Evaluation of the Intraobserver and Interobserver Agreements of the New AO/OTA Classification for Fractures of the Trochanteric Region and the Femoral Neck*

Avaliação das concordâncias intra e inter-observadores da nova classificação AO/OTA para fraturas da região trocantérica e do colo do fêmur

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Abstract

Objective In the present study, we investigated the intra and interobserver agreement of the new Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification for fractures of the proximal extremity of the femur.

Methods One hundred hip radiographs were selected from patients who suffered fractures of the trochanteric region or femoral neck. Four orthopedists, fellowship trained hip surgeons, and four orthopedic residents evaluated and classified fractures according to the new AO/OTA system on two separate occasions. The *kappa* (k) coefficient was used to evaluate intra and interobserver agreement in the different steps of the classification, namely: *type*, *group*, *subgroup*, and *qualifier.*

Results Hip surgery experts obtained almost perfect intraobserver agreement of *type*, substantial for *group* and, only moderate, for *subgroup* and *qualifiers.* The residents had lower performance, with substantial agreement for *type,* moderate for *group*, and reasonable for *subgroup* and *qualifier.* In the specialists' interobserver evaluation, there was also a gradual decrease in the agreement between type (almost perfect) and group (moderate), which was even lower for *subgroup* and *qualifiers.*

Keywords
- femur neck
- hip fractures
- classification

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Residents had a substantial interobserver agreement for *type*, moderate for *group*, and reasonable in the other branches.

Conclusion The new AO/OTA classification for fractures of the trochanteric region and femoral neck showed intra and interobserver agreements considered appropriate for *type* and *group*, with a drop in the subsequent branches, that is, for *subgroup* and *qualifier.* Still, in relation to the old AO/OTA classification, there was an improvement in the agreements for *subgroup.*

Resumo

Objetivo Neste estudo, investigamos a concordância intra e inter-observador da nova classificação *Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association* (AO/OTA) para fraturas da extremidade proximal do fêmur.

Métodos Foram selecionadas 100 radiografias do quadril de pacientes que sofreram fraturas da região trocantérica ou do colo do fêmur. Quatro ortopedistas cirurgiões de quadril e quatro residentes de ortopedia e traumatologia avaliaram e classificaram as fraturas segundo o novo sistema AO/OTA em duas ocasiões distintas. O coeficiente de *kappa* (k) foi utilizado para avaliar a concordância intra e inter-observadores nos diferentes passos da classificação, a saber: *tipo, grupo, subgrupo e qualificador.*

Resultados Especialistas em cirurgia do quadril obtiveram concordância intra-observador quase perfeita de *tipo*, substancial para *grupo* e, apenas moderada para *subgrupo* e *qualificadores*. Os residentes tiveram desempenho inferior, com concordância substancial para o *tipo*, moderada para o *grupo*, e razoável para o *subgrupo* e *qualificador*. Na avaliação inter-observadores dos especialistas, também se observou queda gradual da concordância entre *tipo* (quase perfeita) e *grupo* (moderada), que se mostrou ainda menor para *subgrupo* e *qualificadores*. Residentes tiveram uma concordância inter-observadores substancial para *tipo*, moderada para *grupo* e razoável nas demais ramificações.

Conclusão A Nova Classificação AO/OTA Para Fraturas Da Região Trocantérica E Do Colo Do Fêmur Mostrou Concordâncias Intra E Inter-Observadores Consideradas Adequadas Para Tipo E Grupo com queda nas ramificações subsequentes ou seja para subgrupo e qualificador. Ainda assim em relação à classificação AO/OTA antiga houve melhora nas concordâncias para subgrupo.

Palavras-chave
- colo do fêmur
- fraturas do quadril
- classificação

Introduction

Fractures of the proximal extremity of the femur cause great morbidity and mortality in the short and medium term in the elderly,[1–3] with one third of patients progressing to death within 1 year, and half becoming dependent for locomotion.[4,5] These fractures can also affect young patients victimized by high-energy trauma.[4] The treatment of these lesions requires the interaction of a multidisciplinary team.[6] These lesions recquire eminently surgical treatment and, to define the best treatment, among other data, it is necessary to classify the fracture.

