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A novel angle on helical blade placement in trochanteric fractures – The axis-blade angle

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ABSTRACT

Introduction: For trochanteric fractures, helical blade placement is crucial to the prognosis of operations. Existing measurement methods used for blade placement include the Cleveland zone, the tip-apex distance (TAD), the calcar-referenced tip-apex distance (CalTAD), and the Parker's ratio. These methods all lack a direct view on blade direction. The current study proposed the axis-blade angle (ABA) to solve direction problem and investigated its clinical applicability.
Methods: A retrospective study collected 156 patients between May 2014 and February 2018. The occurrence of mechanical complications was analyzed in relation to age, gender, fracture side, American Society of Anesthesiologists classification, fracture classification, reduction quality, bone quality, the Cleveland zone, the Parker's ratio, the TAD, the CalTAD, and the ABA.
Results: 119 patients, including 25 with mechanical complications, were suitable for full analysis. In the univariate analysis, the Cleveland zone, reduction quality, the TAD, the CalTAD and the ABA were statistically associated with mechanical complications. In the multivariate analysis, reduction quality ($p = 0.008$) and the ABA ($p < 0.001$; adjusted OR 0.86;95% CI 0.77 to 0.96) showed significant results, which indicated that reduction quality and the ABA were two independent influencing factors for mechanical complications. Calculation of the receiver operating characteristic (ROC) curve indicated that the ABA was a reliable predictor of mechanical complications at the cut-off of -10°.
Conclusions: The ABA provides instruction for the intraoperative adjustment of guide wire direction. Placing the helical blade with an ABA $> -10^{\circ}$ can effectively reduce the risk of mechanical complications.

Introduction

Trochanteric fractures have been taking a heavy toll on patients and medical systems worldwide, and the incidence of this kind of fracture is still growing with the increasing number of world's aging population [1,2]. Owing to the development of operative techniques and fixation devices, union rates are high in the status quo. However, postoperative mechanical complications, such as cut-out, varus displacement and excessive lateral migration of the blade, remain challenging [3–5].

Strength of the femur-implant construct is mainly determined by the following factors: (1) bone quality, (2) fragment geometry, (3) reduction, (4) implant design, and (5) implant placement [6,7]. Since the late 1950s, researchers around the world have paid increasing attention to implant placement. So far, the main measurement methods used for helical blade placement include the Cleveland zone, the Parker's ratio, the tip-apex distance (TAD), and the calcar-referenced tip-apex distance (CalTAD) [3,8–10]. Although they have provided some guidance for implant placement, there is still controversy among the reliabilities of them and every method exists its own limitation 8–11].

It is worth noting that these methods all lack a direct view on blade direction. The Cleveland zone is a nine-zones system dividing the femoral head into superior, central, and inferior quadrants on the anteroposterior (AP) view and into anterior, central, and posterior quadrants on the lateral (LAT) view, whereas this method is too general to describe the direction or insertion depth of the blade [12,13]. Through a ratio of 0 to 100 for each view, the Parker's ratio only describes blade direction in an indirect and cumbersome way [10,13,14]. The TAD – defined as the sum of the distance from the blade tip to the femoral head apex in AP and LAT views – takes into consideration the blade depth. However, the TAD still cannot solve the direction problem, therefore two blades with the same TAD could have distinctly different positions [11,13,15]. On the basis of the TAD, the CalTAD moves the original guideline to be adjacent to the medial

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cortex of the femoral neck in AP views, but this modification hasn't attained unanimous agreement yet [8,16–19].

We therefore aimed to (1) propose a new measurement method for helical blade placement, which better quantifies direction, named the axis-blade angle (ABA) (Fig. 1); (2) investigate the clinical applicability of the ABA in predicting mechanical complications; (3) explore the instructive significance of the ABA for the operation.

