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Comparison of Baumgaertner and Chang reduction quality criteria for the assessment of trochanteric fractures

W. Mao,
H. Ni,
L. Li,
Y. He,
X. Chen,
H. Tang,
Y. Dong

Department of Orthopaedics, The Fifth People's Hospital of Shanghai, Fudan University, Shanghai, China

Objectives

Different criteria for assessing the reduction quality of trochanteric fractures have been reported. The Baumgaertner reduction quality criteria (BRQC) are relatively common and the Chang reduction quality criteria (CRQC) are relatively new. The objectives of the current study were to compare the reliability of the BRQC and CRQC in predicting mechanical complications and to investigate the clinical implications of the CRQC.

Methods

A total of 168 patients were assessed in a retrospective observational study. Clinical information including age, sex, fracture side, American Society of Anesthesiologists (ASA) classification, tip-apex distance (TAD), fracture classification, reduction quality, blade position, BRQC, CRQC, bone quality, and the occurrence of mechanical complications were used in the statistical analysis.

Results

A total of 127 patients were included in the full analysis, and mechanical complications were observed in 26 patients. The TAD, blade position, BRQC and CRQC were significantly associated with mechanical complications in the univariate analysis. Only the TAD ($p = 0.025$) and the CRQC ($p < 0.001$) showed significant results in the multivariate analysis. In the comparison of the receiver operating characteristic curves, the CRQC also performed better than the BRQC.

Conclusion

The CRQC are reliable in predicting mechanical complications and are more reliable than the BRQC. Future studies could use the CRQC to assess fracture reduction quality. Intraoperatively, the surgeon should refer to the CRQC to achieve good reduction in trochanteric fractures.

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Keywords: Trochanteric fractures, Baumgaertner reduction quality criteria, Chang reduction quality criteria, Mechanical complications

Article focus

- To compare the reliability of the Baumgaertner reduction quality criteria (BRQC) and Chang reduction quality criteria (CRQC) in predicting mechanical complications.
- To investigate the clinical implications of the CRQC.

Key messages

- The CRQC are reliable in predicting mechanical complications and are more reliable than the BRQC.
- Future studies could use the CRQC to assess fracture reduction quality.
- Intraoperatively, the surgeon should refer to the CRQC to achieve a good reduction in trochanteric fractures.

Strengths and limitations

- Unlike previous studies, the current study adopted a direct comparison of the relatively common BRQC and the relatively new CRQC.
- Limitations include the retrospective design, single-centre design, and limited sample size.

Correspondence should be sent to Y. Dong; email: youhaidong1964@163.com

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Introduction

Hip fracture is a major public health problem that causes 4.5 million people each year to live with disability, and trochanteric fractures account for approximately half of hip fractures.[1,2] Most trochanteric fractures require surgery to prevent bed-related complications and mortality, and poor stability after fracture fixation causes mechanical complications such as cut-out, varus displacement, and excessive lateral migration of the screw or blade.[3-5] These complications can lead to limb shortening, hip pain, functional impairment, and even reoperation.[4,6,7]

Reduction quality is one of the factors determining stability after fracture fixation,[2,8,9] and different criteria for assessing the reduction quality of trochanteric fractures have been reported in the literature.[4,10-12] The criteria developed by Baumgaertner et al[13,14] are widely used (Table I).[4,15] However, reliability has not been established for the Baumgaertner reduction quality criteria (BRQC). Many studies have employed the BRQC, but few have specifically validated it.[4,12,16-18] Subsequent studies have made some minor changes to the BRQC but did not provide reasons for these changes.[5,10,11,19] In 2015, on the basis of the Gotfried reduction technique for subcapital femoral fractures,[20] the Chang reduction quality criteria (CRQC)[21] proposed the concepts of positive medial cortical support (PMCS; Fig. 1) and negative medial cortical support (NMCS; Fig. 2) for fracture reduction of trochanteric fractures (Table II).[4,15]

The BRQC emphasizes anatomical reduction while the CRQC uses a nonanatomical reduction technique, illustrating the significant differences between these approaches. The BRQC and CRQC have different requirements for displacement, so their relative reliability is worth exploring. However, previous studies have not performed an in-depth or direct comparison of these techniques.[21,22]

In the current study, we analyzed the relationship between mechanical complications and the BRQC, CRQC, and other clinical variables, and then directly compared the reliability of the BRQC and CRQC in predicting mechanical complications. Finally, the clinical implications of the CRQC were investigated.

