the physiological load values applied to the FE model. The FE model was fully constrained at the distal end of the femur. Figure 2 shows FE model and boundary condition. The contact condition between bone-bone and implant-bone was set to be a non-relative displacement while implant-implant was set to be a relative displacement. Frictionless model was applied to simplify the computation.

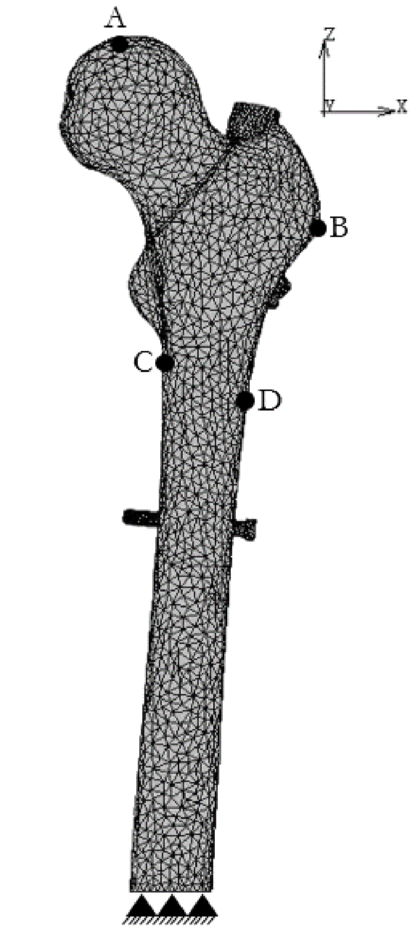


Fig. 2. Finite element model and act point of loading.

3. Result

3.1. Mesh Convergence Test

Figure 3 and Table 3 show the convergence test results. The number of elements over 84,467 shows less

Table 2. Loading condition (N) from previous work of Chantarapanich et al [14].

Force	x	y	z	Force location
Hip contact	230.2	115.1	-921.1	A
Abductor	-468	0	694	B
Tensor fasciae latae	117	158.8	-75.2	B
Vastus medialis	8.4	-33.4	-167	C
Vastus lateralis	8.4	-108	-543	D

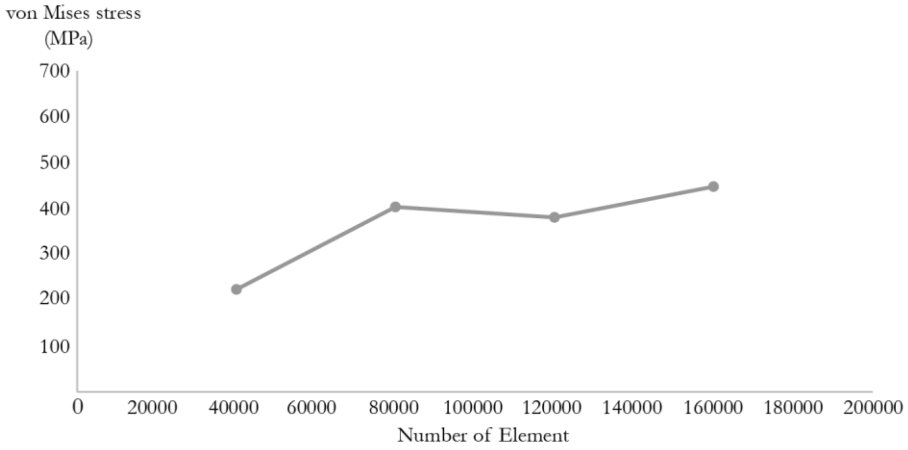


Fig. 3. Convergence test in term of maximum von Mises stress.

different in maximum von Mises stress level. In all convergence tests, the maximum von Mises stress level exhibited on contact between lag screw and TGN. Therefore, the number of elements over 84,467 was used in this study, as shown in Fig. 3.

Table 3. Convergence test result.

