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ORIGINAL STUDY

Clinical outcomes of fractures affecting both the femoral neck and femoral trochanter

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Some types of proximal femoral fractures have poor clinical results. Area classification is a comprehensive classification that can identify such "dangerous" fractures, because it can classify fractures that extend beyond the areas of conventional classifications. In this study, the outcomes of fractures affecting both the femoral neck and trochanter were investigated using Area classification.

A total of 1042 proximal femoral fractures were investigated by Area classification and clinical outcomes. The proximal femur was divided into 4 areas by 3 boundary planes. A fracture only in the first area was classified as a Type 1 fracture ; one in the first and second areas was classified as a Type 1-2 fracture. Cases with cut-out or greater than 10-mm telescoping of the internal fixator were defined as the Failure-group. The group other than the Failure-group was regarded as the Success-group. The ratio of the Failure-group to the whole was defined as the failure rate.

The distribution of Area classification between the Failure-group and Success-group differed (P<0.0001). Even in the 682 cases treated with osteosynthesis, the distribution of Area classification between the Failure-group and Success-group differed (P=0.0123), and the Failure-group had more Type 1-2, Type 3-4, Type 1-2-3, and Type 2-3-4 than the Success-group. Furthermore, when the number of areas that the fracture line involved increased, the failure rate rose (P=0.0413).

Area classification was related to clinical outcomes of proximal femoral fractures. Fractures affecting both the femoral neck and trochanter had a high failure rate.

Keywords : proximal femoral fractures ; femoral neck fracture ; femoral trochanteric fracture.

INTRODUCTION

A proximal femoral fracture is one of the most common injuries *(1-4)*. However, in some unstable type fractures, pseudarthrosis or cut-out of osteosynthesis implants can occur *(5-9)*.

In proximal femoral fractures, the appropriate treatment method is based on whether the fracture is a femoral neck fracture or a femoral trochanteric fracture. In femoral neck fractures, osteosynthesis or total hip replacement (THR) / femoral head replacement (FHR) is chosen based on the Garden

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classification stage *(10)* after having evaluated the age and activity of the patient. Furthermore, when osteosynthesis is performed, the osteosynthesis implant may be chosen using the Pauwels classification *(11)* to evaluate instability at the angle of the main fracture line.

In femoral trochanteric fractures, osteosynthesis is often chosen, but many osteosynthesis methods have been reported *(12,13)*. The Nakano classification *(14)* based on the number of fragments on three-dimensional computed tomography (3DCT) is often used for choosing a therapeutic approach.

In addition, there are also basicervical proximal femoral fractures (proximal femoral fractures through the base of the femoral neck at its junction with the intertrochanteric region) *(15)*. Pauwels classification *(11)* may be applied for these basicervical fractures on the assumption that the instability indicated by the angle of the main fracture line is important. Furthermore, the AO/OTA classification *(16,17)*, which is a systematic classification including femoral neck fracture, basicervical fracture, and trochanteric fracture, is used worldwide.

However, the fractures affecting both the femoral neck (AO classification 31B type) and the femoral trochanter (AO classification 31A type) are "dangerous" fractures that often produce cut-outs of osteosynthesis implants or pseudarthrosis. Therefore, "Area classification" was proposed as a comprehensive classification that can identify such dangerous fractures affecting both the femoral neck and femoral trochanter *(18)*.

In Area classification, so-called neck fractures, basicervical fractures, trochanteric fractures, and subtrochanteric fractures are defined by the boundary planes. In addition, Area classification can classify fractures that cross these regions *(18)*.

No report to date has classified many proximal femoral fractures using Area classification and investigated the incidence of each type. In addition, no investigation has examined what kind of treatment tends to be chosen by fracture type in Area classification. Therefore, in the present study, proximal femoral fractures were retrospectively classified using Area classification, and how often fractures crossed over each region of the conventional classifications, which were not even classified by conventional classifications, was investigated. In addition, whether such fractures that crossed over regions were really "dangerous" fractures and whether Area classification was useful for selecting the treatment approach were examined. In other words, the percentages and outcomes of fractures affecting both the femoral neck and femoral trochanter were investigated based on Area classification.