An ideal classification system should allow communication between physicians, standardize terminology for research, and guide treatment decision.[6] Many attempts to create a classification system for fractures of the proximal femur have been described, with the classifications of Garden,[7] Evans,[8] Boyd and Griffin,[9] Tronzo[10] and the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA)[11] as the best-known ones. The AO/OTA classification has favorable evidence of reliability in the trochanteric region[12–14] and in the femoral neck,[15] when compared to the other commonly used classifications. However, its additional ramifications tend to decrease interobserver confidence[13,16] and require great practice.[16,17]

The validation of a classification occurs with the demonstration of some criteria: good clinical correlation, adequacy in terms of agreement and accuracy, and also constructive validation (relevance).[18] Concerns with the terminology and complex flow line of the previous AO/OTA classification[19] motivated the modernization of the classification. However, we have not located studies in the literature on the reliability of this new version.

In this sense, the present study aimed to evaluate the degree of intra and interobserver agreement in each sequential subdivision of the new AO/OTA classification for fractures of the proximal extremity of the femur, in observers considered experienced (adult hip surgeons) and inexperienced (orthopedic residents).

Materials and Methods

The present retrospective study included radiographic records of patients who suffered fractures of the proximal extremity of the femur between 2015 and 2019, treated at a reference center in orthopedic trauma. A total of 100 consecutive cases were selected for this evaluation. The sample size was arbitrated based on previous studies[4–6,12,13,18] that used smaller samples to validate classifications (between 40 and 70 cases). The project was previously submitted and approved by the Research Ethics Committee of the Institution (CAAE: 30754120.7.0000.5226).

The inclusion criteria were presence of fracture of the proximal extremity of the femur (bone 3, anatomical region 1), the trochanteric region (group A) or the femoral neck (group B), in skeletically mature individuals. Fractures of the femoral head (which are best evaluated by computed axial tomography) and pathological fractures were not included in this study.

Each participant received the digital radiography images in anteroposterior and lateral views for analysis. There was no patient or treatment information on the images used for classification. Four orthopedists specialized in adult hip surgery and 42nd-year orthopedic residents classified all cases (sequentially and uninterruptedly, without time limitation) at 2 distinct moments, with an interval of 4 weeks. At the beginning of the evaluations, the detailed description of the new classification and its illustrative images were made available to the evaluators for learning the system. Each evaluation was performed individually, and neither the answers were allowed to be kept nor were the results discussed among them.

Interobserver reliability was determined through the first response between the evaluators and the intraobserver through a new evaluation 4 weeks after the initial one. This interval was used to reduce the risk of memory bias. Data were collected and stored in spreadsheets for statistical analysis. The Cohen *kappa* coefficient was used to evaluate the intraobserver agreement, and the Fleiss *kappa* coefficient was calculated to evaluate the inter-observer agreement. The SPSS Statistcs for Windows, Version 20.0 software (IBM Corp., Armonk, NY, USA) and the Online kappa Calculator (www.statisticssolutions.com) were used for the analyses. The agreement assessment included 4 stages: *type* of fracture (A - trochanteric or B - neck), *group* (1, 2, or 3), *subgroups* (1, 2, or 3 - except in *type* B3, which does not have subgroups), and also their *qualifiers* when available in the classification, that is, only in A.1.1 (N or O) or B2 1.2 or 3 (P, Q, or R). ►**Table 1** and ►**Table 2** illustrate the differences between the old and new AO/OTA classifications.

Although the degree of agreement has distinct forms of interpretation,[19] the classic proposal of Landis and Koch was adopted,[20] with values between 0.00 and 0.20 considered as mild agreement; 0.21 and 0.40 reasonable agreement; 0.41 and 0.60 moderate agreement; 0.61 and 0.80 substantial agreement, and 0.81 and 1.00 almost perfect agreement (or excellent).