Table I. Baumgaertner reduction quality criteria

Criteria
I. Alignment
a. Anteroposterior view: normal or slight valgus neck-shaft angle*
b. Lateral view: less than 20° of angulation
II. Displacement
a. Anteroposterior view: less than 4 mm of displacement of any fragments
b. Lateral view: less than 4 mm of displacement of any fragments
Reduction quality
Good: both criteria met
Acceptable: only one criterion met
Poor: neither criterion met

*Slight valgus means a valgus of no more than 10°[4,15]

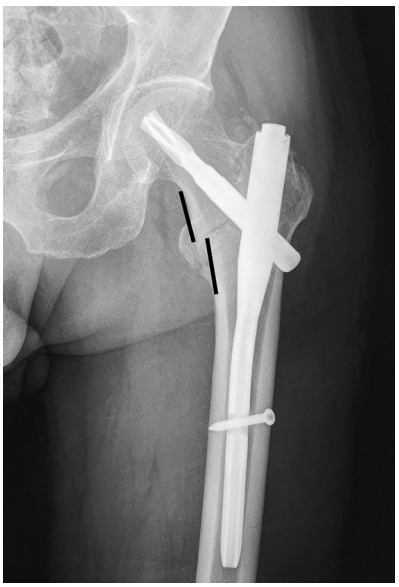

Fig. 1

Radiograph showing positive medial cortex support, which is defined as a situation where the lower edge of the medial cortex of the femoral head–neck fragment is located medially to the upper edge of the medial cortex of the femoral shaft, with the displacement less than one cortex thickness.

Patients and Methods

Study participants. This retrospective observational study was approved by the ethics committee of The Fifth People's Hospital of Shanghai, Fudan University, Shanghai, China (2018EC153). We enrolled 168 trochanteric fracture patients treated using proximal femoral nail antirotation (PFNA; Kanghui Medical, Changzhou, China) between May 2014 and May 2018. The following patients were excluded: 19 patients without standard postoperative radiographs and 22 patients without a postoperative follow-up of at least three months. A total of 127 patients were analyzed in the study. The main part of these data has been utilized in a previous study proposing the concept of the axis-blade angle.[23]

Variables and measurements. A standard anteroposterior (AP) radiograph required the patient to be in the supine position and the leg to be medially rotated 15° to 20°. A standard lateral radiograph required the x-ray beam to be perpendicular to the femoral neck axis.[24,25]

Age at time of surgery, sex, fracture side, and American Society of Anesthesiologists (ASA) classification were gathered from the hospital database. The tip-apex distance (TAD), fracture classification according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) system, the blade position according to the Cleveland zone,[26] BRQC, CRQC, and bone quality at the fracture were determined using preoperative or postoperative AP and lateral radiographs in a Picture Archiving and Communication System (PACS; Neusoft, Shenyang, China).

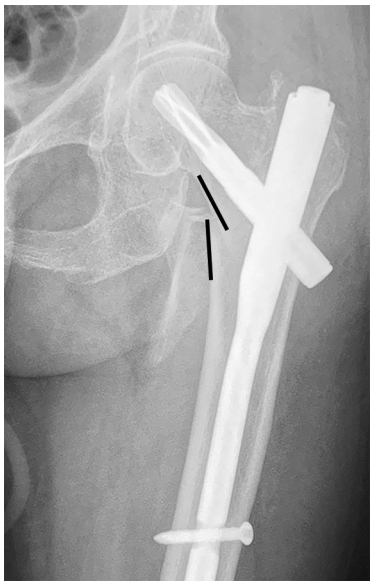

Fig. 2

Radiograph showing negative medial cortical support, which is defined as a situation where the lower edge of the medial cortex of the femoral head–neck fragment is located laterally to the upper edge of the medial cortex of the femoral shaft, regardless of the distance of displacement.