PATIENTS AND METHODS

All proximal femoral fracture patients treated at 8 general hospitals from January 2014 to December 2015 were included in this study. Each hospital contributed from 31 to 217 fractures. The subjects were 1042 patients, and the patients' average age was 82 years (26-108 years) ; there were 209 male and 833 female cases. Approval for this study was granted by the institutional review board of our university, and subjects gave their informed consent to participate.

In Area classification, the proximal femur is divided into 4 areas with 3 boundary planes (Fig. 1) : the first boundary plane is the centre of the femoral neck ; the second boundary plane is the border between the femoral neck and femoral

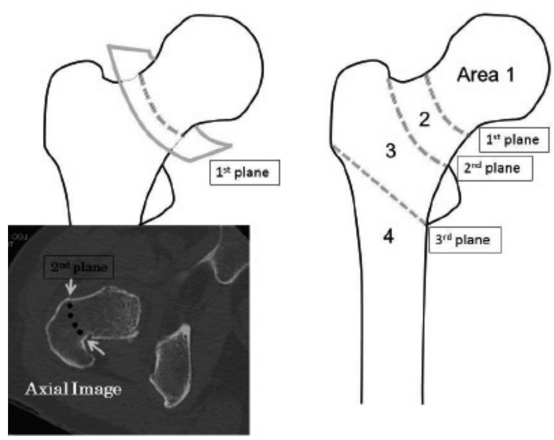

Fig. 1. — Definition of the areas in Area classification
In Area classification, the proximal femur is divided into 4 areas with 3 planes - the centre of the neck; the border between the femoral neck and the trochanter; and the plane links the inferior borders of the greater and lesser trochanters.

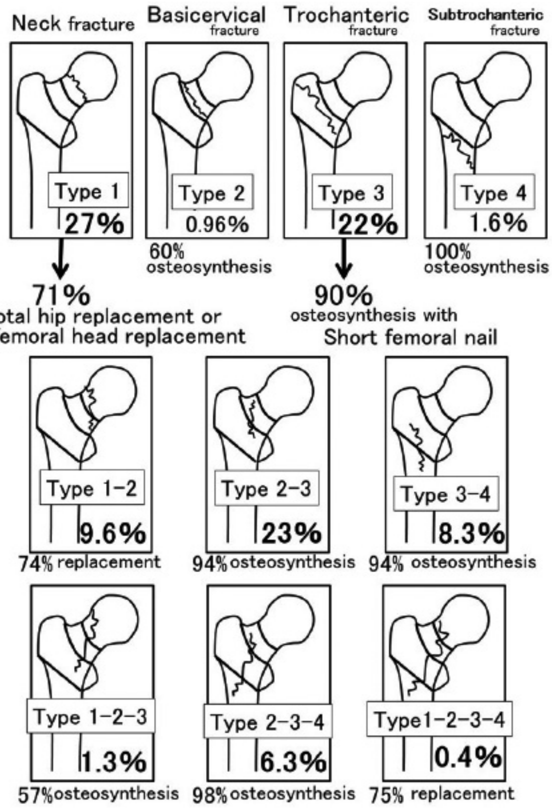

Fig. 2. — The incidences of each type in Area classification Type 1 is a femoral neck fracture, and total hip replacement or femoral head replacement was performed in 71% of Type 1. Type 3 is a femoral trochanteric fracture, and osteosynthesis with short femoral nail was performed in 90% of Type 3. Most cases of Types 1, 1-2, and 1-2-3-4 underwent total hip replacement or femoral head replacement.