In the population sample studied, the mean age was 77.71 years (ranging from 57–98 years, standard deviation of 10.12). The female gender was predominant, with 63% of

Table 1 Illustrated comparison between the AO/OTA systems (Group A)

	Old AO/OTA		New AO/OTA	
Group A1	Simple transtrochanteric		Simple transtrochanteric	
A1.1	Simple undisplaced		Isolated fracture of trochanter *Qualifiers: n: greater trochanter o: lesser trochanter	
A1.2	Simple displaced		Two-part fracture	
A1.3	Simple with distal to calcar extension		Fracture with intact lateral wall (> 20.5 mm)	
Group A2	Transtrochanteric cominution		Multifragmentary transtrochanteric, incompetent lateral w all (<20.5 mm)	
A2.1	Comminuta undisplaced			
A2.2	Displaced with cominution		Fracture with 1 intermediate fragment	

(*Continued*)

Table 1 (*Continued*)

	Old AO/OTA		New AO/OTA	
A2.3	Multifragmented (> 3 fragments)		Fracture with 2 or more fragments intermediate	
Group A3	Reverse transtrochanteric		Reverse transtrochanteric	
A3.1	Reverse obliquity		Simple, reverse obliquity	
A3.2	Transverse reverse obliquity		Simple transverse, reverse obliquity	
A3.3	Reverse obliquity with fracture of lesser trochanter		Reverse obliquity with wedge or multifragmentary	

Table 2 Illustrated comparison between the AO/OTA systems (Group B)

	Old AO/OTA		New AO/OTA	
Group B1	Subcapital fracture with minimal displacement		Subcapital fracture	
B1.1	Valgus impaction > 15 degrees		Valgus impaction	
B1.2	Valgus impaction < 15 degrees		Undisplaced	
B1.3	Not impacted		Displaced	
Group B2	Transcervical fracture		Transcervical fracture	
B2.1	Basicervical		Simple Qualifiers: $p < 30°$ q = 30–70° r > 70°	
B2.2	Adducted mid-cervical		Multifragmented Qualifiers: $p < 30°$ q = 30–70° r > 70°	
B2.3	Shear mid-cervical		With shear Qualifiers: $p < 30°$ q = 30–70° r >70°	
Group B3	Subcapital displaced fracture, not impacted		Basicervical fracture	
B3.1	Moderate varus displacement and lateral rotation			
B3.2	Moderate vertical displacement and lateral rotation			
B3.3	Significant displacement			