Element	Maximum von Mises stress (MPa)
47,828	223.2
84,467	403.2
136,186	380.1
174,412	447.4

3.2. Von Mises Stress on the Implants

3.2.1. Neck fracture Type 1

During the early stage of fracture, the high von Mises stress concentration regions were the lag screw and nail contact surface, tip of lag screw, distal screw and nail contact surface, as shown in Fig. 4. According to Table 4, it shows that the TGN with single lag screw presents a stress level close to double lag screw.

3.2.2. Neck fracture Type 2

According to Table 4, the von Mises stress on the single lag screw TGN for stabilization femoral neck fracture with loss of lesser trochanter were higher than fracture type 1. However, the von Mises stress on a double lag screw TGN trochanter was reduced to lower value.

3.3. Fracture Stabilization

Table 5 show the equivalent elastic strain at the fracture site of each cases. The high equivalent elastic strain was observed in a single lag screw TGN. The result implied that a single lag screw model has lower fracture stabilization.

3.4. Bone Stress

According to Table 6, it represents slight differences in magnitude of stress for both femoral head and femoral shaft regions. High bone stress regions are around nail insertion hole, distal screw hole and proximal femoral head, which the magnitude of stress around nail insertion hole are highest. The nail insertion hole exhibits high level of stress which ranged from 111.51 to 123.30 MPa. However, the stress on the distal screw presents the lower value which approximately 9.18-16.60 MPa.

3.5. Strain Energy Density on Cancellous Bone

Table 7 shows strain energy density (SED) on cancellous bone. Figure 5 shows the high concentrate

Table 5. Equivalent elastic strain (με) at the fracture site.

Fracture	Equivalent elastic strain	
	Single	Double
Fracture type 1	127.98	71.79
Fracture type 2	94.10	54.64

Table 4. The von Mises stress on each part of TGN.

Part	von Mises stress on the implant (MPa)			
	Fracture Type 1		Fracture Type2	
	Single	Double	Single	Double
Lag screw	403.2	387.5	951.2	133.3
Distal screw	243.6	255.9	295.3	274.7
Nail shaft	382.1	331.0	336.0	265.6

