Comparison of internal fixation with Gamma3 Long nails and INTERTAN nails in the treatment of Seinsheimer type V subtrochanteric femoral fractures in elderly patients

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Abstract
The aim of this study was to clinically compare the therapeutic effects of internal fixation using a third-generation Gamma Long Nail (TGLN) with that of INTERTAN in the treatment of Seinsheimer Type V subtrochanteric femoral fractures in elderly patients. The therapeutic effect of internal fixation with TGLN, compared with that with INTERTAN, was retrospectively analyzed in elderly patients diagnosed with Seinsheimer Type V subtrochanteric fracture. Twenty-five cases were divided into 2 groups based on the fixation devices: the TGLN group (13 cases; 5 men and 8 women) and the INTERTAN group (12 cases; 5 men and 7 women). Patients were followed up postoperatively, and their clinical history, intraoperative blood loss, fracture healing, Harris Hip Scores, and postoperative complications were recorded and compared. Patients in the TGLN group had shorter operation time and less intraoperative blood loss, compared with those in the INTERTAN group \(P < .05\). There were no significant between-group differences in postoperative complications, fracture healing time and Harris Hip Scores during the follow-up \(P > .05\).

Abbreviations: AO = Arbeitsgemeinschaft für Osteosynthesefragen, CPM = continuous passive motion, DCS = dynamic compression screw, DHS = dynamic hip screw, PFN = proximal femoral nail, PFNA = proximal femoral nail anti-rotation, TGLN = third-generation Gamma Long nail.

Keywords: internal fixation, INTERTAN, lengthened Gamma3 nails, subtrochanteric fracture

1. Introduction
Subtrochanteric fracture is an orthopedic injury that is commonly seen in elderly patients and is associated with a profound difficulty of management because of the high rate of nonunion and failure of internal fixation.\cite{1-3} With the increase in the geriatric populations worldwide, there has been a continuous increase in the incidence of subtrochanteric fractures. Moreover, low foreign force induced subtrochanteric fractures is predominantly caused by trauma in elderly individuals, and is associated with the higher incidence of falls in this population that accounts for 10% to 34% of all hip fractures.\cite{4-7}

The classification of subtrochanteric fractures is debatable\cite{8-11}; however, Seinsheimer classification has been widely accepted as one of the most practical classification systems for this condition.\cite{11} The injury is categorized into 5 types (I–V), based on the number of fractured bone pieces, location, and shape of the fracture line. Of these 5 types, Type V involves subtrochanteric and intertrochanteric spaces and is also known as a comminuted subtrochanteric hip fracture. Given the complexity of injury, the clinical management of a Type V hip fracture remains very challenging. Conservative therapy for subtrochanteric fractures can be complicated by life-threatening conditions such as deep vein thrombosis and pulmonary embolism. Currently, surgery with internal fixation is the treatment of choice in subtrochanteric fractures.\cite{12-14}

Fixation systems for subtrochanteric fractures include extramedullary systems, such as the dynamic hip screw (DHS),\cite{15-18} and intramedullary systems including, but not limited to, Gamma nails, the proximal femoral nail (PFN), and the PFN anti-rotation (PFNA).\cite{19-33} Compared with the extramedullary systems, intramedullary nail systems are less invasive, incur less intraoperative blood loss, and have decreased risks of nonunion, postoperative infection, and failure of surgery. In addition, it allows early weight bearing and postoperative mobility for the patients. As such, intramedullary nail systems have gained wide popularity and are recognized as the preferred internal fixation option for subtrochanteric fractures.\cite{34-37}