Patients and methods

Study participants

A retrospective study collected 156 cases of trochanteric fractures treated with proximal femoral nail anti-rotation (PFNA; 135°, Kanghui Medical, China), between May 2014 and February 2018. The Hospital Ethics Committee approved the current study.

Patients were identified through a query of our hospital's database. 156 patients who had trochanteric fractures were screened for inclusion. 18 patients whose postoperative radiographs were nonstandard for radiograph assessment were excluded. 19 patients who did not complete a follow-up of at least 3 months postoperative were also excluded, because most mechanical complications related to the operation occurred within 3 months as claimed in previous studies [13,20]. This left 119 patients for full analysis.

Variables and measurements

The collected clinical data included age at the operation, gender, fracture side, American Society of Anesthesiologists (ASA) classification, fracture classification according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) system, reduction quality, bone quality at the fracture, the Cleveland zone, the Parker's ratio, the TAD, the CalTAD, and the ABA.

A standard AP radiograph was taken in the supine position, with the leg internally rotating 15° – 20° to achieve femoral anteversion; a standard LAT radiograph was taken in the supine position, with the X-ray beam perpendicular to the femoral neck axis [21,22].

The AO/OTA classification and bone quality were identified via preoperative AP and LAT radiographs. The fractures were classified into classes 31–A1, 31–A2 and 31–A3 without using subgroups. We utilized the Singh Osteoporosis Index (SOI) of contralateral radiographs to determine bone quality [23].

Reduction quality, the Cleveland zone, the TAD, the CalTAD, the Parker's ratio, and the ABA were identified via immediate postoperative AP and LAT radiographs. Reduction quality was classified into three grades based on a method developed by Baumgaertner et al [13]. The first criterion was normal or slight valgus alignment in AP views, and less than 20° of angulation on the LAT view. The second criterion was no more than 4 mm of displacement of any fragment. A good reduction met both criteria. An acceptable reduction only met one criterion, and a poor reduction met none.

The measurement of the ABA is shown in Fig. 1. The femoral neck axis was defined as a line through the femoral head center and the femoral neck center (NC). The NC was defined as the midpoint of the femoral neck at its narrowest part [22,24]. Because this method measures the size of angles, the consideration of the inherent magnification or correction is unnecessary.

The data of the AO/OTA classification, reduction quality, the Cleveland zone, the TAD, the CalTAD, the Parker's ratio, and the ABA were collected by two observers who were blinded to the outcomes. The mean of two sets of continuous data was used. Disagreements in categorical data were resolved through the help of a third author. The observers were systematically trained on the AO/OTA classification system, the Baumgaertner fracture reduction system, the SOI, and the measurements of the Cleveland zone, the TAD, the CalTAD, the Parker's ratio, and the ABA. Radiographs and the relevant measurements were evaluated with the aid of Picture Archiving and Communication System (PACS).

Outcomes

Two observers evaluated radiographs of last follow-up available to assess the mechanical complications. Discrepancies were resolved through consensus. Varus displacement was defined as a secondary decrease > 10° of the neck-shaft angle, compared with the immediate postoperative film [5,16,25]. Excessive lateral migration of the