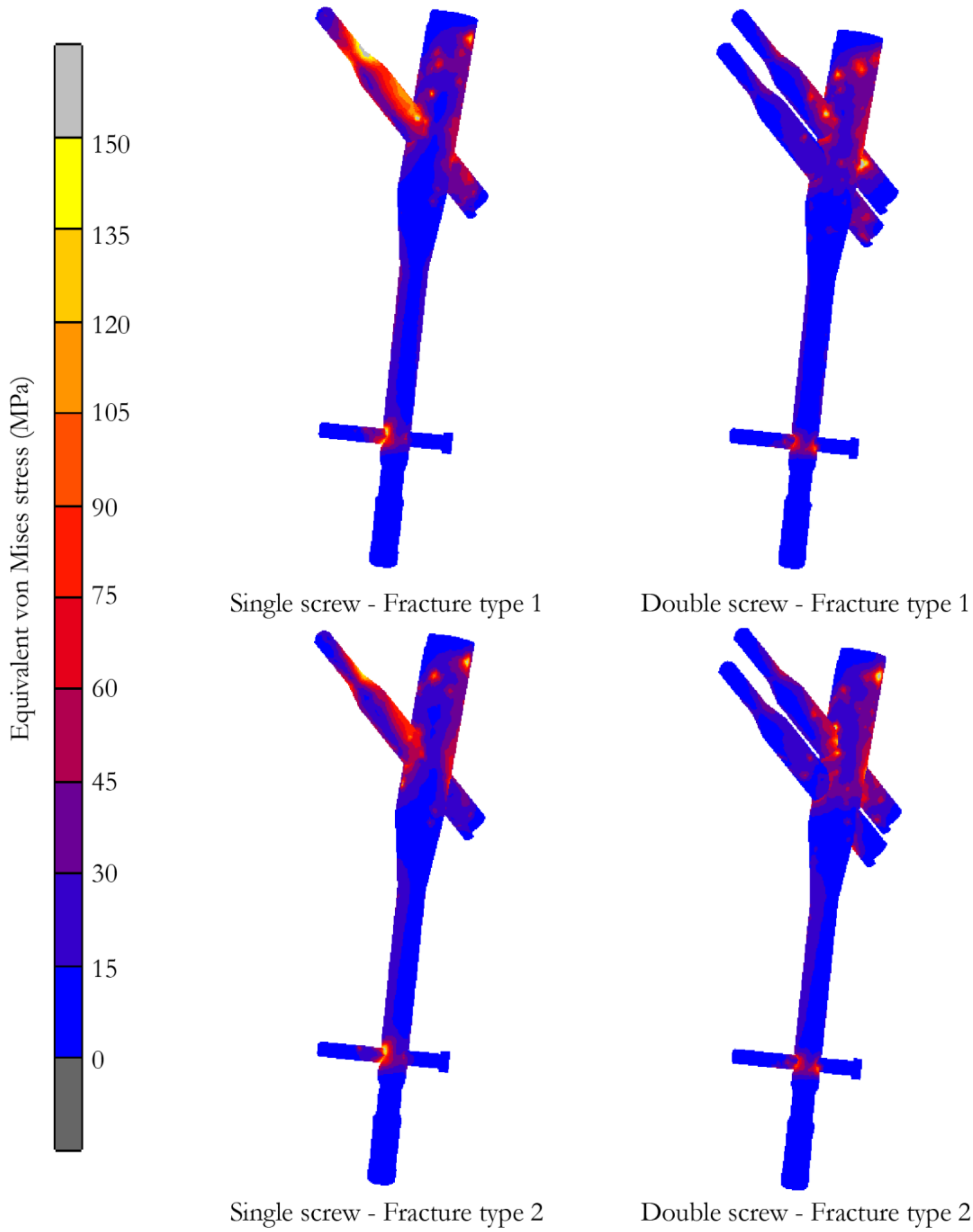


Fig. 4. Stress distribution on the implant in all cases.

Table 6. Bone stress.

Portion	Von Mises stress (MPa)			
	Fracture type 1		Fracture type 2	
	Single	Double	Single	Double
Insertion hole	118.70	123.30	111.51	113.49
Distal screw	16.60	9.41	11.73	9.18

Table 7. Strain energy density (SED) on cancellous cone.

Portion	SED (J/mm³)			
	Fracture type 1		Fracture type 2	
	Single	Double	Single	Double
Superior	0.029	0.139	0.028	0.048
Inferior	0.156	0.357	0.060	0.280

SED regions are around lag screw and nail. Especially in a double lag screw TGN. The region between both lag screw in femoral head present relatively high SED magnitude which is 0.357 J/mm^3 and 0.280 J/mm^3 for fracture type 1 and 2, respectively. SED absorbed by cancellous bone in fracture type 2 reduce to a lower value in both single and double lag screw, compared with fracture type1.

4. Discussion

Intramedullary fixation is an effective choice to treat proximal femoral fracture. From the previous studies [15-17], the implant showed a good post-operative outcome. However, some of these still reported an implant-related complication especially a screw cut out and implant failure. A double lag screw nail has been proposed to solve with

