Journal of Bone Research
ISSN: 2572-4916
OPEN ACCESS Freely available online
Short Communication

Role of Anti-Rotation Screw in Intertrochanteric Curved Varus Osteotomy: A Finite Element Study

Wei-hua Feng, Hang-hang Zhang*, Zheng-Kang

Luoyang Orthopedic Hospital of Henan Province, Orthopedic Hospital of Henan Province, Zhengdong New District, Henan, China

ABSTRACT

Whether the use of anti-rotation screw is controversial when a transtrochanteric Curved Varus Osteotomy (CVO) is performed fixed with Compression Hip Screw System (CHS) for the treatment of osteonecrosis of the femoral head. The Purpose of the study was to evaluate the role of anti-rotation screw in stress reduction of CHS after CVO fixation quantitively using a finite element method. CVO models with three configurations (15°, 20° and 25°) fixed by CHS with or without anti-rotation screw were established and simulated in initial post-operative stage and finish of bone-healing stage. The von Mises stress of implant was evaluated. High stress level and concentration of stress was present in non-antirotation screw models, and the significant reduction of stress was addressed in anti-rotation models in initial postoperative stage, especially for the large degree CVO model. Anti-rotation screw can reduce the stress level of implant effectively in initial postoperative stage of CVO. We recommended the anti-rotation screw should be a necessary when CVO above 20° is performed to avoid complications.

Keywords: Transtrochanteric curved varus osteotomy, Anti-rotation screw, Finite element analysis

INTRODUCTION

Transtrochanteric Curved Varus Osteotomy (CVO) was developed by Nishio and Sugiooka [1], for the treatment of Osteotonecrosis of The Femoral Head (ONFH) in order to overcome the complications of the conventional wedge osteotomy [2]. From clinical perspective, although the good results were reported for CVO, however, the complications such as Nonunion, Metal failure, and Periprosthetic fracture were found after CVO surgery [3-5].

Moreover, the fixation of CVO is Dynamic Hip Screw System (DHS) or Compression Hip Screw System (CHS) in the market. However, whether the use of anti-rotation screw is controversial, because of extra expenses from patients. If not, the failure risk of fixation should be high and few studies have been discussed the role of anti-rotation screw in CVO from a biomechanical view.

The purpose of the study was to evaluate the role of anti-rotation screw in stress reduction of CHS after CVO fixation quantitively using a finite element method.

MATERIALS AND METHODS

The intact femur model was extracted from the CT data obtained from a healthy volunteer using a medical image processing software (Mimics16, Materialise Corp, Belgium), respectively, Reverse processing was performed for a solid femoral 3-D model with a computer assist design software (SolidWorks2016, Dassault Systemes, France) (Figure. 1A1). Then, CVO was created using the solid model, and the osteotomy method adopted from our previous report [6] (Figure. 1A2).

The fixation device of CHS system and anti-screw were provided by a company (KYOCERA, Tokyo, Japan) (Figure. 1a3), CHS was created consistent with the size of device in SolidWorks, however, the simulated implant was simplified compared to the device, which the lag screw and compression screw was created as one part without assembling later, and screws were not sculptured by the springs for the convergence.

CHS system and two parts of osteotomy were assembled and a low-risk cone necrosis with 60° was simulated in a computer assist engineering software (Abaqus2019, SIMULIA, USA). CHS system combined with and without anti-rotation screw were created with 15°, 20° and 25° three osteotomy complex (Figure. 1A4).

Mesh type was C3D4 with an element size of 1 mm for the two osteotomy parts of femur before assigning an elastic isotropic heterogeneous material property based on CT images according to the equations (1) (2) (3) by using an in-house subroutine (Figure. 1b) [7-9]

$$\rho_{QCT}(g/cm^3) = 0.000764HU - 0.0056148 \quad (1)$$

Correspondence to: Hang-hang Zhang, Luoyang Orthopedic Hospital of Henan Province, Orthopedic Hospital of Henan Province, Zhengdong New District, Henan, China, Telephone: 86+15737933282; E-mail: zhh129666@sina.com

Received: June 4, 2021; **Accepted:** June 10, 2021; **Published:** June 25, 2021

Citation: Wei-hua Feng, Hang-hang Zhang, Zheng-Kang (2021) Role of Anti-Rotation Screw in Intertrochanteric Curved Varus Osteotomy: A Finite Element Study. J Bone Res. 9:126.