The Gamma Nail, a relatively new intramedullary nail system, was introduced by Grosse in the 1990s\cite{19,38,39} The Gamma Nail system consists of a lag screw and a rod to overcome problems in
sliding-screw fixations, and has superior efficacy in the fixation of intertrochanteric and subtrochanteric fracture. Moreover, it has been found to favorably address outcomes in pathological hip fractures.[21,40] However, the clinical application of Gamma Nails is associated with several complications, including breakage of the lag screw and fracture of the femora distal to the intramedullary device.[24,41–44] Another robust intramedullary nail system, INTERTAN, is a new-generation intramedullary fixation device manufactured by Smith & Nephew for fixation of proximal femoral fractures. The main features of INTERTAN are a preloaded cannulated set screw that facilitates sliding; a figure-
8-shaped integrated interlocking lag and compression screws that offer superior inner compression and enhanced stability; and the trapezoidal surface of the proximal nail that enhances the rotational stability of the nail in the medullary cavity.[21,45]

Despite the increasing use of TGLN and INTERTAN in the clinic, a comparison of their applications in complex types of subtrochanteric fracture (i.e., Seinsheimer Type V) has not been undertaken. The Seinsheimer Type V subtrochanteric fracture is different from other subtypes of subtrochanteric fracture. Although their incidence is not high, these fractures involve both the intertrochanteric and subtrochanteric areas, and have a large fracture span. The management of such fractures involves internal fixation to fix the 2 fractures; therefore, the choice of an internal fixation system is particularly important. Herein, we report our experience with these 2 systems together with a side-by-side comparison.

2. Materials and methods

2.1. Ethics statement

This study was carried out in accordance with the guidelines for the care for human subjects adopted by the First Hospital of Jilin University; the study protocol was approved by the Research Ethics Committee of the First Hospital of Jilin University (ref. no. 2012/026); and written informed consent was obtained from all participants.

2.2. Patients

The inclusion criteria for this study were patients 60 years of age or older, with Seinsheimer Type V closed subtrochanteric fracture that was surgically treated with TGLN or INTERTAN. Patients with high-energy trauma, open fractures, multiple injuries, pathologic fractures, an American Society of Anesthesiologists (ASA) scoring of 5, severe cognitive dysfunction, and those who were nonambulant were excluded.

The primary assessment included evaluation of cognitive function, based on the Simple Portable Mental State Questionnaire (SPMSQ).[46] and general health status, based on the ASA classification.[47] The SPMSQ is a 10-item test that classifies patients as lucid, with mild to moderate cognitive dysfunction, or with severe cognitive dysfunction, depending on the number of correct responses by the patient. Only patients without severe cognitive dysfunction (3 correct answers) were included in our study. Moreover, the patient’s living conditions and the ability to walk in the last week before the fracture were interviewed as a baseline parameter. Living conditions were categorized as independent (living in one’s own home or in housing for the elderly) or institutionalized (living in a nursing home or a hospital). Walking ability was based on the patient’s need for walking aids and was categorized as no need for a walking aid, need for a stick or crutches, need for a walking frame, or nonambulant. Only patients who had independent walking capability before the fracture were included.

In total, 28 patients with 28 Seinsheimer Type V closed subtrochanteric fractures were recruited for this study. The Type V Seinsheimer fracture was defined as a fracture wherein the fracture line traversing the femur was situated mainly within 7 cm of the femur distal to the lower margin of the lesser trochanter, with 4 or more fragments and the greater trochanter involved.[41] The mean follow-up duration was 13 (7–19) months for the TGLN group and 12 (6–17) months for the INTERTAN group. During the study, 2 patients in the TGLN group (1 death, and 1 lost to follow-up) and 1 in the INTERTAN group (1 death) were excluded. Patients were divided into 2 groups by the internal fixation methods: The TGLN group comprised 13 patients (5 men and 8 women), aged 65 to 88 years (mean age 67.3 years); 5 patients sustained fracture due to falls, 5 due to car accidents, and 3 due to a drop from high places. The INTERTAN group recruited 12 patients (5 men and 7 women), aged 63 to 86 years (mean age 68.4 years); of those, 7 fractures were due to falls, 3 due to car accidents, and 2 due to a drop from high places.

2.3. Medical devices

The TGLN was manufactured by Stryker Trauma Gmbh Company (Schonkirchen, Germany), and the INTERTAN nail system was manufactured by Smith & Nephew, Inc (Memphis, TN).