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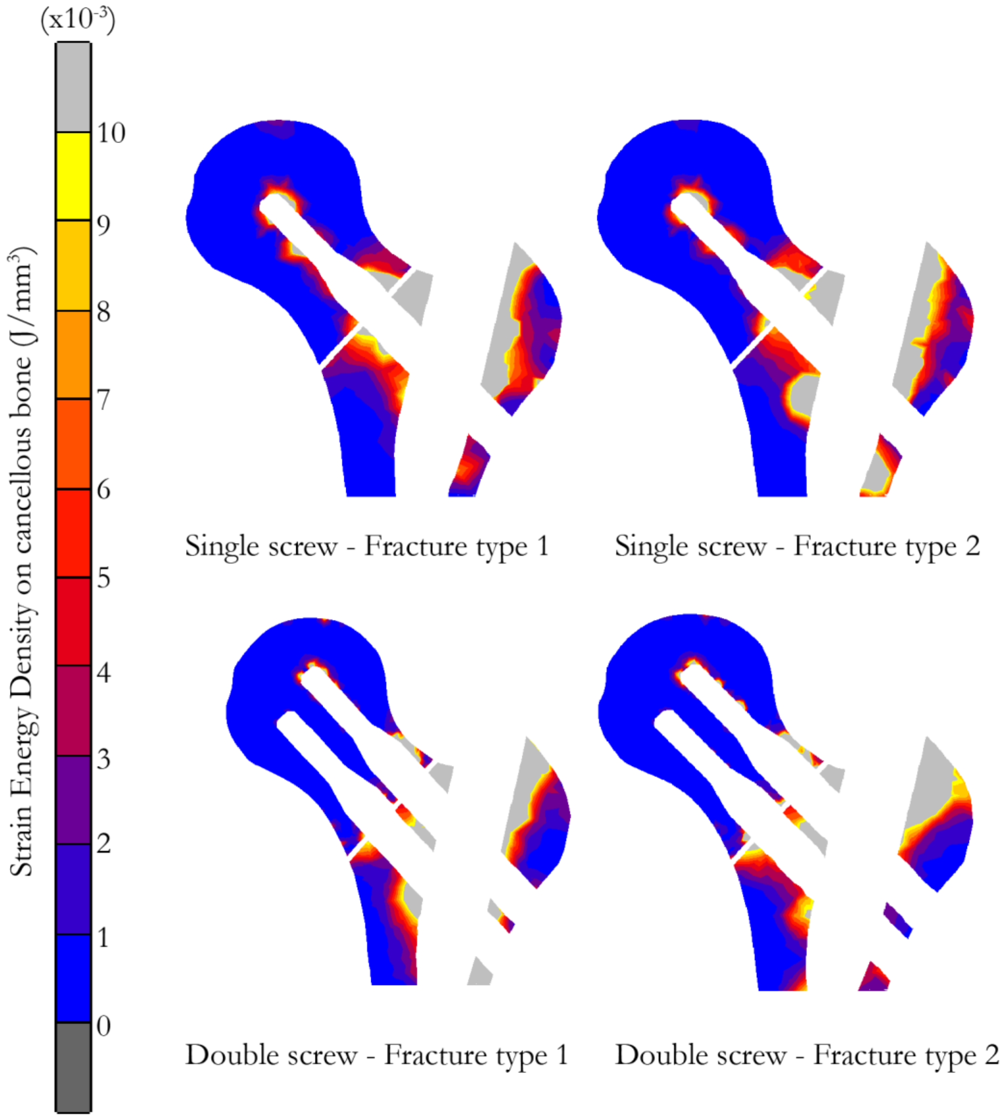

Fig. 5. Strain energy density contour on superior and inferior cancellous bone.

these complications. It is believed to improve the stability and reduce the risk of lag screw cut out.

The principal goal of this study was to compare the biomechanical performance between a single and double lag screw TGN when treated with femoral neck fracture. Loading used in this study was one-legged stance including influence of muscles forces which reflects the reality physiological loading conditions.

According to the finding, it can be observed that the stress concentrates highly in lag screws, especially in single lag screw stabilization. This can be explained that the effect of moment due to hip contact loading influences the bending of lag screw. Contact surface between lag screw and TGN is considered to be a pivot point of bending moment. As a result, the Equivalent von Mises stresses w high in these regions. In addition, a double lag screw produces the lower stress level than single lag screw. This can be explained that a double lag screw has the larger area to withstand the hip contact (body weight) than single lag screw. Stress in superior lag screw were higher than inferior lag screw because the load transferred to superior lag screw first before to inferior screw. Load is shared between both screws, therefore, the stress reduces to the lower magnitude. In the same way, the contact between lag screw and TGN acts as a pivot point, the stress then concentrates around that area.