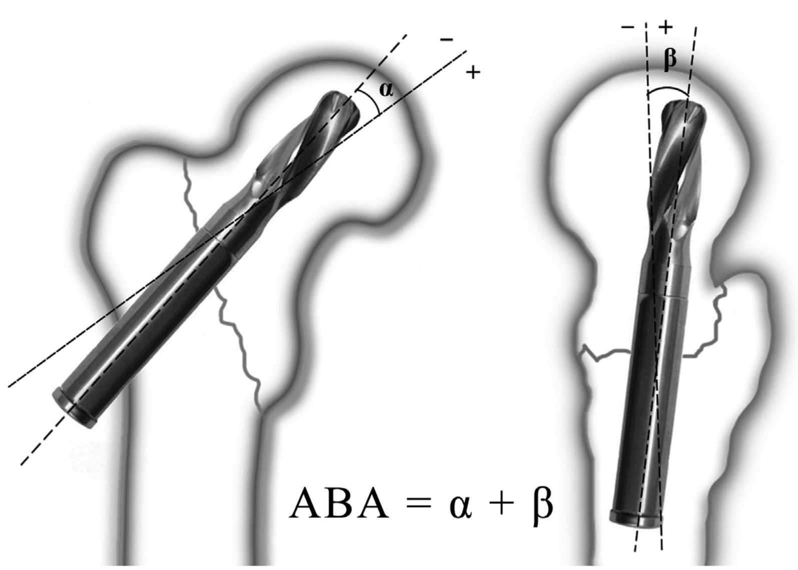

Fig. 1. The approach to calculating the axis-blade angle (ABA). The angle α and the angle β are angles between the helical blade axis and the femoral neck axis on anteroposterior and lateral views, respectively. The ABA is calculated as the sum of the angle α and the angle β, in degrees. The value of the angle α or β is defined as positive if the blade orients toward the inferior or posterior, and as negative if the blade orients toward the superior or anterior.

blade was defined as an increase > 10 mm of the length from the lateral prominence of the blade to the lateral edge of the nail, compared with the immediate postoperative film [4,26,27].

Statistical analysis

Statistical analysis was performed using SPSS version 22 (SPSS, Chicago, Illinois) and MedCalc version 15.2.2 (MedCalc Software, Mariakerke, Belgium). As for univariate analysis, with the occurrence of mechanical complications set as the dependent variable, the chi-square test and the Student *t*-testwere used to determine statistical significance of categorical and continuous independent variables, respectively, then univariate logistic regression was used for crude odds ratio (OR) with 95% confidence interval (CI). Significance was defined as $p < 0.05$. Multivariate logistic regression was conducted with all the independent variables with $p < 0.05$ in the univariate analysis. The likelihood ratio forward test was performed to identify the best-fit model, with the entry set at $p < 0.05$ and removal at $p > 0.10$. The receiver operating characteristic (ROC) curve for the ABA was used to calculate its reliability and best cut-off point in predicting mechanical complications. The Hosmer-Lemeshow test was used to judge goodness of fit for the logistic regression model (the model passed the test if the p-value was > 0.05).

To assess interobserver reliability for continuous data, we calculated the intraclass correlation coefficients (ICCs) using 95% CI, and the two-way random-effects model with agreement was selected. For categorical data, we calculated κ coefficients with 95% CI.

Results

119 cases (50 men and 69 women) were suitable for full analysis. The mean follow-up period was 6.8 months (3–35 months) after the operation. 94 patients had uneventful union, and there were 28 mechanical complications happening in 25 patients, including 2 of implant failure (1 cut-out and 1 loss of fixation, both with nonunion), 18 of varus displacement, 8 of excessive lateral migration of the blade.

Interobserver Reliability

Table 1 presents the results of the ICCs and κ coefficients with 95% CI. They were interpreted according to the rating by Landis and Koch [28]. For the ABA, the Parker's ratio (AP), the Parker's ratio (LAT), the TAD and the CalTAD, the average measures ICCs were > 0.80, showing an almost perfect reliability with the measures; the κ coefficient of the AO/OTA classification indicated an excellent reliability (0.61–0.80); the Cleveland zone, reduction quality had a moderate reliability (0.41–0.60); The discrepancy in the measurements of the SOI showed poor reliability ($\kappa \leq 0.40$).

Table 1
Reliability between the two observers for different variables*.