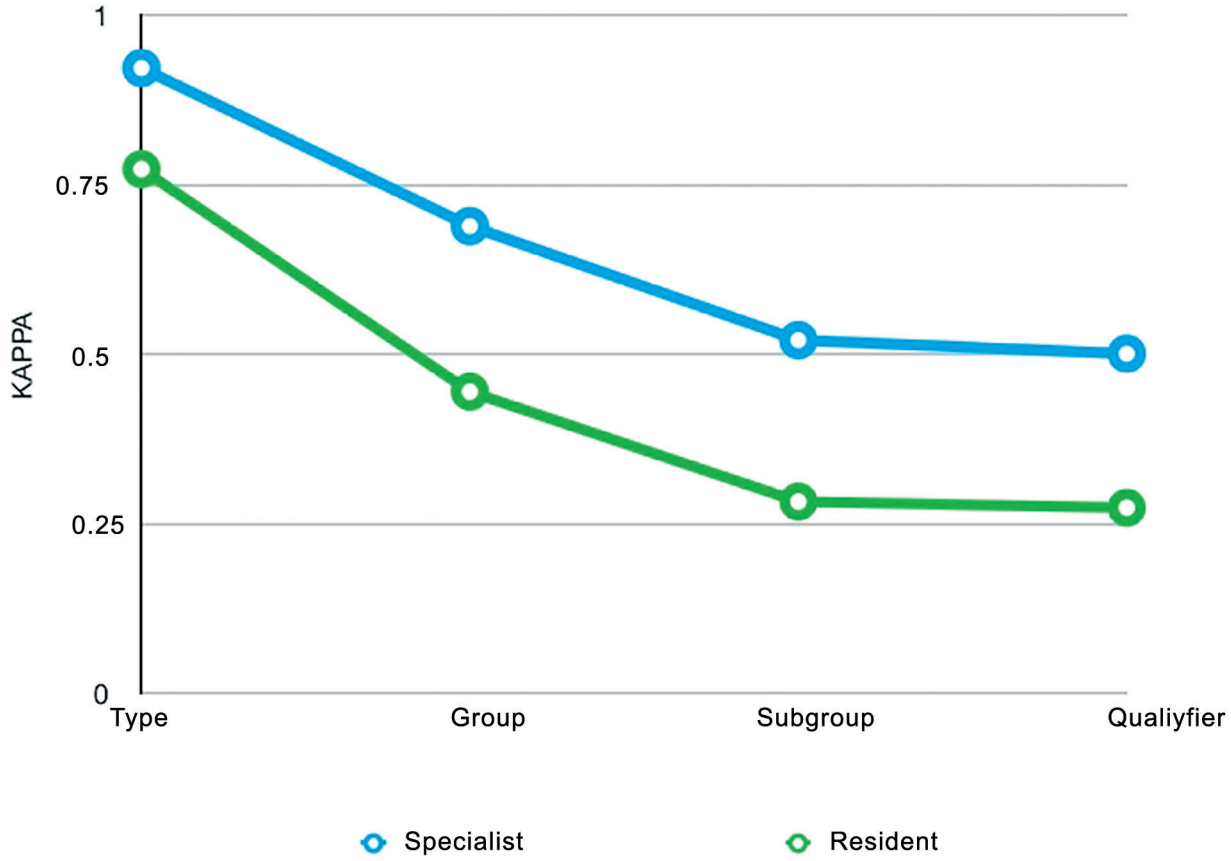

Fig. 1 Comparison between specialists and residents of the mean *kappa* coefficient (intraobserver).

the cases, and the right side had one more case of fracture (51%).

Results

Intraobserver agreement

In the repeated evaluation with an interval of 4 weeks, the intraobserver agreement of *type* was almost perfect for specialists, with a mean *k* of 0.92, while that of residents was substantial (mean *k* 0.77). In the *group* classification, the specialists presented a substantial agreement (mean *k* 0.68), and residents a moderate agreement (mean *k* 0.44). For *subgroup*, the agreement of the specialists was moderate (mean *k* 0.52), and for the residents it was reasonable (mean *k* 0.28). Finally, in relation to *qualifiers*, the agreement of the specialists was also moderate (mean *k* 0.50), and that of the residents was reasonable (mean *k* 0.27).

In general, specialists perform better than residents. It is also observed (►**Figure 1**) that the coefficients are decreasing as the branches of the classification are followed. ►**Table 3** describes in detail the intraobserver findings.

Inter-observer agreement

Considering the first round as standard (used in most studies) for interobserver evaluation, we have an agreement in the *type* of 93.67% for *specialists (k* 0.87, almost perfect) and 90.17% for residents (*k* 0.80, substantial). In the *group*, the agreement was 60.83% for the specialists (k 0.53, moderate) and 55.5%for the residents (*k* 0.47, moderate). Advancing to *subgroup*, agreement dropped to 44.5% among specialists (k 0.41, moderate) and 42.7% for residents (*k* 0.39, reasonable). Finally, in the *qualifiers* the agreement was 42.67% for the *specialists (k* 0.40, reasonable) and 41.0% for the residents (k 0.39, reasonable).