Table II. Chang reduction quality criteria

Item	Score
I. Alignment	
a. Anteroposterior view: normal or slight valgus neck-shaft angle*	1
b. Lateral view: less than 20° of angulation	1
II. Displacement	
a. Anteroposterior view: neutral or positive medial cortical support†	1
b. Lateral view: smooth anterior cortical contact‡	1
Reduction quality	
Excellent	4
Acceptable	2 or 3
Poor	0 or 1

*Slight valgus means a valgus of no more than 10°[4,15]
†Neutral medial cortical support is shown in Supplementary Figure a
‡The displacement is less than half of the cortex thickness

Table III. Types and numbers of mechanical complications; 29 mechanical complications occurred in 26 patients

Mechanical complication	n
Implant failure*	2
Varus displacement	19
Excessive lateral migration of the blade	8

*Including one cut-out and one loss of fixation, both with nonunion

The TAD was measured as the sum of the distance, in millimetres, from the blade tip to the femoral head apex in AP and lateral views.[13] The AO/OTA classification was used without subgroups. Bone quality was determined using the Singh Osteoporosis Index (SOI) of the contralateral knee.

Assessment of the TAD, AO/OTA classification, blade position, BRQC, CRQC, and the SOI were performed by two observers (WM and HT) who were blinded to the outcomes. The mean TAD was used, and disagreements concerning categorical data were solved by the assistance of the third author (YD). The observers were systematically trained on the measurements of the TAD, AO/OTA classification system, blade position, BRQC, CRQC, and the SOI.

Outcomes. An assessment of mechanical complications was performed by two observers (YH and XC), and discrepancies were solved via consensus. Mechanical complications include implant failure (Supplementary Fig. b) such as cut-out, loss of fixation, and varus displacement (Supplementary Fig. c), which was defined as a change of more than 10° in the postoperative neck-shaft angle,[4,27,28] and excessive lateral migration of the blade (Supplementary Fig. d), which was defined as a lateral blade sliding distance of more than 10 mm postoperatively.[3,29,30]

Statistical analysis. With the occurrence of mechanical complications as the dependent variable, Student's *t*-test and the chi-squared test were used for univariate analyses of continuous and categorical variables, respectively. We applied a univariate logistic regression for crude odds ratios (ORs) with 95% confidence intervals (CIs). The significant independent variables from the univariate analysis were entered in the multivariate analysis with the likelihood-ratio test. We conducted the Hosmer–Lemeshow goodness-of-fit test to evaluate if the logistic regression model fits the data. The comparison of receiver operating characteristic (ROC) curves was performed by z-test to assess the discrimination ability of relevant independent variables.

We calculated the intraclass correlation coefficient (ICC) to evaluate interobserver reliability for continuous variables, using a two-way random effects model with 95% CI. We used κ coefficients with 95% CI to assess interobserver reliability for categorical data.

All analyses were performed using SPSS version 22 (IBM, Armonk, New York) and MedCalc version 15.2.2 (MedCalc Software, Mariakerke, Belgium). Statistical significance was set at $p < 0.05$, and all tests were two-sided.

Results

A total of 127 patients with trochanteric fractures were included in the full analysis. Mechanical complications were observed in 26 patients (Table III). Demographics of included and excluded patients are shown in Supplementary Table i. The results of a reliability analysis are shown in Table IV, in accordance with the rating devised by Landis and Koch.[31]

Univariate analysis. The results of a univariate analysis are shown in Table V. There were no significant differences in age, sex, fracture side, ASA classification, AO/OTA classification, or SOI. As for the 26 patients who had mechanical complications, the mean TAD was 22.9 mm, compared