Variable	Average measures intra-class correlation coefficient (κ)	95% CI
AO/OTA classification (κ)	0.696	0.573–0.812
Cleveland zone (κ)	0.405	0.274–0.527
ABA (°)	0.930	0.899–0.951
Reduction Quality (κ)	0.578	0.453–0.703
Parker's ratio (AP)	0.806	0.722–0.865
Parker's ratio (LAT)	0.860	0.799–0.903
TAD (mm)	0.894	0.848–0.926
CalTAD (mm)	0.838	0.767–0.887
SOI (κ)	0.358	0.242–0.472

* AO/OTA, AO Foundation and Orthopaedic Trauma Association; ABA, axis-blade angle; AP, anteroposterior view; LAT, lateral view; TAD, tip-apex distance; CalTAD, calcar reference tip-apex distance; SOI, Singh Osteoporosis Index; CI, confidence interval.

Univariate analysis

The results shown in Table 2 present the numbers and percentages or the means and the standard deviations of patient characteristics.

Statistically significant outcome was not observed with age, gender, fracture side, ASA classification, the AO/OTA classification, the Parker's ratio (AP), the Parker's ratio (LAT) or the SOI. A greater TAD ($p = 0.033$) and a greater CalTAD ($p < 0.001$) were significantly associated with the occurrence of mechanical complications. The Cleveland zone showed a significant result ($p < 0.001$), and the superior-central (6/7) as well as the central-anterior (7/13) had the highest rates of mechanical complications. Reduction quality is also significantly associated with mechanical complications ($p < 0.001$), and 8 had complications in 9 poor reduction.

A greater ABA was an important factor in preventing mechanical complications ($p < 0.001$; crude OR 0.82; 95% CI 0.75 to 0.89). For the 25 patients with poor results, the average ABA (and standard deviation) was -16.8 ± 8.7 compared with -1.9 ± 8.7 for the 94 patients without complications.

Multivariate analysis

Table 3 presents a multivariate model including all variables with $p < 0.05$ amid the univariate analysis. Reduction quality ($p = 0.008$) and the ABA ($p < 0.001$; adjusted OR 0.86; 95% CI 0.77 to 0.96) showed significant results. The p-value of the Hosmer-Lemeshow test was 0.603, indicating that the model fit the data very well.

Calculation of the ROC curve indicated that the ABA was a reliable predictor of mechanical complications (Fig. 2). The Youden test was applied to balance the highest values of sensitivity and specificity, which showed that the best cut-off point was $-10°$.

Bivariate logistic regression showed predicted probability of mechanical complications for any given ABA (Fig. 3). When the ABA was below $-10°$, as the decrease of it, predicted probability of mechanical complications zoomed up.

Discussion

The incidence of mechanical complications in trochanteric fractures is fairly influenced by implant placement. However, previous measurement methods for blade placement all lack a direct view on blade direction. Our study proposed a new method to solve direction problem. By comparing the ABA with other methods, we identified that the ABA was a reliable predictor of mechanical complications.

In the univariate analysis, the Cleveland zone, reduction quality, the TAD, the CalTAD and the ABA were statistically linked to mechanical complications. Then in multivariate logistic regression which allows us to study the simultaneous effect of multiple factors, the results showed that reduction quality and the ABA were two independent influencing factors for mechanical complications. The multivariate model indicated that a greater ABA was associated with a 0.86-times lower risk of mechanical complications per degree increase of the ABA. The ROC curve found a threshold value for the ABA at the $-10°$ level. A greater number of cases should be evaluated to verify the observation.

The current study defined the inferior and the posterior as positive values because of reference to previous clinical and biomechanical studies which recommended the central or inferior

Table 2
Univariate analysis*.