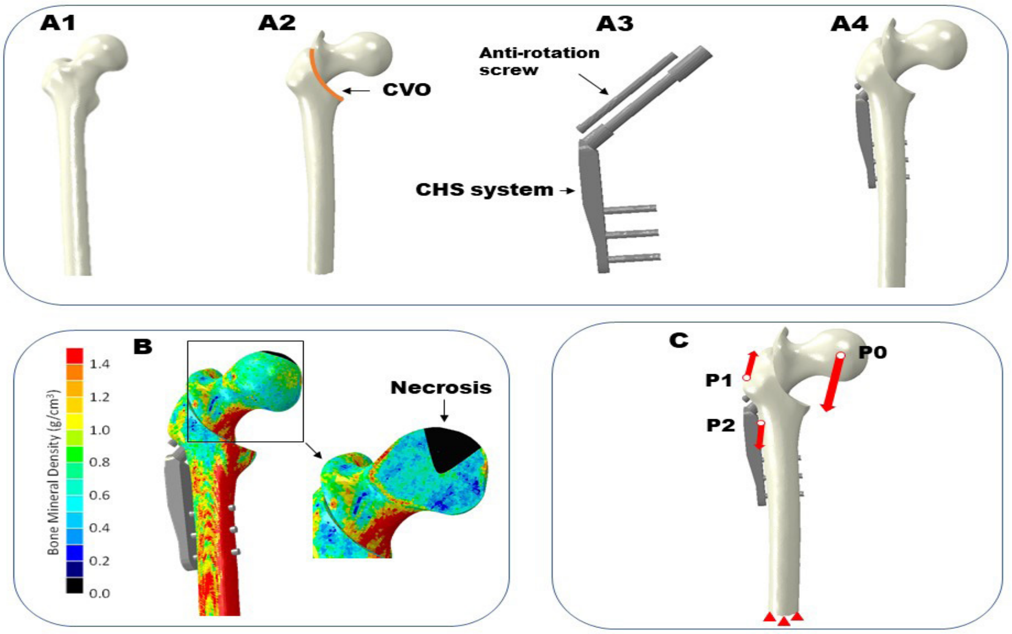

Figure 1. Reconstruction of CVO finite element model; A1): Intact femur 3D model; A2): Intertrochanteric curved varus osteotomy; A3): CHS system with anti-rotation screw; A4): CVO complex fixed with CHS system and anti-rotation screw; B): Femoral bone was assigned with isotropic elastic heterogeneous material properties; C): CVO finite element model with loading conditions.

$$\rho_{ash}(g/cm^3) = 0.877 \times \rho_{QCT} + 0.0789 \quad (2)$$

$$E = 6850\rho_{app}^{1.49} \quad (3)$$

Then, implant, anti-rotation screw and necrotic bone were assigned with elastic isotropic homogeneous properties [10,11] (Table 1).

For boundary and loading conditions (Figure. 1C), anti-rotation screw and bone, the tip of lag screw and bone, cortical screws and bone, were bonded, the middle part of lag screw and bone, the barrel and bone, were contact relationship, the distal part of lag screw was fixed in the barrel by the compression screw, defined as a bonding relationship with the barrel. The two osteotomy interfaces were created with non-friction and bonding for simulating initial post-operative stage and finish bone, the distal femoral was constrained fully, physiological loading condition of maximum value of walking was added (Table 2).

Table 1. Summary of material property assignment.

Components	Young´s modulus	Poisson's ratio	Material property
Bone	$E = 6850\rho_{app}^{1.49}$	0.3	Isotropic Heterogeneous
Implant	110GPa	0.3	Isotropic Homogeneous
Antirotation screw	110 GPa	0.3	Isotropic Homogeneous

Table. 2. Loading conditions of CVO finite element models.