Table IV. Reliability between the two observers for different variables

Variable	ICC or κ	95% CI	Reliability
Tip-apex distance, mean measures ICC	0.888	0.841 to 0.921	Almost perfect
AO/OTA classification, κ	0.635	0.491 to 0.749	Excellent
Blade position, κ	0.420	0.295 to 0.544	Moderate
Baumgaertner reduction quality criteria, κ	0.589	0.458 to 0.705	Moderate
Chang reduction quality criteria, κ	0.731	0.615 to 0.833	Excellent
Singh Osteoporosis Index, κ	0.339	0.213 to 0.457	Poor

ICC, intraclass correlation coefficient; κ, kappa coefficient; CI, confidence interval; AO/OTA, AO Foundation and Orthopaedic Trauma Association

Table V. Univariate analysis of patient demographics and clinical characteristics

Characteristic	Without mechanical complications (n = 101)	With mechanical complications (n = 26)	Crude OR (95% CI)	p-value
Mean age, yrs (range)	69.7 (27 to 94)	74.0 (54 to 91)	1.03 (0.99 to 1.06)	0.068*
Male, n (%)	43 (*42.6*)	11 (*42.3*)	0.99 (0.41 to 2.37)	1.000†
Left side, n (%)	55 (*54.5*)	13 (*50.0*)	0.84 (0.35 to 1.98)	0.826†
Mean TAD, mm (range)	22.9 (7.2 to 47.9)	26.7 (16.0 to 48.2)	1.07 (1.01 to 1.13)	0.020*‡
ASA classification, n (%)				0.309†
I	25 (*24.8*)	2 (*8.0*)	N/A	
II	47 (*46.5*)	17 (*64.0*)	N/A	
III	27 (*26.7*)	6 (*24.0*)	N/A	
IV	2 (*2.0*)	1 (*4.0*)	N/A	
AO/OTA classification, n (%)				0.094†
A1	51 (*50.5*)	11 (*42.3*)	N/A	
A2	44 (*43.6*)	9 (*34.6*)	N/A	
A3	6 (*5.9*)	6 (*23.1*)	N/A	
Blade position	§	§	N/A	< 0.001†‡
BRQC	§	§	N/A	< 0.001†‡
CRQC	§	§	N/A	< 0.001†‡
SOI, n (%)				0.167†
I	2 (*2.0*)	0 (*0.0*)	N/A	
II	2 (*2.0*)	1 (*3.8*)	N/A	
III	14 (*13.9*)	8 (*30.8*)	N/A	
IV	52 (*51.5*)	11 (*42.3*)	N/A	
V	22 (*21.8*)	6 (*23.1*)	N/A	
VI	9 (*8.9*)	0 (*0.0*)	N/A	

*Student's *t*-test
†Chi-squared test
‡Statistically significant
§The distribution of values is indicated in Figure 3 and Figure 4
OR, odds ratio; CI, confidence interval; TAD, tip-apex distance; ASA, American Society of Anesthesiologists; N/A, not applicable; AO/OTA, AO Foundation and Orthopaedic Trauma Association; BRQC, Baumgaertner reduction quality criteria; CRQC, Chang reduction quality criteria; SOI, Singh Osteoporosis Index

with 26.7 mm for the 101 patients who had uneventful union, and the difference between the two groups was significant (p = 0.020). The blade position also showed significant differences in terms of treatment outcome (p < 0.001). No blade was placed in the superior-anterior position, and the superior-central position had the highest rate (85.7%) of poor outcomes (Fig. 3).

The BRQC (p < 0.001) and CRQC (p < 0.001) were both significantly associated with the occurrence of mechanical complications. As shown in Figure 4, the CRQC-Excellent group had a lower rate of mechanical complications (3.8%) than the BRQC-Good group (8.6%). The CRQC-Poor group had a higher rate (92.3%) than the BRQC-Poor group (88.9%).

Multivariate analysis. We adjusted each association for possible confounding factors by applying a multivariate logistic regression analysis (Table VI). The blade position and the BRQC were no longer significantly associated. The TAD (adjusted OR 1.088, 95% CI 1.007 to 1.175; p = 0.025) and the CRQC (p < 0.001) were independently associated with mechanical complications. Compared with the CRQC-Poor category, the OR for CRQC-Excellent was 0.003 (95% CI 0.000 to 0.030; p < 0.001), and the OR for CRQC-Acceptable was 0.026 (95% CI 0.003 to 0.243; p = 0.001). The p-value of the Hosmer–Lemeshow test was 0.190, indicating that the multivariate model fit the data very well.