Characteristic	Without mechanical complications (n = 94 (%))	With mechanical complications (n = 25 (%))	p-value†	Crude odds ratio	95% CI for odds ratio
Age (yr)	69.7 ± 15.4	74.0 ± 9.2	0.087	1.02	0.99–1.06
Gender			1.000		
Male	40 (42.6)	10 (40.0)			
Female	54 (57.4)	15 (60.0)			
Side			1.000		
Left	51 (54.3)	13 (52.0)			
Right	43 (45.7)	12 (48.0)			
ASA classification			0.304		
I	25 (26.6)	2 (8.0)			
II	42 (44.7)	16 (64.0)			
III	25 (26.6)	6 (24.0)			
IV	2 (2.1)	1 (4.0)			
AO/OTA classification			0.172		
A1	48 (51.0)	11 (44.0)			
A2	40 (42.6)	9 (36.0)			
A3	6 (6.4)	5 (20.0)			
Cleveland zone			< **0.001**		
Central-Central	63 (67.0)	9 (36.0)			
Inferior-Central	10 (10.6)	1 (4.0)			
Inferior-Posterior	3 (3.2)	0 (0)			
Superior-Central	1 (1.1)	6 (24.0)			
Superior-Posterior	2 (2.1)	2 (8.0)			
Central-Anterior	6 (6.4)	7 (28.0)			
Central-Posterior	4 (4.3)	0 (0)			
Inferior- Anterior	5 (5.3)	0 (0)			
Reduction Quality			< **0.001**		
Good	50 (53.2)	4 (16.0)			
Acceptable	43 (45.7)	13 (52.0)			
Poor	1 (1.1)	8 (32.0)			
Parker's ratio (AP)	45.9 ± 10.1	50.2 ± 9.7	0.057	1.04	1.00–1.09
Parker's ratio (LAT)	51.8 ± 9.6	55.3 ± 11.0	0.120	1.04	0.99–1.08
TAD (mm)	22.8 ± 7.6	26.5 ± 7.8	**0.033**	1.06	1.00 –1.13
CalTAD (mm)	25.5 ± 7.4	34.0 ± 8.0	< **0.001**	1.15	1.07–1.22
ABA (°)	−1.9 ± 8.7	−16.8 ± 8.7	< **0.001**	0.82	0.75–0.89
SOI			0.099		
I	2 (2.1)	0 (0)			
II	1 (1.1)	1 (4.0)			
III	12 (12.8)	8 (32.0)			
IV	49 (52.1)	10 (40.0)			
V	21 (22.3)	6 (24.0)			
VI	9 (9.6)	0 (0)			

† Chi-square test for categorical variables and Student's *t*-test for continuous variables. Significant p-values ($p < 0.05$) are indicated in bold.
* ASA, American Society of Anesthesiologists; AO/OTA, AO Foundation and Orthopaedic Trauma Association; ABA, axis-blade angle; AP, anteroposterior view; LAT, lateral view; TAD, tip-apex distance; CalTAD, calcar reference tip-apex distance; SOI, Singh Osteoporosis Index; CI, confidence interval.

position in AP views and the central or posterior position on LAT views [3,7,10,11]. Although position and direction are different concepts, our results share commonality with previous studies. To acquire an ABA $> -10°$, the blade should avoid orienting toward the superior or anterior.

With the help of a C-arm X-ray machine, we provide several tips to place the blade within the recommended range of the ABA intraoperatively. Firstly, with the help of a C-arm X-ray machine, the entry point of the intramedullary nail should be slightly medial to the exact tip of the greater trochanter. Secondly, a normal or slightly valgus reduction should be performed. Finally, before the insertion of the blade, the surgeon can appropriately adjust the direction of the guide wire until the ABA of the guide wire is $> -10°$. In the current study, the ABA was measured via immediate postoperative radiographs, while in clinical practice surgeons could easily estimate the ABA of the guide wire through intraoperative AP and LAT views.

Table 3
Multivariate analysis*.

Characteristic	p-value‡	Adjusted odds ratio	95% CI for odds ratio
Cleveland zone	0.733		
Reduction Quality†	**0.008**		
Good	**0.013**	0.03	0.00–0.46
Acceptable	**0.012**	0.02	0.00–0.43
TAD (mm)	0.926	0.89	0.75–1.07
CalTAD (mm)	0.586	1.11	0.91–1.35
ABA (°)	< **0.001**	0.86	0.77–0.96

† The poor reduction is the reference category.
‡ Significant p-values ($p < 0.05$) are indicated in bold.
* ABA, axis-blade angle; TAD, tip-apex distance; CalTAD, calcar reference tip-apex distance; CI, confidence interval.