►**Table 4** details the interobserver results. Both specialists and residents decreased the coefficients as the classification

Table 3 Intraobserver agreement kappa coefficient

	kappa (Cohen)			
Expert	Type	Group	Subgroup	Qualifier
1	0.972	0.705	0.607	0.607
2	0.972	0.589	0.376	0.338
3	0.894	0.747	0.599	0.600
4	0.851	0.713	0.500	0.459
Resident				
1	0.828	0.468	0.298	0.300
2	0.851	0.443	0.259	0.260
3	0.806	0.640	0.421	0.391
4	0.608	0.230	0.153	0.144

Table 4 Interobserver agreement kappa coefficient

	Rating 1		Rating 2	
Type	% agreement	Kappa	% agreement	Kappa
Experts	93.67	0.87	97.00	0.94
Residents	90.17	0.80	94.50	0.89
Group				
Experts	60.83	0.53	58.83	0.51
Residents	55.50	0.47	69.50	0.63
Subgroup				
Experts	44.50	0.41	39.67	0.35
Residents	42.67	0.39	57.67	0.55
Qualifier				
Experts	42.67	0.40	37.33	0.35
Residents	41.00	0.39	57.17	0.55

branches out. However, in the *subgroup-qualifier* transition, the decrease in agreement was not significant. In the first round, residents reached coefficients always below the coefficients of the specialists (►**Figure 2**), but in the second round, residents presented a greater agreement with each other than the specialists (►**Figure 3**).

Discussion

In the previous AO/OTA classification, some fracture patterns occurred so rarely that there was no need for an exclusive coding for them. The terminology was the focus of confusion, due to the wide variety of terms for similar fractures. There