Comparison of ROC curves. On the basis of the ROC curves in Figure 5, the BRQC (area under the curve (AUC) 0.74, 95% CI 0.65 to 0.81) and CRQC (AUC 0.87, 95% CI 0.80 to 0.92) were both reliable predictors of mechanical complications. The difference between the AUC values indicated a significantly better performance for the CRQC than for the BRQC (p = 0.012).

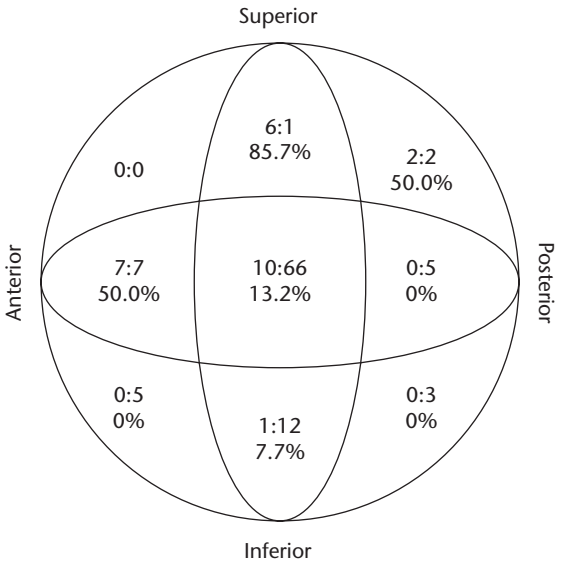

Fig. 3

The blade position according to the Cleveland zone. The first number represents the group with mechanical complications and the second number represents the group without mechanical complications. Percentages demonstrate the proportion of mechanical complications associated with each Cleveland zone.

Discussion

Reduction quality is critical to the stability of fracture fixation. Many studies have included reduction quality, but only as a confounding variable rather than as the main object of the study.[4,12,16-18] The current study focused on the relatively common BRQC and the relatively new CRQC. We validated their clinical applicability and identified that the CRQC had greater reliability than the BRQC in predicting mechanical complications.

The BRQC and CRQC both showed significant results in the univariate analysis. While the BRQC and CRQC are the same type of variable and have noticeable collinearity, of the two the multivariate model can only include the CRQC, which contributes more to the relevant p-value. The model indicated that the CRQC-Excellent and CRQC-Acceptable groups were associated, respectively, with a 0.003-fold and a 0.026-fold lower risk of mechanical complications, compared with the CRQC-Poor group. In a comparison of the ROC curves, the CRQC also demonstrated better performance.

Unlike previous studies using PMCS as the object of analysis,[21,22] we directly compared the BRQC and CRQC because the value of the new criteria needs to be contextualized through comparison with the old criteria. In addition, reduction quality depends not only on PMCS but on many factors, so we used two complete sets of criteria as the object of analysis.

The biggest difference between the BRQC and CRQC lies in the concept of PMCS. To some extent, the study explored whether a good AP view reduction means a displacement of less than 4 mm or a neutral or PMCS. This difference cannot be ignored, because PMCS and NMCS can both occur under the premise of a displacement of less than 4 mm. A displacement of less or more than 4