In aspect of biomechanics, the TAD and the CalTAD both only focus on the blade tip point, whereas the ABA regards the blade as a line rather than a point because the blade implanted at proximal femur is a cylinder-like body. The variation of blade direction changes the contact area between the blade and bone, which leads to the difference of anchoring force that is important for the efficacy. On the one hand, with a greater ABA, the threaded portion of the blade tend to locate in or be closer to the inferior-posterior quadrant of the femoral head, where bone is formed by the decussation of tension and compression trabeculae, which assuring maximal proximal fragment control [7,29]. On the other hand, a greater ABA rendered the blade thread closer to the calcar femorale, which provides mechanical support and aids in load distribution within the proximal femur, thus helping to support the posteromedial cortex and achieve

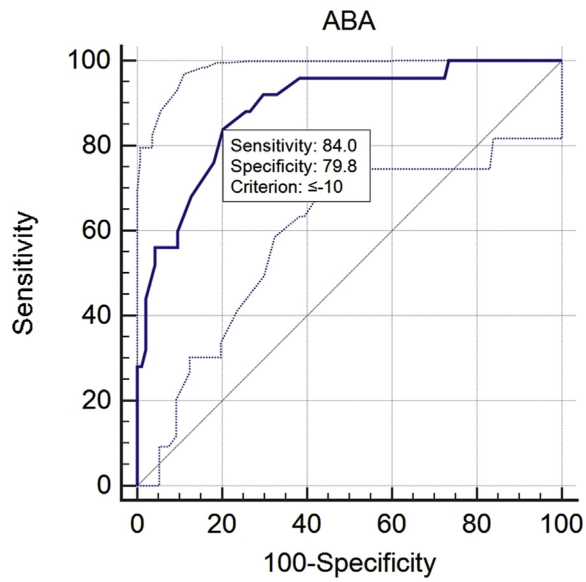

Fig. 2. The graph showing the receiver operating characteristic (ROC) curve obtained by plotting the sensitivity against their respective 100-specificity values. The area under the curve (AUC 0.89; 95% CI 0.82 to 0.94) showed the accuracy of the axis-blade angle (ABA) in predicting the risk of mechanical complications. The best cut-off point was −10°.

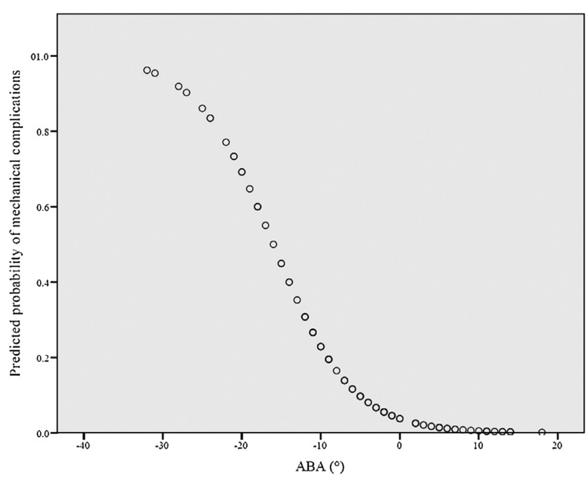

Fig. 3. The graph above showing the predicted probability of mechanical complications as a function of the axis-blade angle (ABA).

greater axial and torsional stiffness [7,10,19,29]. For lag screws, based on the above biomechanical principles, we tend to think that the ABA is equally applicable.

With regard to mechanical complications in this study, it has been reported that varus displacement correlated with the occurrence of limb shortening and failure of the osteosynthesis, and excessive lateral migration of the blade was associated with an increase in hip pain, lateral protrusion, and functional impairment [16,20]. As for implant failure, both cut-out and loss of fixation are severe complications. With a greater number of patients, some future research can try to focus exclusively on the association between the ABA and these severe complications.