Success of lag screws stabilization in TGN depends also on the quality of bone. The quality of bone determines its ability to resist deformation and absorb stress [18]. A deterioration of bone is one of factors that related to bone fragility and loss of bone mass such as osteoporosis can lead to secondary fracture [19]. With lower bone density, although the double lag screw is used, it may not be able to withstand the load. This may lead to lag screw penetration through cortical bone layer [20].

Under single leg stance loading condition. It can be noticed that there is a little difference in the maximum von Mises stress between both implant in fracture type 1. According to Table 4, a single lag screw TGN exhibit only 4% higher stress than double lag screw. In addition, the maximum von Mises stress of both implants are not reach beyond the yield of the stainless-steel material, which ranges from 750-960 MPa [14]. This indicated that there is a low risk in implant failure for both implants, so we can use either single or double lag screw TGN in the treatment of a femoral neck fracture. This finding is relevant to a previous work of Hsu et al. [11]. They found that there is no significant difference between gamma nail and double screw nail when used in stable fracture. They proposed that any kind of the implant could be used to treat with the neck fracture or subtrochanteric fracture.

In the fracture type 2, the result revealed that a stress is much higher in a single lag screw TGN. The stress value reach over the yield stress. This behaviour occurs because the loss of lesser trochanter reduced the structural integrity of bone and lose mechanical support [21], so the stress mostly concentrates on the implant. It can be considered that a single lag screw TGN has a very high implant failure rate in this type of fracture. However, the double screw model showed a favourable result. An additional screw increase load sharing. The double screw TGN is highly recommended in the treatment of fracture without lesser trochanter.

According to the result, the distal screw is another region where high stress occurs. A hole on the nail surface causes a stress riser effect, high stress is concentrated near the contact of distal screw and insertion hole. This mechanical behaviour is considered as a risk of distal screw breakage. However, the stress level in these areas are much below the yield stress of material.

Elastic strain is an indicator to evaluate the stability of fracture after implant stabilization. Many previous studies used elastic strain to evaluate so [11, 14, 22]. Lower elastic strain presents the better fracture stability. According to Table 5, a double lag screw TGN showed lower elastic strain value which provided a better neck fracture stabilization. The result agreed to those the clinical studies, which proposed that a double lag screw has an increased rotational stability [23, 24].

For mechanical behaviour of bone, according to table 6, femoral head and distal screw hole present a slight difference in magnitude of stress value. With these values, it is considered as sufficient low to be not a risk of fracture in this region. However, the nail insertion hole exhibited much higher stress. The values are just below the yield strength of the bone, which is around 100-170 MPa [25-29] depend on gender, age and size of the bone. There is a risk of a fracture in this region.

In order to analyse the cancellous bone, SED is used for determining the amount of energy that bone absorb. The results showed that a double lag screw TGN has a higher SED value, especially in the inferior region. This can be explained that a double lag screw TGN has to bore greater bone amount than single lag screw TGN for two lag screws insertion. The significant reduction of bone mass causes the bone in double lag screw TGN case absorb higher energy.

5. Conclusion

The study used a FE method to perform comparative biomechanical analysis between single lag screw and double lag screw TGN used to stabilize femoral neck fracture and femoral neck fracture with loss of lesser trochanter. According to the result, the double lag screw TGN revealed a greater stability in both type of fracture. In addition, the equivalent von Mises stress exhibited much lower compare to a single lag screw in the femoral neck fracture without lesser trochanter. However, both implants have similar performance in the stable femoral neck fracture. It is highly recommended to use a double lag screw TGN to stabilize femoral neck fracture with loss of lesser trochanter.

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References

[1] P. Maniscalco, F. Rivera, J. D'Ascola, *et al.*, "Failure of intertrochanteric nailing due to distal nail jamming," *Journal of Orthopaedics and Traumatology: Official Journal of the Italian Society of Orthopaedics and Traumatology,* vol. 14, no. 1, pp. 71-74, 2013.