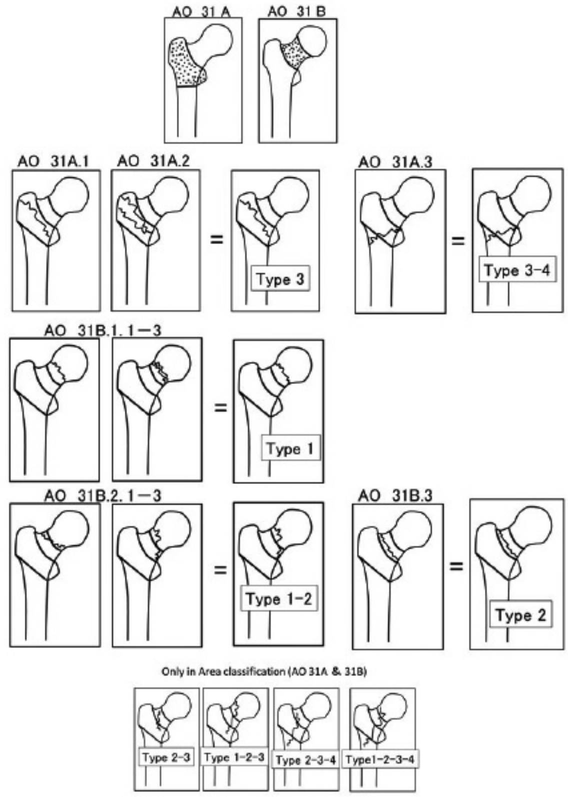

Fig. 3. — Comparison of the AO classification and Area classification
31A.1 and 31A.2 of the AO classification are classified into Type 3 of the Area classification. AO classification 31A.3 is classified into Area classification Type 3-4. 31B.1 of the AO classification is classified as Type 1 of the Area classification. AO classification 31B.2 is classified into Area classification Type 1-2. 31B.3 of the AO classification is classified as Type 2 of the Area classification. However, fractures with fracture lines in both 31A and 31B regions of the AO classification (Type 2-3, 1-2-3, 2-3-4, 1-2-3-4 of Area classification) can only be classified by Area classification.

trochanter ; and the third boundary plane links the inferior borders of the greater and lesser trochanters. A fracture in only Area-1 is classified as a Type 1 fracture ; one in Area-1 and Area-2 is classified as a Type 1-2 fracture (Figs. 2 and 3). In the same way, fractures are classified as Type 1, Type 2, Type 3, Type 4, Type 1-2, Type 2-3, Type 3-4, Type 1-2-3, Type 2-3-4, and Type 1-2-3-4 (10 types) (Figs.1-5). Therefore, in Area classification, so-called neck fractures, basicervical fractures, trochanteric fractures, and subtrochanteric fractures are defined by the boundary planes, and Area classification can classify proximal femoral fractures affecting both the femoral neck and femoral trochanter. When classifying proximal femoral fractures by Area classification, it is unnecessary to consider the number of fragments or the direction of the fracture line. This is one of the advantages of Area classification. Therefore, it was confirmed that the reliability of Area classification is higher than that of other classifications *(18)*. Because it is necessary to determine only where the fracture line exists and extends, proximal femoral fractures can be classified very easily by Area classification on 3DCT, axial CT slices, and reconstructed coronal CT slices.

After 2016, the orthopaedic surgeons of each hospital classified the proximal femoral fractures of the above subjects by Area classification, with

Table I

Area classification	Osteosynthesis	Total hip or femoral neck replacement	Conservative Treatment	Total cases
Type 1	53 cases (19)	198 (71)	27 (9.7)	278
Type 2	6 (60)	3 (30)	1 (10)	10
Type 3	205 (90)	5 (2.2)	17 (7.5)	227
Type 4	17 (100)	0 (0)	0 (0)	17
Type 1-2	23 (23)	74 (74)	3 (3)	100
Type 2-3	222 (94)	1 (0.43)	12 (5.1)	235
Type 3-4	82 (94)	2 (2.3)	3 (3.4)	87
Type 1-2-3	8 (57)	4 (29)	2 (14)	14
Type 2-3-4	65 (98)	1 (1.5)	0 (0)	66
Type 1-2-3-4	1 (25)	3 (75)	0 (0)	4
Unclear	0 (0)	0 (0)	4 (100)	4
Total number	682 (65)	291 (28)	69 (6.2)	1042