Because the ABA doesn't account for the insertion depth, we recommend that both the ABA and the TAD (or the CalTAD) should be considered in clinical practice. In our study, both the TAD and the CalTAD were significantly associated with mechanical complications. As a classic method that takes into consideration the insertion depth, the TAD has been recognized by many research results [3,10]. However, in the AP view, a superior placement and an inferior placement could have the same TAD (AP), and in the LAT view, an anterior placement and a posterior placement could have the same TAD (LAT).

This study has some limitations. Firstly, the current study was carried out retrospectively, on patients recruited over a long period of time. Via calculating the adjusted OR and 95% CI for multivariate logistic regression analysis, we minimized the confounding bias. Secondly, the upper limit of the ABA was hard to identify with our sample. What the ABA provides is a relatively safe range of angles, not a pursuit of the extremely inferior or extremely posterior orientation. Apparently, the value of the ABA cannot be infinite, but in fact a very large ABA is pretty rare in the clinical setting. Hence, identifying the upper limit of the ABA does not have much clinical significance.

In conclusion, the axis-blade angle is a reliable predictor for mechanical complications. This novel method complements the TAD (or the CalTAD) and provides instruction for the intraoperative adjustment of the guide wire direction. Placing the helical blade with an ABA > −10° can effectively reduce the risk of mechanical complications.

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Ethical approval

This retrospective observational study was approved by the Ethics Committee of our hospital (2018EC153).

Informed consent

After our application, the informed consent was waived by the Ethics Committee of our hospital.

Disclosure of conflict of interest

The authors report no conflict of interest related to this manuscript.

References

[1] Ballane G, Cauley J, Luckey M, Fuleihan G-H. Secular trends in hip fractures worldwide: opposing trends East versus West. J Bone Miner Res 2014;29:1745–55.
[2] Cummings S, Rubin S, Black D. The future of hip fractures in the United States. Numbers, costs, and potential effects of postmenopausal estrogen. Clin Orthop Relat Res 1990;163–6.
[3] De Bruijn K, den Hartog D, Tuinebreijer W, Roukema G. Reliability of predictors for screw cutout in intertrochanteric hip fractures. J Bone Joint Surg Am 2012;94:1266–72.
[4] Liu W, Zhou D, Liu F, Weaver M, Vrahas M. Mechanical complications of intertrochanteric hip fractures treated with trochanteric femoral nails. J Trauma Acute Care Surg 2013;75:304–10.
[5] Peyser A, Weil Y, Brocke L, Sela Y, Mosheiff R, Mattan Y, et al. A prospective, randomised study comparing the percutaneous compression plate and the compression hip screw for the treatment of intertrochanteric fractures of the hip. J Bone Joint Surg Br 2007;89:1210–7.
[6] Biber R, Berger J, Bail H. The art of trochanteric fracture reduction. Injury 2016;47(Suppl 7):S3–6.
[7] Kaufer H. Mechanics of the treatment of hip injuries. Clin Orthop Relat Res 1980;53–61.
[8] Caruso G, Bonomo M, Valpiani G, Salvatori G, Gildone A, Lorusso V, et al. A six-year retrospective analysis of cut-out risk predictors in cephalomedullary nailing for pertrochanteric fractures: Can the tip-apex distance (TAD) still be considered the best parameter? Bone Joint Res 2017;6:481–8.
[9] Kashigar A, Vincent A, Gunton M, Backstein D, Safir O, Kuzyk P. Predictors of failure for cephalomedullary nailing of proximal femoral fractures. Bone Joint J 2014;96-B:1029–34.