2.4. Procedures

Three surgeons chose from 2 methods based on their personal preferences. All of the hospitalized patients were operated on under general anesthesia within 5 days of injury. Patients in the TGLN group were placed in the supine position, under continuous cutaneous traction with internal rotation for closed reduction. The junction of the top one-third and bottom two-thirds of the greater trochanter was selected as the nail-access site. A guide needle was introduced into the narrow cavity of the femur, the cavity was exposed, and the fractured end was internally reduced; this was followed by a widening of the marrow cavity and insertion of the TGLN (Stryker). The fracture reduction was adjusted under X-ray visualization for optimal alignment. Similar techniques were used to install the lag screw (Fig. 1). The length of the nail was determined by the location of the fracture and the length of the femur, and was situated at least 8 cm from the fracture line and, preferably, to the area of the femoral supracondyle.

A similar procedure was undertaken for fracture fixation using INTERTAN. After the guide needle reached the femoral neck and the center of the femoral head, the anti-rotation rod was inserted along the guide needle and the lag screw was screwed in at an appropriate length. Then, the anti-rotation rod was removed, and the compression screw was screwed in manually beneath the lag screw (Fig. 2).

Radiography of the hip joint was conducted in anteroposterior and lateral projections before the operation, during distraction, after apparatus removal, and throughout the follow-up period. Manual drawings on x-rays were used to assess radiographic parameters. The tip–apex distances (TADs) were calculated from the sum of the distances between the tip of the lag screw to the
apex of the femoral head on both the anteroposterior and lateral views. The caput–collum–diaphyseal (CCD) angle that formed between the neck of the femur and its shaft were calculated on the anteroposterior views.

The surgical area was covered with surgical foil, together with a drainage bag to collect blood. The actual blood volume in the bag and in the surgical swabs was recorded and determined by subtracting the total quantity of irrigants from the total volume of the blood bag and the surgical swab. The blood in the swab was determined by weight, on the assumption that 1 g blood equates to 1 mL blood.

2.5. Postoperative management
A bolus of antibiotics was used postoperatively for prophylaxis. Low-dose heparin was administered to prevent deep vein
thrombosis. All patients were instructed to undertake active early quadriceps movement and continuous passive motion (CPM) limb exercises. Partial weight bearing was allowed according to each patient’s individual health status from 2 weeks to 2 months. On the basis of the radiological status, full weight bearing was normally allowed 12 weeks after surgery. Anteroposterior and lateral views on radiography were acquired at follow-up visits at 3 months, 6 months, and 1 year after surgery. All implant position changes, fixation failures, wound complications, pain in the hip, walking ability, Harris Hip Score, and complications were recorded.

2.6. Statistical analysis
Quantitative data are presented as mean ± standard deviation. Comparative analysis of quantitative data was undertaken by *t* test, whereas categorical data were analyzed using the Chi-square test. All statistical analyses were conducted with the SPSS 19.0 software (SPSS version 19.0, Armonk, NY: IBM Corp). *P* < .05 was considered indicative of statistical significance.

3. Results
Patient demographics as well as preoperative clinical and subjective parameters are summarized in Table 1. There were no significant between-group differences in gender, age, body mass index (BMI), smoking status, and fracture side. The general physical health of the patient was assessed by the attending anesthesiologist based on the ASA score. There were no patients with an ASA score 5, those who were not expected to live for 24 hours regardless of surgical intervention.

Intraoperative data are summarized in Table 2. The mean waiting time to surgery, operating time, and hospital stay were 1.1 (range 0–4) days, 57.2 (range 25–103) minutes, and 8.1 (range 2–17) days in the TGLN group and 1.3 (range 0–5) days, 90.5 (range 50–132) minutes, and 8.4 (range 2–17) days in the INTERTAN group, respectively. The mean blood loss was 140 (range 10–300) mL in the TGLN group and 255 (range 50–450) mL in the INTERTAN group.

Our data showed that the operation duration was shorter and there was less intraoperative blood loss in the TGLN group, compared with the INTERTAN group (*P* < .05). No significant differences were observed with regard to hospital stay.