Values are n (%).

reference to preoperative X-ray images and CT including 3DCT. Classification was performed by 11 orthopaedic surgeons. In 8 hospitals, 1 surgeon of each hospital classified the fractures, and 4 orthopaedic surgeons at 1 university hospital discussed the classification, but all classifications of cases in the university hospital were agreed by all 4 orthopaedic surgeons. Thus, there was no need to have several examiners perform classification, because Area classification has been shown to have high reliability *(18)*.

Then, with reference to the X-ray images and the medical records at the time of the last follow-up, the therapeutic method and the clinical outcomes of the cases were examined. Cases with cut-out or more than 10-mm telescoping of the internal fixator were defined as the Failure-group, while cases without cut-out or telescoping of the internal fixator were defined as the Success-group. The ratio of the Failure-group to the whole was defined as the failure rate.

The purpose of this study was also to confirm whether the fracture type classified by Area classification is related to the clinical outcomes of proximal femoral fractures. Therefore, the percentages of the fracture types according to Area classification were compared in the Failure-group and the Success-group using the chi-squared test, and significance was set at $P<0.05$. This study received no funding.

RESULTS

The mean follow-up period was 155 days (25-547 days) from the injury date to the time of the last follow-up date in the medical records. Thus, the follow-up rate at 25 days after injury was 100%, but the rate at 3 months after injury was 70.3%.

Using Area classification, 278 cases (27%) were Type 1, 10 cases (0.96%) Type 2, 227 cases (22%) Type 3, 17 cases (1.6%) Type 4, 100 cases (9.6%) Type 1-2, 235 cases (23%) Type 2-3, 87 cases (8.3%) Type 3-4, 14 cases (1.3%) Type 1-2-3, 66 cases (6.3%) Type 2-3-4, 4 cases (0.38%) Type 1-2-3-4, and 4 cases were unclear (Fig. 2). Table I summarizes how each type of fracture was treated.

Type 1 was a so-called femoral neck fracture (AO classification 31B.1), and THR or FHR was performed in 71% of Type 1 cases (Figs. 2, 3), while 19% of Type 1 fractures underwent osteosynthesis. The remainder (9.7%) of the Type 1 cases underwent no operation.

Type 2 fracture was a so-called basicervical fracture (AO classification 31B.3), and there were only 10 Type 2 fracture cases. Among them, osteosynthesis was performed in 6 cases (a short femoral nail (SFN) was used in 4 cases, and a compression hip screw (CHS) was used in 2 cases), and FHR was performed in 3 cases. Conservative treatment was performed in 1 case of Type 2 fracture.

Fig. 4. — An example of a Type 2-3-4 fracture
The fracture line extends from the basal neck part (Area-2) to the subtrochanteric part (Area-4).

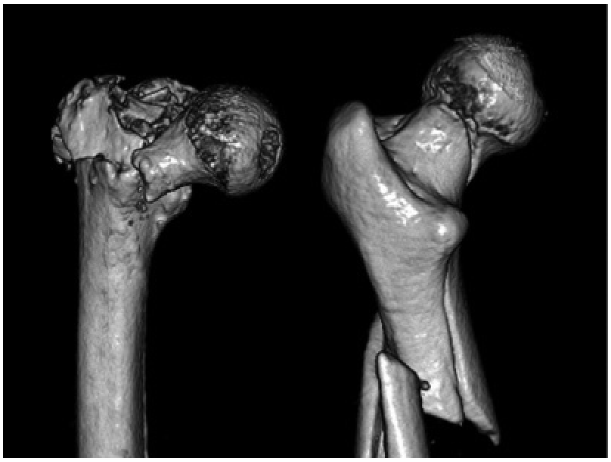

Fig. 5. — An example of a Type 1-2-3-4 fracture
The fracture line extends from the subcapital part (Area-1) to the subtrochanteric part (Area-4).