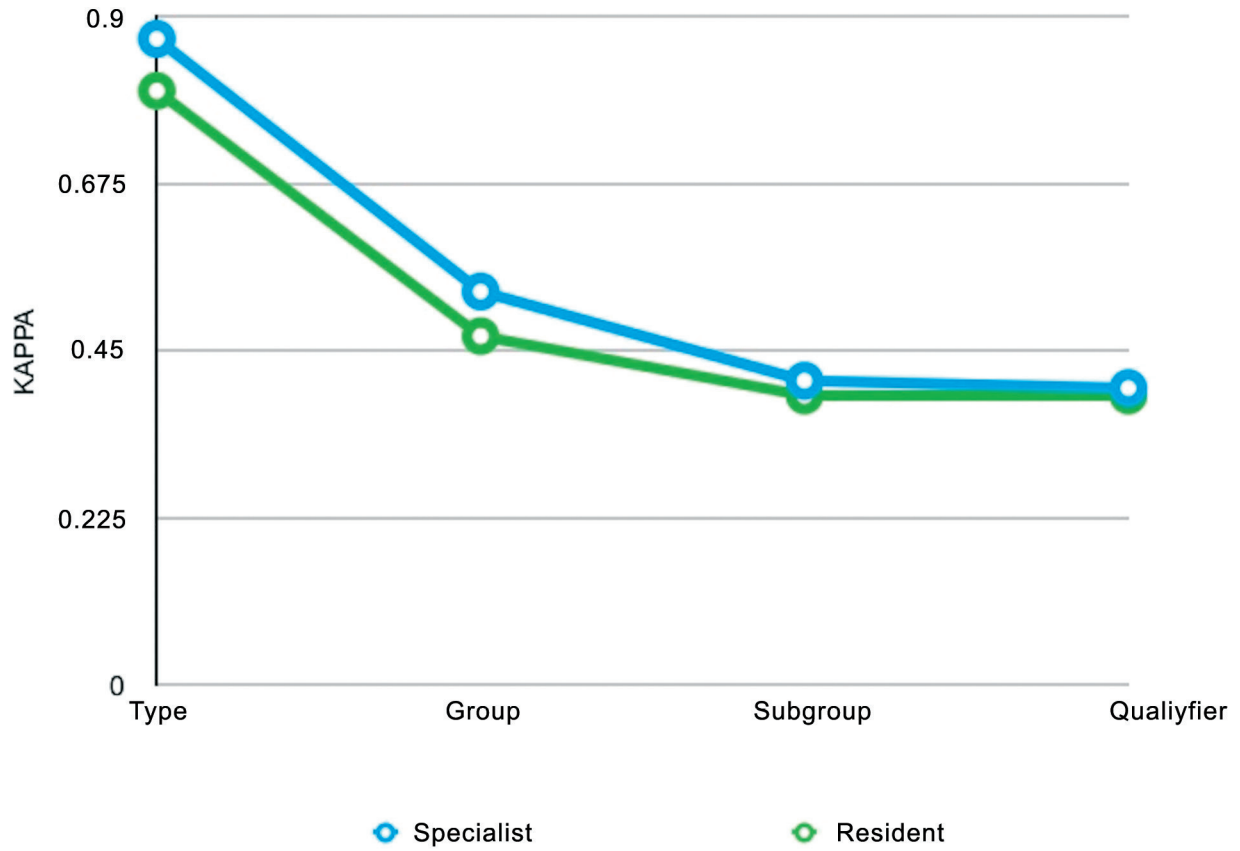

Fig. 2 Interobserver agreement in the first evaluation.