[2] D. Wu, G. Ren, C. Peng, *et al.*, "InterTan nail versus Gamma3 nail for intramedullary nailing of unstable trochanteric fractures," *Diagnostic Pathology,* vol. 9, pp. 191-191, 2014.

[3] G. A. Macheras, S. D. Koutsostathis, S. Galanakos, *et al.*, "Does PFNA II avoid lateral cortex impingement for unstable peritrochanteric fractures?," *Clinical Orthopaedics and Related Research,* vol. 470, no. 11, pp. 3067-3076, 2012.

[4] Y. A. Weil, M. J. Gardner, G. Mikhail, G. Pierson, D. L. Helfet, and D. G. Lorich, "Medial migration of intramedullary hip fixation devices: A biomechanical analysis," *Archives of Orthopaedic and Trauma Surgery*, vol. 128, no. 2, pp. 227-234, 2008.

[5] D. Hernández-Vaquero, D. Pérez-Hernández, A. Suárez-Vázquez, *et al.*, "Reverse oblique intertrochanteric femoral fractures treated with the gamma nail," *International Orthopaedics,* vol. 29, no. 3, pp. 164-167, 2005.

[6] J. Henschel, S. Eberle, and P. Augat, "Load distribution between cephalic screws in a dual lag screw trochanteric nail," *Journal of Orthopaedic Surgery and Research*, vol. 11, no. 1, pp. 1-10, 2016.

[7] B. A. Zelle, A. J. Webb, C. Matson, *et al.*, "Safety and efficacy of a two-screw cephalomedullary nail for intertrochanteric femur fracture fixation: A retrospective case series in 264 patients," *Patient Safety in Surgery*, vol. 12, no. 1, pp. 1-10, 2018.

[8] A. F. Mavrogenis, V. G. Igoumenou, P. D. Megaloikonomos, *et al.*, "Dual head screw hip nailing for trochanteric fractures," *SICOT-J,* vol. 3, pp. 61-61, 2017.

[9] A. Kouzelis, A. Kravvas, S. Mylonas, *et al.*, "Double axis cephalocondylic fixation of stable and unstable intertrochanteric fractures: early results in 60 cases

with the veronail system," *The Open Orthopaedics Journal,* vol. 8, pp. 60-68, 2014.

[10] X. Wu, M. Yang, L. Wu, *et al.*, "A biomechanical comparison of two intramedullary implants for subtrochanteric fracture in two healing stages: A finite element analysis," *Applied Bionics and Biomechanics,* vol. 2015, pp. 475261-475261, 2015.

[11] C. C. Hsu, J. Lin, Y. Amaritsakul, *et al.*, "Finite element analysis for the treatment of proximal femoral fracture," *Computers, Materials and Continua,* vol. 11, pp. 1-13, 2009.

[12] P. Helwig, G. Faust, U. Hindenlang, A. Hirschmüller, L. Konstantinidis, C. Bahrs, N. Südkamp, and R. Schneider, "Finite element analysis of four different implants inserted in different positions to stabilize an idealized trochanteric femoral fracture," *Injury*, vol. 40, no. 3, pp. 288-295, 2009.

[13] C. J. Brown, C. J. Wang, A. L. Yettram, and P. Procter, "Intramedullary nails with two lag screws," *Clinical Biomechanics*, vol. 19, no. 5, pp. 519-525 2004.

[14] N. Chantarapanich, K. Sitthiseripratip, B. Mahaisavariya, *et al.*, "Biomechanical performance of retrograde nail for supracondylar fractures stabilization," Medical & Biological Engineering & Computing, vol. 54, no. 6, pp. 939-952, 2016.

[15] Y.-S. Shin, J.-E. Chae, T.-W. Kang, *et al.*, "Prospective randomized study comparing two cephalomedullary nails for elderly intertrochanteric fractures: Zimmer natural nail versus proximal femoral nail antirotation II," *Injury,* vol. 48, no. 7, pp. 1550-1557, 2017.