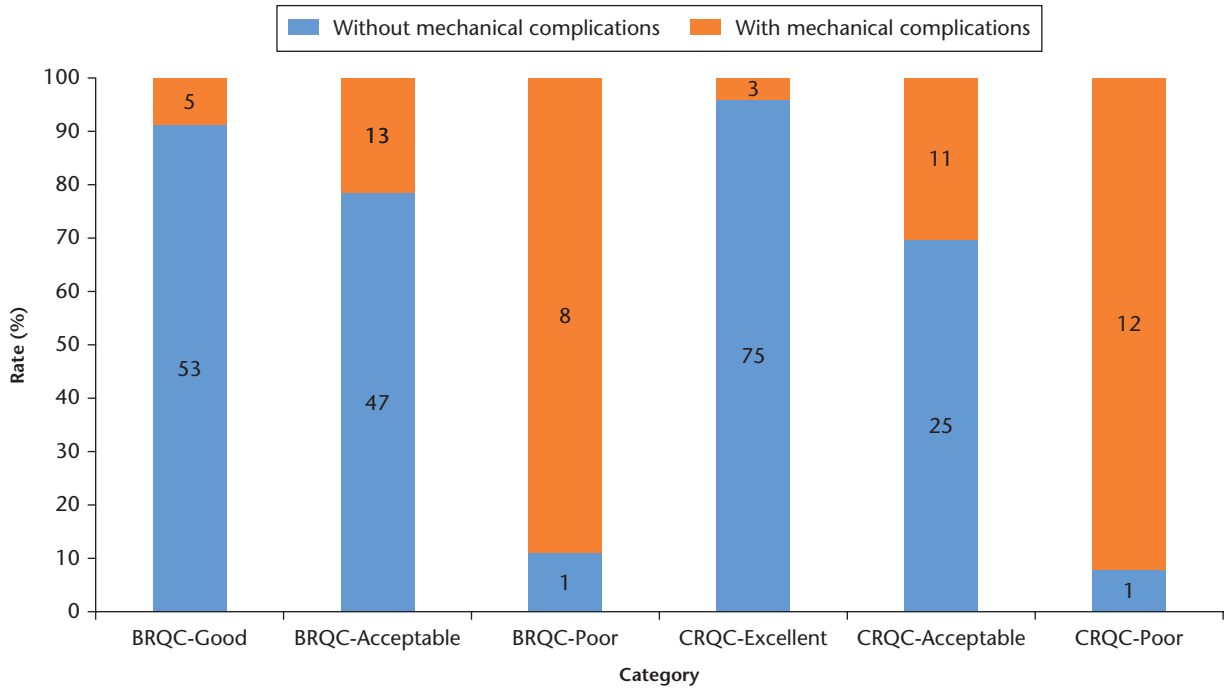

Fig. 4

Distribution of outcomes according to Baumgaertner reduction quality criteria (BRQC) and Chang reduction quality criteria (CRQC). The rates of mechanical complications were 8.6% (BRQC-Good), 21.7% (BRQC-Acceptable), 88.9% (BRQC-Poor), 3.8% (CRQC-Excellent), 30.6% (CRQC-Acceptable), and 92.3% (CRQC-Poor).

Table VI. The results of multivariate logistic regression analysis

Characteristic	Adjusted OR (95% CI)	p-value
Tip-apex distance, mm	1.088 (1.007 to 1.175)	0.025*
Blade position	N/A	0.201
Baumgaertner reduction quality criteria	N/A	0.505
Chang reduction quality criteria†		< 0.001*
Excellent	0.003 (0.000 to 0.030)	< 0.001*
Acceptable	0.026 (0.003 to 0.243)	0.001*

*Statistically significant
†The poor reduction was the reference category
OR, odds ratio; CI, confidence interval; N/A, not applicable

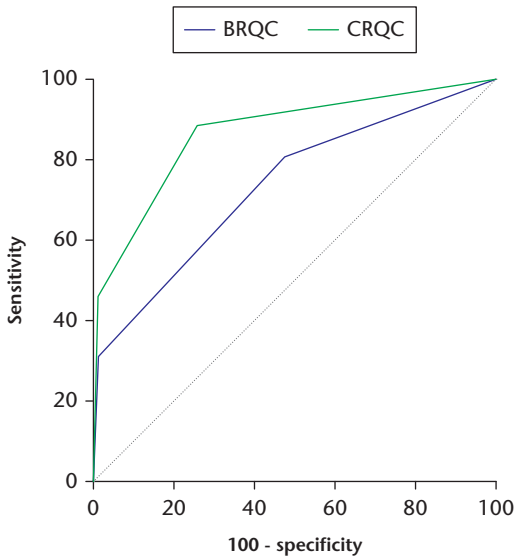

Fig. 5

The receiver operating characteristic (ROC) curves comparing performance of Baumgaertner reduction quality criteria (BRQC) and Chang reduction quality criteria (CRQC) in predicting mechanical complications. The area under the curve (AUC) of the BRQC was 0.74 (95% confidence interval (CI) 0.65 to 0.81). The AUC of the CRQC was 0.87 (95% CI 0.80 to 0.92). The difference between the AUCs was significant (p = 0.012; z-test).

mm can occur under the premise of PMCS whose upper limit of displacement is one cortex thickness.