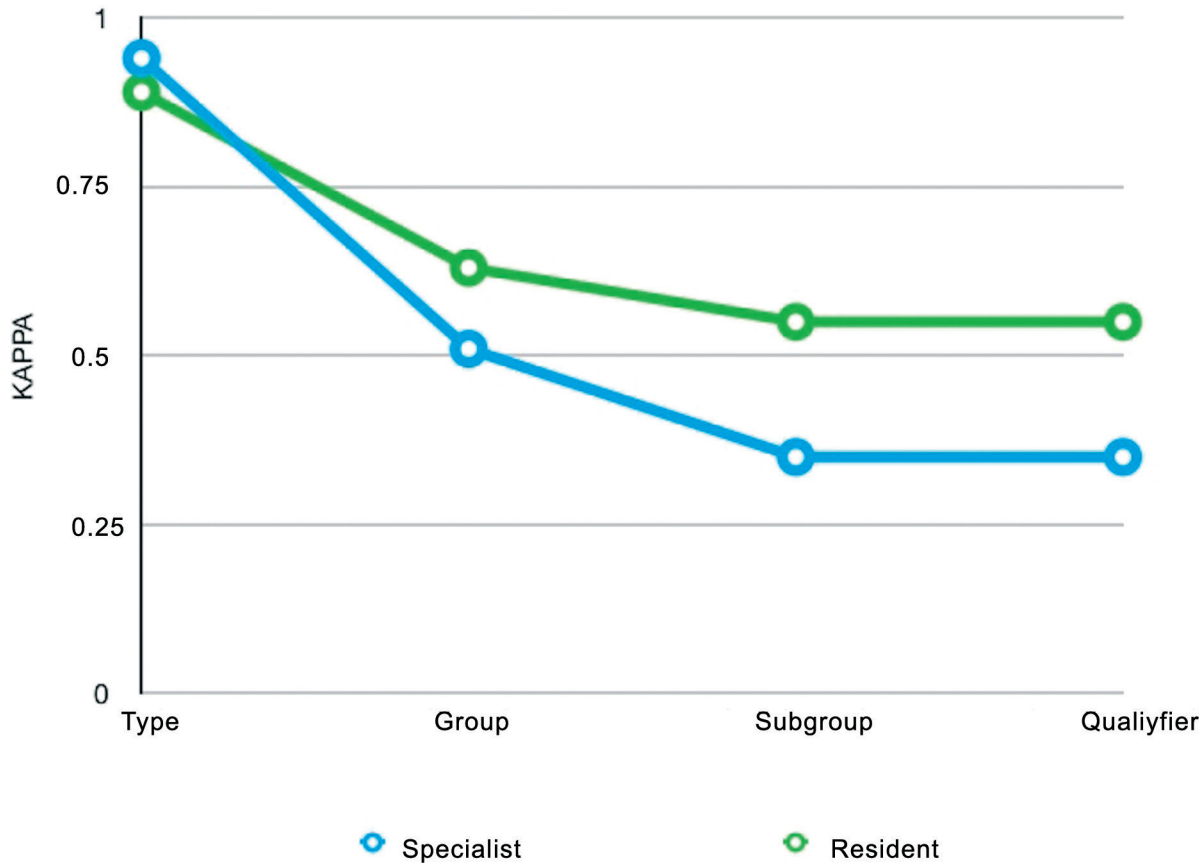

Fig. 3 Interobserver agreement in the second evaluation.

was also difficulty in defining the fractures of group A2. In the new classification, the definitions and codes have been updated and simplified. The neck fractures were reorganized, and the Pauwels qualifier added to better definition of instability, especially in high-energy fractures.[19]

A fracture classification system should have adequate agreement between the same observer at different opportunities (intraobserver) and between different observers at the same time (interobserver).[6,17,18] The *kappa (k)* coefficient is one of the most used methods to evaluate the diagnostic accuracy of a classification system; its calculation has been adjusted for possible coincidences at random.[3]

In the current study, for the specialists, intraobserver agreement was almost perfect for *type*, substantial for *group* and moderate for *subgroup* and *qualifier,* while residents performed worse in all divisions.

Comparing interobserver agreements in both rounds was an interesting aspect of this research. A curious observation is that the interobserver agreement of the residents increased between the rounds, which may have indicated the capacity of learning the new classification.

Studies on the previous AO/OTA system obtained results similar to those obtained in our study, but with small variations. The study by Pervez et al.[3] obtained an average *k* among its observers of 0.62 for *group*, higher than that observed in our study (*k* 0.53 - moderate) and 0.33 in the *subgroups*, lower than we found (*k* 0.41 - moderate). Urrutia et al.[6] obtained moderate agreement, as our results, among its 9 evaluators for the *groups*, and only reasonable for the *subgroups* which is lower than in our study (*k* 0.41 - moderate). Mattos et al.[4] also obtained similar results with AO/OTA and Tronzo. Schwartsmann et al.,[14] in a study also involving orthopedic surgeons and residents, obtained moderate agreement (0.60) for *group*, similar to the present study, and reasonable (0.34) for *subgroups,* lower than that observed in the present study (*k* 0.41). Another interesting study,[15] with 100 fractures of the femoral neck, graded the Garden[7] classification as only reasonable interobserver agreement, which increased to moderate by simplifying the criterion for fracture displacement. This indicates that, in certain fractures, even a fairly simple classification can generate only moderate agreement.

In summary, considering the old classification, in the present study we obtained similar agreement to that of the literature for *type* and *group* and better agreement for *subgroup*, while *qualifiers* were not available in the old classification. This indicates that the new system was successful in bringing greater agreement in the *subgroups*, which were more extensively modified.

Evaluating the issue of experience of the examiners in the AO/OTA classification, Crijins et al.[16] did not observe a difference between 65 surgeons divided between more and less experienced according to the variables of practice time (> or < 17 years), work time dedicated to trauma (>

or < 80%), and fractures treated per year (> or < 50). In an analogy with our study, we evaluated that the residents matched the specialists in the second evaluation, indicating a fast-learning curve in this system. Fung et al.[21] also noted that more experienced residents, in their final part of training, had a better assessment than the less experienced, indicating the learning of the old classification.