Force component	Loading location	Coordinates (N)		
		X	Y	Z
Hip contact complex Abductor complex	P0 P1	365.148 -380.436	-268.126 89.376	-1807.51 474.516
Vastus lateralis	P2	5.292	108.78	-546.252

A body weight of 600 N was assumed for the present study.

RESULTS

The max von Mises stress was 345.8 MPa, 536.7 MPa, and 1073.0 MPa without anti-rotation screw, 190.4 MPa, 244.6 MPa, and 293.7 MPa with anti-rotation screw in initial postoperative stage with CVO of 15°, 20°, 25°. The max von Mises stress was 281.3 MPa without anti-rotation screw, 247.8 MPa with anti-rotation screw in finish bone-healing stage with CVO of 25° (Figure. 2). The stress concentration was addressed located in the interface of osteotomy on the implant, especially, CVO 25° without anti-rotation screw in initial post-operative stage, and the reduced stress distribution was present in anti-rotation screw models (Figure. 3). The stress distribution of CVO 25° was similar with or within anti-rotation screw in finish bone-healing stage.

DISCUSSION

CVO models fixed by CHS system with or without anti-rotation screw were simulated based on finite element method. The von Mises stress was used to evaluate the role of anti-rotation in stress reduction of implant with three CVO operations by simulating the initial post-operative stage and finish bone-healing stage. The results were outstanding as expected that the anti-rotation screw can reduce the stress level of implant, especially, for large degree of CVO in initial post-operative stage.

The max von Mises stress suffered by the implant without anti-rotation screw was significantly higher than those of models with anti-rotation screw after CVO immediately compared to finish bone-healing stage models (Figure. 2), the influence of anti-rotation screw was obvious in large degree of CVO. Thus, we recommended that an anti-rotation screw should be an necessary to prevent complications when a large (above 20°) degree of CVO is performed.

The distribution of von Mises stress of implant was different obviously with or without anti-rotation screw, that the higher stress could be seen in the interface on lag screw (Figure. 3), without