The difference between the BRQC and CRQC in the lateral view is relatively small. In the CRQC, smooth anterior cortical contact means that displacement is less than half of the cortex thickness, which is more stringent than the requirement for the BRQC. This is because anterior cortical contact also provides a rigid buttress.[32,33] At present, most implants are not suitable for fixation of lesser trochanteric fragments, so the CRQC do not include an explicit requirement for posterior cortex alignment.[21]

There are three main reasons why the CRQC demonstrate higher reliability than the BRQC. First, use of the BRQC could result in the loss of some details. For example, in the BRQC, failing to meet alignment criteria includes three possible situations: poor alignment only in AP views; poor alignment only in lateral views; and poor alignment in AP and lateral views, whereas the BRQC do not differentiate between these situations. By contrast, the CRQC use a more refined four-point system, which retains more details. Secondly, the concept of PMCS employed in the CRQC is reasonable. PMCS achieves cortical support between the two main fragments and resists the further lateral sliding of the femoral head–neck fragment.[21] Thirdly, using one or one-half cortex thickness to describe displacement is better than using the actual distance of 4 mm because femoral cortex thickness varies among people of different sex, race, and height.[34,35]

The results of the current comparison provide guidance for the intraoperative reduction of trochanteric fractures. In the process of reaming, nail insertion, and blade insertion, the original fracture reduction may undergo some changes, resulting in a nonanatomical reduction, but as long as these changes are in accordance with the CRQC, the surgeon usually does not need to make more adjustments. In the current study, reduction quality was assessed via immediate postoperative radiographs, whereas intraoperatively the surgeon can assess reduction quality with the help of a C-arm x-ray machine. Moreover, future studies that incorporate reduction quality as a confounding factor could use CRQC to assess it.

This study has several limitations including its retrospective design, single-centre design, and limited sample size. We used multivariate logistic regression analysis to eliminate partially the confounding bias. Because of the limitations in the sample size, the current study only included a PFNA device. Therefore, multicentre and large-scale studies are needed to investigate further the impact of using the CRQC intraoperatively for the prognosis of trochanteric fracture surgery.

In conclusion, the CRQC are reliable in predicting mechanical complications and are more reliable than the BRQC. Future studies could use the CRQC to assess fracture reduction quality. Intraoperatively, the surgeon should refer to the CRQC to achieve good reduction in trochanteric fractures.

Supplementary Material

Radiographs of negative medial cortical support for fracture reduction of trochanteric fractures and mechanical complications including implant failure, varus displacement, and excessive lateral migration of the blade. Table showing demographics of included and excluded patients.

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Authors information
- W. Mao, MD, Resident Doctor,
- H. Ni, MD, Resident Doctor,
- L. Li, MD, Resident Doctor,
- Y. He, MD, Attending Doctor,
- X. Chen, MD, Attending Doctor,
- H. Tang, MD, Resident Doctor,
- Y. Dong, MD, Chief Surgeon, Department of Orthopaedics, The Fifth People's Hospital of Shanghai, Fudan University, Shanghai, China.

Authors contributions
- W. Mao: Collected and analyzed the data, Wrote the manuscript.
- H. Ni: Designed the study, Revised the manuscript.
- L. Li: Revised the manuscript, Interpreted the data.
- Y. He: Collected the data, Revised the manuscript.
- X. Chen: Collected the data, Supervised the study.
- H. Tang: Collected and analyzed the data.
- Y. Dong: Interpreted the data, Supervised the study.
- W. Mao and H. Ni contributed equally to this work.

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