About the new AO/OTA system specifically, it is interesting to note the elimination of subgroup A2.1, which can help distinguish stable patterns (group A1), from the unstable ones (groups A2 and A3). Studies of the previous system[11] that tried to discern the extent to which a trochanteric fracture was stable had somewhat conflicting results. Radaideh et al.,[22] in a study on the use of cephalomedullary stems, defined groups A2 and A3 as unstable, as well as Zhang et al.[23] However, Knobe et al.[24] mention that groups A2 and A3 are generally considered unstable in the literature, but in a direct evaluation, the fracture of the lesser trochanter was the main criterion of instability for 82% of surgeons, among other considered factors (fracture of the greater trochanter, lateral wall fracture and reverse obliquity). Another study[25] considered subgroups A2.1, A2.2, and A3.3 as unstable.

The current classification has the integrity of the lateral wall (width greater than 20.5 mm) as the division pattern between groups A1 and A2. The rationale for this division was initially described by Gottfried[26] and Palm et al.,[27] who defined the lateral wall as an important structure for implant support. Later, Hsu et al.[28] were able to evaluate the thickness of the lateral wall would be necessary for safe synthesis with sliding screw plate, which motivated the current change of classification. Other studies[29] reviewed the subject and brought strategies for lateral wall reconstruction even with the use of intramedullary synthesis. Based on this literature review and the difficulties of classification into subgroups, we find it interesting to divide the groups from A2 (including) as a parameter to consider an unstable fracture that requires accurate technique of reduction and intramedullary synthesis.

Our study evidences the difficulties in classification systems for fractures of the proximal extremity of the femur. Despite these difficulties, this system demonstrated advantages over its predecessor[11] by simplifying a division for unstable exchange fractures at group level (A2 and A3) and may facilitate a possible choice of implant and reduction techniques. In neck fractures (type B), the new subdivision is simpler than the previous subgroup complexes (►**Table 1**), and also encompasses the Pauwels qualifier. Additionally, we verified through the literature a higher reliability of the new AO/OTA classification when compared to other very widespread systems (Garden, Evans, Boyd, Tronzo).

In the present study we sought a consistent methodology for evaluating a classification of fractures, having as strengths the size and representativeness of the sample (larger than previous studies, and all the patterns of the new classification were identified by at least one evaluator), in addition to an adequate number of observers for better reliability of the *Kappa* coefficient.[20] The methodology of reliability of orthopedic classifications was examined by Audigé et al.,[18] and the present study encompasses all the quality criteria described. In addition, no study was found evaluating this new system in *Pubmed, Medline* and *Scielo* databasis, which brings new and relevant data on this classification very popular among orthopedic surgeons. Another interesting point was the evolution of interobserver agreement noted among resident physicians between evaluations, indicating the learning of the system. A deficient point in this research was the inclusion of hip specialists compared to only four second-year residents. Perhaps the inclusion of first- and third-year residents could further demonstrate the learning process.

As another possible limitation of the present study, we highlight the relatively high mean age of the sample, indicating a characteristic typical of the population profile of the hospital where it was performed. However, although there is a potential risk of not representing some more specific fractures of high-energy trauma, more common in younger patients, yet all the patterns of the new AO/OTA classification were identified at some point during the study. If we were to go to other younger patients to include in the sample, we would incur in selection bias. Moreover, studies of this nature have limitations inherent to its design, such as potential memory bias, which we consider low due to the large number of cases, the complexity of the classification and the time elapsed between evaluations.

The new AO/OTA system has moderate interobserver and substantial intraobserver reliability for experienced evaluators. Resident physicians were able to achieve the same levels of agreement after a short learning period. Further studies are needed to assess their ability in relation to the indication of treatment (especially on type of synthesis) and prognosis.

Conclusion

The new AO/OTA classification for fractures of the trochanteric region and femoral neck showed appropriate intra and interobserver agreements for *type* and *group,* with worsening in subsequent branches, that is, *subgroup* and *qualifier*. Nevertheless, in relation to the old AO/OTA classification, there was an improvement in the agreements for *subgroups.*

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Conflict of Interests
The authors declare that there is no conflict of interests.

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