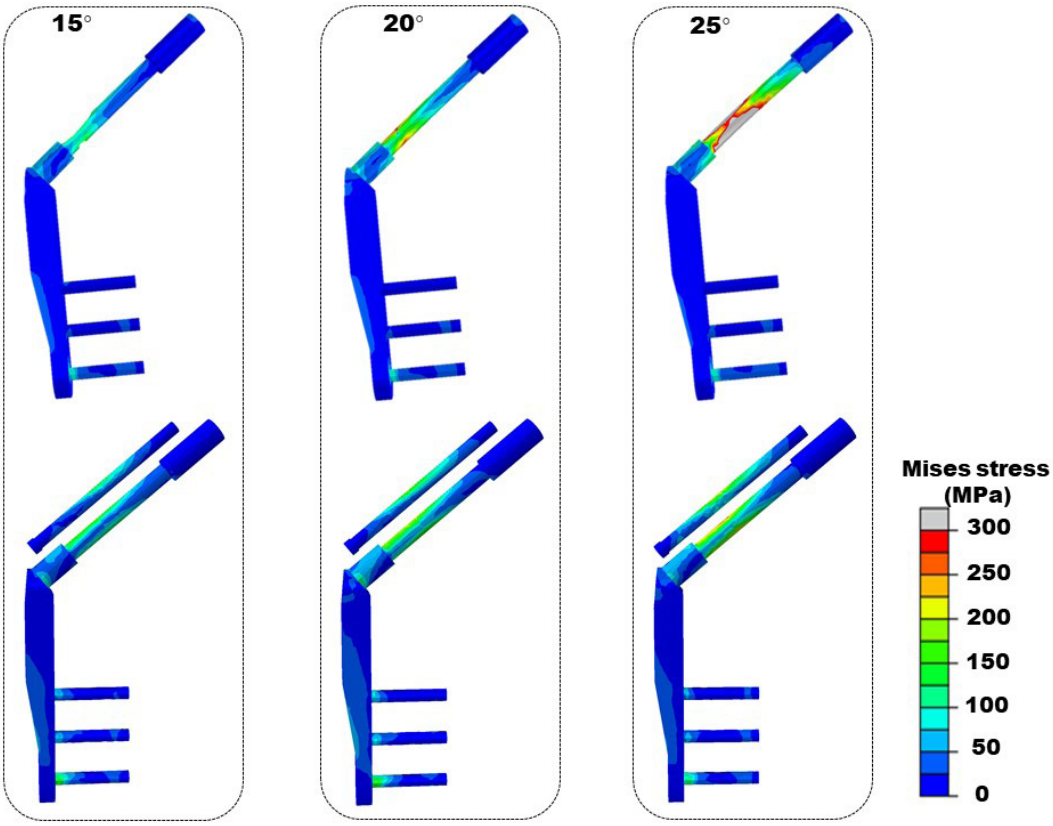

Figure 2. The stress distribution of CHS system with different operations in initial postoperative stage of osteotomy.

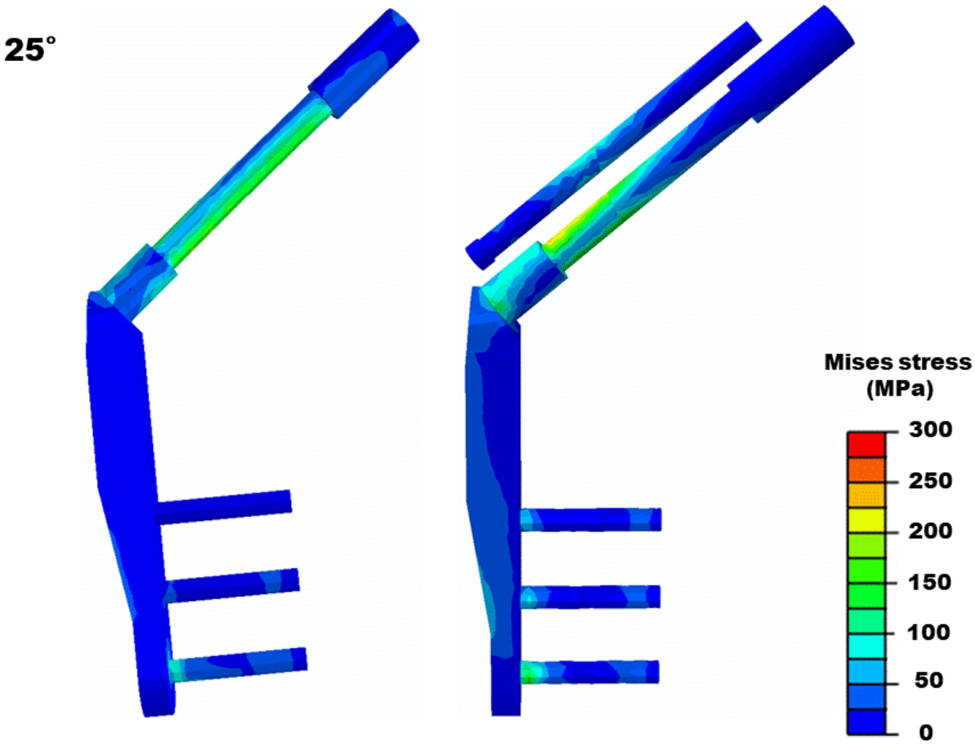

Figure 3. The stress distribution of CHS system of 25° CVO in bone-healing stage of osteotomy.

anti-rotation screw, the lag screw acted as the main mechanical support after CVO immediately, the motion was available in the interface, leading to concentration stress in this area, as a pivot of loading, which could be explained for the Periprosthetic fracture in the initial post-operative period. Because no strong compression or fixation in the interface for balancing the load added from upper body weight. With anti-rotation screw, the interface of osteotomy cannot slide easily and the load transfer path was unobstructed from upper body weight to lower, moreover, the main mechanical support was shared by anti-rotation screw with a relative low stress distribution of implant. Thus, the fracture risk of implant should be avoided effectively.