Type 3 was a so-called femoral trochanteric fracture (AO classification 31A.1 and 31A.2), and osteosynthesis with an SFN was performed in 90% of Type 3 cases (Fig. 2) ; 1.3% of Type 3 cases underwent osteosynthesis with a CHS, and 1.3% of Type 3 cases underwent osteosynthesis with a long femoral nail (LFN). Conservative treatment was performed in 7.5% of Type 3 fractures.

Type 4 was a so-called femoral subtrochanteric fracture (AO classification 32), and all Type 4 factures underwent osteosynthesis.

In Type 1-2 fractures (AO classification 31B.2), THR or FHR was performed in 74%, and osteosynthesis was performed in 23%. Conservative treatment was performed in 3.0% of Type 1-2 fractures.

In Type 2-3 fractures, which cannot be classified by the AO classification, osteosynthesis was performed in 94%, of which 90% were treated by SFN. Only 1 case of Type 2-3 fracture underwent FHR. Conservative treatment was performed in 5.1% of Type 2-3 fractures.

In Type 3-4 fractures (AO classification 31A.3), osteosynthesis was performed in 94%, of which 51% and 46% were treated by SFN and LFN, respectively. The remainder of the Type 3-4 cases underwent osteosynthesis with a CHS. Only 2 cases of Type 3-4 fractures underwent FHR. Conservative treatment was performed in 3.4% of Type 3-4 fractures.

In Type 1-2-3 cases, which cannot be classified by the AO classification, 36% and 21% underwent osteosynthesis with an SFN and with a CHS, respectively, 29% underwent FHR, and 14% underwent conservative treatment.

In Type 2-3-4 cases, which cannot be classified by the AO classification, osteosynthesis was performed in 98%, of which 49% were treated by SFN, and 38% were treated by LFN. The remainder of the Type 2-3-4 osteosynthesis cases underwent osteosynthesis with a CHS. Only 1 case of Type 2-3-4 fracture underwent FHR.

There were only 4 cases of Type 1-2-3-4 fracture, which cannot be classified by the AO classification (FHR was performed in 3 cases, and osteosynthesis with an LFN was performed in 1 case).

The distributions of each fracture type were significantly different between the Failure-group and the Success-group ($P<0.0001$). However, these included cases that underwent THR or FHR. There were 682 cases that underwent osteosynthesis and did not undergo THR or FHR. The cases that underwent osteosynthesis had many fracture types around Area-3 : Type 3, Type 2-3, Type 3-4, and Type 2-3-4 (Fig. 6). On the other hand, there were 291 cases that underwent THR or FHR. The cases that underwent THR or FHR had many fracture types around Area-1 : Type 1, Type 1-2, and Type

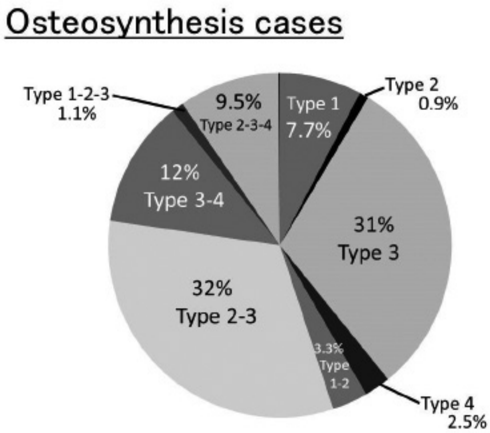

Fig. 6. — The distributions of fracture types in the cases that underwent osteosynthesis
The cases that underwent osteosynthesis have many fracture types around Area-3: Type 3, Type 2-3, Type 3-4, and Type 2-3-4.