The difficulty of fracture reduction was not significantly different between the 2 groups. Semi-open reduction and temporary fixation (bone-holding forceps or cerclage wire) were required in 5 cases (38.5%) in the TGLN group and in 4 cases (33.3%) in the INTERTAN group. There were no other intraoperative complications, such as femoral shaft fractures, in the study groups nor was supplementary fixation required.

All complications for the INTERTAN and TGLN groups are summarized in Table 3. In the TGLN group, a fracture united in

| Table 1 | Patient demographics. |
|---------|-----------------------|
| Factors | TGLN group | INTERTAN group | *P* |
| Sample size (n) | 13 | 12 | .425 |
| Age (mean ± SD, y) | 67.3 ± 13.7 | 68.4 ± 15.1 | .448 |
| Gender, female (n) | 8 | 7 | .695 |
| Body mass index, kg/m² | 25.1 ± 3.4 | 24.9 ± 4.2 | .448 |
| ASA score (n) | 1 | 3 | 1 | .646 |
| 2 | 5 | 6 | .859 |
| 3 | 4 | 3 | .901 |
| 4 | 1 | 2 | .593 |
| Smoking status (n) | 5 | 4 | .695 |
| Cognitive function (mean ± SD) | 6.9 ± 2.3 | 5.7 ± 2.7 | .121 |
| Details of trauma (n) | | | |
| Fall from standing height | 5 | 7 | .437 |
| Drop from a high place | 3 | 2 | .541 |
| Traffic accident | 5 | 3 | .386 |
| Walking aids (n) | | | |
| None | 6 | 7 | .417 |
| Stick or crutches | 5 | 4 | .559 |
| Walking frame | 2 | 1 | .531 |
| From independent living (n) | 11 | 10 | .327 |
| Preoperative HHS (mean ± SD) | 84.11 ± 7.21 | 81.86 ± 4.65 | .184 |

*AO=Arbeitsgemeinschaft für Osteosynthesefragen, ASA=American Society of Anesthesiologists, HHS=Harris Hip Score, NA=not available.*
Table 2
Intraoperative data.

| Factors                  | TGLN group | INTERTAN group | P   |
|--------------------------|------------|----------------|-----|
| Waiting time (mean ± SD; d) | 1.1 ± 2.3  | 1.3 ± 2.7       | .421|
| Mean operative time (mean ± SD; min) | 57.25 ± 38.70 | 90.52 ± 54.06 | .014*|
| Mean blood loss (mean ± SD; mL) | 140 ± 26   | 255 ± 36        | <.001*|
| Mean hospital stay (mean ± SD; d) | 8.1 ± 4.3  | 8.4 ± 5.1       | .437|
| Intraoperative complications |            |                |     |
| Semi-open reduction and temporary fixation | 5          | 4              | .559|
| Surgical procedure change | 0          | 0              | NA  |

8° varus, whereas, in the INTERTAN group, there was a deformity with 5° varus. The mean time to union was 15 and 16 weeks in the TGLN and INTERTAN groups, respectively ($P = .163$). In the TGLN group, a contralateral femoral neck fracture occurred 6 months after the operation in a new injury and was treated with hemiarthroplasty. No infection, implant failure, implant cut out, distal nail perforation, readmission, or reoperation occurred in this study.

A functional evaluation of 25 cases at the final follow-up showed that 76.9% of the patients in the TGLN group and 66.7% in the INTERTAN group regained their initially walking ability. Other patients needed 1 or 2 Crutches to walk. Table 3 summarizes the clinical and functional outcomes at the final follow-up. The mean Harris Hip Score was 82.7 for the TGLN group and 79.8 for the INTERTAN group, and there were no significant between-group differences ($P = .147$).

All of the 25 patients were postoperatively followed up for 6 to 18 (mean 12) months. Our data showed that the TGLN group had shorter operation duration and less intraoperative blood loss, compared with the INTERTAN group ($P < .05$). However, there was no significant difference in the bone-healing time or Harris Hip Scores on last follow-up between the study groups ($P > .05$, Table 1). All patients had primary healing of the incision, without complications such as postoperative infection, deep venous thrombosis, or fat embolism syndrome.