[16] O. Ovesen, M. Andersen, T. Poulsen, *et al.*, "The trochanteric gamma nail versus the dynamic hip screw: A prospective randomised study. One-year follow-up of 146 intertrochanteric fractures," *Hip International: The Journal of Clinical and Experimental Research on Hip Pathology and Therapy,* vol. 16, pp. 293-8, 2006.

[17] P. Catania, D. Passaretti, G. Montemurro, *et al.*, "Intramedullary nailing for pertrochanteric fractures of proximal femur: A consecutive series of 323 patients treated with two devices," *Journal of Orthopaedic Surgery and Research,* vol. 14, no. 1, pp. 1-7, 2019.

[18] N. H. Hart, S. Nimphius, T. Rantalainen, A. Ireland, A. Siafarikas, and R. U. Newton, "Mechanical basis of bone strength: Influence of bone material, bone structure and muscle action," *Journal of Musculoskeletal & Neuronal Interactions*, vol. 17, no. 3, p. 114, 2017.

[19] B. R. McCreadie and S. A. Goldstein, "Biomechanics of fracture: Is bone mineral density sufficient to assess risk?," *Journal of Bone and Mineral Research*, vol. 15, no. 12, pp. 2305-2308, 2000.

[20] T. A.-O. Celik, I. Mutlu, A. Ozkan, *et al.*, "Comparison of the lag screw placements for the treatment of stable and unstable intertrochanteric femoral fractures regarding trabecular bone failure," *Journal of Medical Engineering*, vol. 2016, 2016, Article ID 5470798.

[21] J. Chen, J.-X. Ma, Y. Wang, *et al.*, "Finite element analysis of two cephalomedullary nails in treatment of elderly reverse obliquity intertrochanteric fractures: Zimmer natural nail and proximal femoral nail antirotation-II," *Journal of Orthopaedic Surgery and Research,* vol. 14, no. 1, pp. 422-422, 2019.

[22] L. Wang, F. Zhao, J. Han, C. Wang, and Y. Fan, "Biomechanical study on proximal femoral nail antirotation (PFNA) for intertrochanteric fracture," *Journal of Mechanics in Medicine and Biology*, vol. 12, no. 4, p. 1250075, 2012.

[23] G. K. Kouvidis, M. B. Sommers, P. V. Giannoudis, *et al.*, "Comparison of migration behavior between single and dual lag screw implants for intertrochanteric fracture fixation," *Journal of Orthopaedic Surgery and Research,* vol. 4, pp. 16-16, 2009.

[24] G. Kouvidis, V. I. Sakellariou, A. F. Mavrogenis, *et al.*, "Dual lag screw cephalomedullary nail versus the classic sliding hip screw for the stabilization of intertrochanteric fractures. A prospective randomized study," *Strategies in trauma and limb reconstruction,* vol. 7, no. 3, pp. 155-162, 2012.

[25] J. R. Jameson, "Characterization of bone material properties and microstructure in osteogenesis imperfecta/brittle bone disease," Dissertation, Biomedical Engineering, Marquette Univerity, 2014.

[26] M. J. Mirzaali, J. J. Schwiedrzik, S. Thaiwichai, *et al.*, "Mechanical properties of cortical bone and their relationships with age, gender, composition and microindentation properties in the elderly," *Bone,* vol. 93, pp. 196-211, 2016.

[27] U. A.-O. Wolfram and J. Schwiedrzik, "Post-yield and failure properties of cortical bone," *BoneKEy Reports*, vol. 5, 2016.

[28] R. Havaldar, S. C. Pilli, and B. B. Putti, "Insights into the effects of tensile and compressive loadings on human femur bone," *Advanced Biomedical Research*, vol. 3, no. 101, 2014.

[29] H. H. Bayraktar, E. F. Morgan, G. L. Niebur, G. E. Morris, E. K. Wong, and T. M. Keaveny, "Comparison of the elastic and yield properties of human femoral trabecular and cortical bone tissue," *Journal of Biomechanics*, vol. 37, no. 1, pp. 27-35, 2004.

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