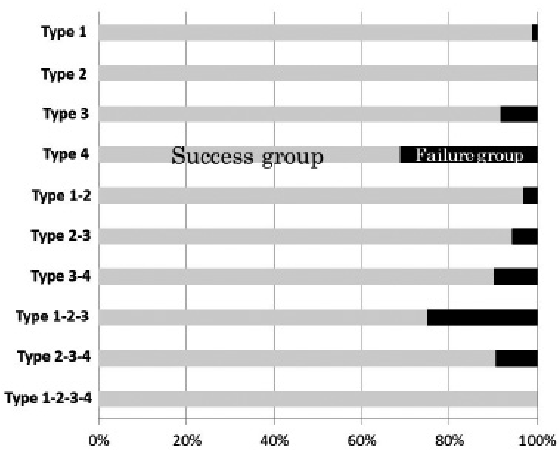

Fig. 7. — Failure rates according to the fracture types of Area classification
The failure rate is the highest in Type 4 (subtrochanteric fracture) (31%). The next highest is Type 1-2-3 (25%). The failure rate of osteosynthesis is high, in the order of Type 3-4 (10%) and Type 2-3-4 (9.5%).

1-2-3-4. Only 4 of these cases had problems (1.4%, dislocation in 3 cases and surgical site infection in 1 case).

For the fractures that underwent osteosynthesis, the distributions of each fracture type were also significantly different between the Failure-group and the Success-group (P=0.0123). The Failure-group had more Type 4, Type 1-2, Type 3-4, Type 1-2-3, and Type 2-3-4 cases than the Success-group.

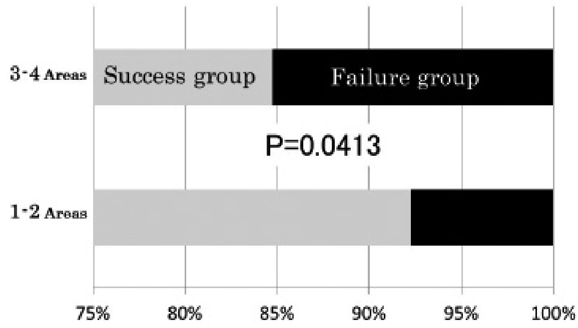

Fig. 8. — Relationship between the failure rate and the number of areas involved in the fracture line
When the number of areas that the fracture line involves increases, the failure rate rises.

Figure 7 shows the failure rates according to the fracture type of Area classification. The failure rate was the highest in Type 4 (subtrochanteric fracture) (31%). The next highest was Type 1-2-3 (25%). The failure rate of osteosynthesis was high in the order of Type 3-4 (10%) and Type 2-3-4 (9.5%). In addition, when the number of areas that the fracture line involved increased, the failure rate increased (Fig. 8).

DISCUSSION

As a result of having classified over 1000 proximal femoral fractures using Area classification and having investigated their clinical outcomes, it was found that the distributions of each fracture type were significantly different among the outcomes. In other words, the fracture type classified by Area classification is related to the clinical outcomes of proximal femoral fractures.

Overall, 30.6% of fractures (Types 2-3, 1-2-3, 2-3-4, 1-2-3-4) could not be classified by conventional classifications because they extended beyond the target regions of conventional classifications. Actually, it is common knowledge that a certain number of fractures do not fit in the regular pattern of every classification. However, the fraction of almost one-third is astonishing. This high value has not been reported in the past and was first identified in the present study.

In addition, whether such fractures that crossed over areas were really "dangerous" fractures was investigated. It was found that fractures that crossed the boundary planes of each area were significantly more common in cases with implant cut-out or excessive telescoping. In other words, it became clear from the results of the present study that fractures having fracture lines extending over the regions of multiple classifications, which cannot be classified by conventional classifications, are unstable and dangerous proximal femoral fractures.