[10] Güven M, Yavuz U, Kadioğlu B, Akman B, Kilinçoğlu V, Unay K, et al. Importance of screw position in intertrochanteric femoral fractures treated by dynamic hip screw. Orthop Traumatol Surg Res 2010;96:21–7.
[11] Goffin J, Pankaj P, Simpson A. The importance of lag screw position for the stabilization of trochanteric fractures with a sliding hip screw: a subject-specific finite element study. J Orthop Res 2013;31:596–600.
[12] Cleveland M, Bosworth D, Thompson F, Wilson H, Ishizuka T. A ten-year analysis of intertrochanteric fractures of the femur. J Bone Joint Surg Am 1959;41-A:1399–408.
[13] Baumgaertner M, Curtin S, Lindskog D, Keggi J. The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. J Bone Joint Surg Am 1995;77:1058–64.
[14] Parker M. Cutting-out of the dynamic hip screw related to its position. J Bone Joint Surg Br 1992;74:625.
[15] Jenkins P, Ramaesh R, Pankaj P, Patton J, Howie C, Goffin J, et al. A micro-architectural evaluation of osteoporotic human femoral heads to guide implant placement in proximal femoral fractures. Acta Orthop 2013;84:453–9.
[16] Jiamton C, Boernert K, Babst R, Beeres F, Link B. The nail-shaft-axis of the of proximal femoral nail antirotation (PFNA) is an important prognostic factor in the operative treatment of intertrochanteric fractures. Arch Orthop Trauma Surg 2018;138:339–49.
[17] Li S, Chang S, Jin Y, Zhang Y, Niu W, Du S, et al. A mathematical simulation of the tip-apex distance and the calcar-referenced tip-apex distance for intertrochanteric fractures reduced with lag screws. Injury 2016;47:1302–8.
[18] Murena L, Moretti A, Meo F, Saggioro E, Barbati G, Ratti C, et al. Predictors of cut-out after cephalomedullary nail fixation of pertrochanteric fractures: a retrospective study of 813 patients. Arch Orthop Trauma Surg 2018;138:351–9.
[19] Kuzyk P, Zdero R, Shah S, Olsen M, Waddell J, Schemitsch E. Femoral head lag screw position for cephalomedullary nails: a biomechanical analysis. J Orthop Trauma 2012;26:414–21.
[20] Tsukada S, Okumura G, Matsueda M. Postoperative stability on lateral radiographs in the surgical treatment of pertrochanteric hip fractures. Arch Orthop Trauma Surg 2012;132:839–46.
[21] Sakagoshi D, Sawaguchi T, Shima Y, Inoue D, Oshima T, Goldhahn S. A refined definition improves the measurement reliability of the tip-apex distance. J Orthop Sci 2016;21:475–80.
[22] J M, E D. The normal hip joint space: variations in width, shape, and architecture on 223 pelvic radiographs.%A Lequesne M. Ann Rheum Dis 2004;63:1145–51.
[23] Singh M, Nagrath AR, Maini PS. Changes in trabecular pattern of the upper end of the femur as an index of osteoporosis. J Bone Joint Surg Am 1970;52:457–67.
[24] W E, S O, A J. To what degree is digital imaging reliable? Validation of femoral neck shaft angle measurement in the era of picture archiving and communication systems. Br J Radiol 2011;84:375–9.
[25] Ippolito E, Farsetti P, Boyce A, Corsi A, De Maio F, Collins M. Radiographic classification of coronal plane femoral deformities in polyostotic fibrous dysplasia. Clin Orthop Relat Res 2014;472:1558–67.
[26] Lee S, Niikura T, Iwakura T, Sakai Y, Kuroda R, Kurosaka M. Complete traumatic backout of the blade of proximal femoral nail antirotation: a case report. Orthop Traumatol Surg Res 2014;100:441–3.
[27] Liu W, Wang J, Weaver M, Vrahas M, Zhou D. Lateral migration with telescoping of a trochanteric fixation nail in the treatment of an intertrochanteric hip fracture. Chin Med J 2014;127:680–4.
[28] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[29] Garden RS. The structure and function of proximal end of the femur. J Bone Joint Surg 1961;43:.