The vital step for the study was to assign the isotropic heterogeneous material property for the bone, which was mapped into mesh element in condition that the position of meshed bone must be the same as the original configuration, which was extracted from Mimics. The more complicated was the two parts of osteotomy could not be assigned at the same time. We needed to integrate the two materials property INP files of separated osteotomy parts into one INP file, manually, for displacing the material property of the two parts at the same time.

However, the limitation was not avoided. Firstly, the finite element analysis was a predictive method, in most cases, the validated experiment was necessary to confirm whether the predictive results was acceptable and useful for the research, in this study, the authors just managed the predictive results using finite element analysis to behave the bio-mechanical features of the model. So honestly, it was questioned for the accuracy to some parameters, for example, the max von Mises stress of the implant, were high, even exceeding the yield strength in the prediction of initial post-operative stage, generally, the real human body could bear such values, even more without destroy of bone quality. Secondly, the interaction relationship between components, the related importance was to simulate the function of compression screw in the barrel, for the present study, the authors just made the lag screw non-micro motion in the barrel, the further study needs to reach for a more accuracy of prediction.

Finally, the conclusion was that anti-rotation screw can reduce the stress level of implant effectively in initial postoperative stage of CVO, especially, in situation of large degree of osteotomy. We recommended the anti-rotation screw should be a necessary when CVO above 20° is performed to avoid complications.

REFERENCES

1. Nishio A, Sugioka Y. A new technique of the varus osteotomy at the upper end of the femur. Orthop Trauma. 1971;20:227-244.
2. Ito H, Kaneda K, Matsuno T. Osteonecrosis of the femoral head: simple varus intertrochanteric osteotomy. J Bone J Surg Br. 1999;81:969-974.
3. Dongmin Xiao, Ming Ye, Xinfa Li, Lifeng Yang. Development of femoral headinterior supporting device and 3d finite element analysis of its application in the treatment of femoral head avascular necrosis. Med Sci Monit. 2015;21:1520-1526.
4. Ikemura S, Yamamoto T, Jingushi S, Nakashima Y, Mawatari T, Iwamoto Y. Leg- length discrepancy after transtrochanteric curved varus osteotomy for osteonecrosis of the femoral head. J Bone J Surg Br. 2007;89:725-729.
5. Kazuhiko S, Takuaki Y, Goro M, Yasuharu N, Ryosuke Y, Iwamoto Y. Outcome of transtrochanteric rotational osteotomy for posttraumatic osteonecrosis of the femoral head with a mean follow up of 12.3 years. Arch Orthop Trauma Surg. 2015;135:1257-1263.
6. Feng WH, Zhang HH, Tian TT, Kang Z. A finite element analysis of transtrochanteric curved varus osteotomy combined with compression hip screw system. J Osteopor Phys Act. 2021;9:232.
7. Schileo E, Dall'Ara E, Taddei F, Malandrino A, Schotkamp T, Viceconti M, et al. An accurate estimation of bone density improves the accuracy of subject-specific finite element models. J Biomech. 2008;41:2483-2491.
8. Ali AA, Cristofolini L, Schileo E, Hu H, Taddei F, Kim RH et al. Specimen-specific modeling of hip fracture pattern and repair. J Biomech. 2014;47:536-543.
9. Morgan EF, Bayraktar HH, Keaveny TM. Trabecular bone modulus-density relationships depend on anatomic site. J Biomech. 2003;36:897-904.
10. Zhou GQ, Pang ZH, Chen QQ, He W, Chen ZQ, Chen LL, et al. Reconstruction of the biomechanical transfer path of femoral head necrosis: A subject-specific finite element investigation. Comput Bio Med. 2014;52:96-101.
11. Chen WP, Tai CL, Shih CH, Hsieh PH, Leou MC, Lee MS. Selection of fixation devices in proximal femur rotational osteotomy: clinical complications and finite element analysis. Clin Biomech. 2004;19:255-262.