In recent years, due to severe osteoporosis in elderly persons or high-energy injuries such as traffic accidents, proximal femoral fractures have been aggravated, and complex femoral fractures extending beyond the target region of various classifications now appear more often (Figs. 4 and 5). Conventional classifications cannot be used to classify such cases. Thus, a new comprehensive classification of proximal femoral fractures, which is directly connected with treatment methods and related to clinical outcomes, was considered necessary. It appears from the results of the current study that Area classification fulfils that need.

In addition, with recent progress in imaging technology, multidirectional reconstructed CT and 3DCT are deployed at most hospitals handling injuries. Multidirectional reconstructed CT and 3DCT are useful for choosing treatment for proximal femoral fractures. 3DCT was performed in all 1042 cases in the present study. Therefore, the reliability of the Area classification was sufficient, because classification was performed using not only simple X-rays, but also 3DCT *(18)*.

Area classification can be used together with familiar conventional classifications, because Type 1, Type 2, Type 3, and Type 4 in Area classification are approximately the same as the so-called femoral neck fracture, basicervical fracture, trochanteric fracture, and subtrochanteric fracture. When a fracture extends to involve multiple areas, it requires special evaluation. For example, Type 1-2 (AO classification 31B.2) is a shear fracture that extends from the femoral neck to the basal neck. Therefore, evaluation of correspondence for rotational instability and shear force is necessary. Type 3-4 (AO classification 31A.3) is approximately the same as the so-called Evans classification type 2. Thus, it has greater instability than the general trochanteric fracture. The need to evaluate instability led to trying Area classification. Using Area classification, a more careful choice of treatment is possible.

In addition, for example, double lag screws should be considered for fractures extending from the trochanteric part to the basal neck (Type 2-3, which cannot be classified by the AO classification), because such fractures have more rotational instability than Type 3 fractures, and a long nail should be considered for fractures extending from the trochanteric part to the subtrochanteric part (Type 3-4 : AO classification 31A.3), because such fractures have more distal instability than Type 3 fractures. In other words, the Area classification may be connected directly with the choice of treatment. However, subgroup analysis is necessary to clarify this *(19)*.

In the present study, cases with cut-out or telescoping of the internal fixator of more than 10 mm were defined as the Failure-group. This is because excessive telescoping often leads to a cut-out of the implants *(20-22)*. However, because there are cases in which excessive telescoping is not connected directly with poor clinical results, longer-term follow-up is also necessary. In addition, the degree of telescoping and cut-out depends on the delicate nature of the osteosynthesis and the postoperative reposition state, as well as the fracture type. However, in the present study, this was not evaluated ; this is one of the limitations of this study.

As for the factors affecting the clinical results, there are many, such as age, sex, degree of displacement, number of fragments, direction of the fracture lines, degree of repositioning, bone mineral density, bone quality, postoperative rehabilitation, and the kind of internal fixator used. The data of each hospital differ in demographics, time to surgery, operation time, experience of the surgeons, number of surgeons, type of implant used, and the like. Therefore, it is necessary to perform multivariate analysis including all of them. This was not done in the present study and is also one of its limitations. Other limitations of this study include the short follow-up period and the small number of orthopaedic surgeons doing the evaluations.

Another limitation of this study was that the clinical outcomes with the conventional way of thinking about treatment were re-examined by Area classification, rather than examining the clinical results when the treatment methods were decided based on Area classification. Nevertheless, consistent tendencies in treatment methods were recognized based on every type of Area classification. In other words, Area classification appears useful for selecting treatment methods.

In the future, the effects of Area classification and the treatment methods on the clinical outcomes should be investigated in more cases. Furthermore, basic research to evaluate which treatment is the best choice, for example using the fracture models made based on Area classification, should be performed. Such studies are needed to determine whether Area classification is directly related to the choice of treatment of proximal femoral fractures. The current study is the first step in that direction.

CONCLUSION

Area classification could not only predict progress after surgery by evaluating instability, but it could also be useful in the choice of surgical methods for proximal femoral fractures, especially those affecting both the femoral neck and the femoral trochanter.

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