4. Discussion

The term subtrochanteric fractures refers to a fracture between the lesser trochanter and the isthmus of the femoral shaft, a transitional zone of cancellous to cortical bone and an area with unfavorable blood supply. [34, 48] Subtrochanteric fractures are often seen in injuries caused by high-energy force, which leads to a comminuted fracture in the proximal femur and is characterized by prominent displacement of the bone ends, remarkable soft-tissue damage, and disruption of blood supply in the fractured bones. In elderly patients with osteoporosis, subtrochanteric fractures caused by weaker forces are more common. The subtrochanteric area is a region that experiences concentrated stress; therefore, fractures in this area are difficult to manage. Most surgeons advocate early surgery for internal fixation and early functional exercise. [49–51] The Seinsheimer classification is commonly used to categorize subtrochanteric femoral fractures and is based on the number, location, and type of fracture fragments. Although it is complex, this method can clearly describe the fracture status. Seinsheimer Type V fractures are subtrochanteric fractures associated with intertrochanteric fractures, usually caused by a strong force, and seen in elderly patients with osteoporosis. This is the most complex and unstable subtrochanteric fracture, and is difficult to manage surgically. [11, 12, 52] Because these fractures are mostly comminuted, the broken ends of the fractures are more separated and displaced, and they are pulled by the surrounding muscles; this makes fracture reduction difficult. Furthermore, the influence of the hip abductor, iliopsoas, and medial femoral muscles as well as the stress concentration of internal fixation can make this fracture prone to failure of internal fixation and malunion.

Subtrochanteric fractures can be fixed with extramedullary or intramedullary methods. Devices commonly used in intramedullary fixation include Gamma intramedullary nail, PFN, and PFNA; devices for extramedullary fixation include gooseneck nail, Richards nail, DCS, and Arbeitsgemeinschaft für Osteosynthesefragen (AO) steel plate. The gooseneck nail, AO steel plate, and Richards nail are unsuitable for management of subtrochanteric fracture, because their rates for fixation failure and nonunion are as high as 20%. [53, 54] Intramedullary fixation is less invasive and has a higher healing rate of up to 99.3%. [55] In most intramedullary fixations, nailing can be carried out away from the fracture ends, which protects the blood supply to the fracture. [55] Intramedullary fixation occurs close to the load force line, which is advantageous to loading transmission, and it is more aligned with the biomechanical requirements.

The TGLN and INTERTAN are more advanced systems for intramedullary nailing fixation in the treatment of intertrochanteric fractures. These 2 fixation nail systems effectively fix the femoral head and neck with the intertrochanteric area, subtrochanteric area, and femoral shaft with superior overall stability of the fractured bone, thereby ensuring early functional exercise and ambulation. Both of these nailing systems can use the apex of the greater trochanter for entering the marrow cavity,
which minimizes trauma caused by operation and preserves the blood supply around the fracture site. The proximal shape of the INTERTAN system is trapezoidal, and reaming produces more cut bone. As with the double-nail system, there was a greater amount of bone loss in the femoral head and neck. INTERTAN proximal interlocking nails enhance the rotational stability of the head and neck, reduce the incidence of postoperative complications such as pullout or retraction of the nails, head and neck varus collapse, and shortening of the femoral neck. The TGLN, with its anti-rotation screw and head–neck lag screws, facilitates fracture healing by enabling dynamic compression of the fracture section and, thus, effectively improves the rotational stability of the head-and-neck fracture block. In vitro biomechanical experiments demonstrated that INTERTAN was superior to the TGLN; however, clinical studies have not found any significant differences.\(^{[45,54]}\)

In this study, we observed significantly less blood loss and shorter duration of operation in the TGLN group. This difference could be because the TGLN system is a single-screw system, with greater operational ease, and causes less damage to the femoral head and neck as compared to the INTERTAN system. We speculated that the shorter operation time was due to less proximal locking and because the distal locking could be assisted by the target device. More intraoperative blood loss in the INTERTAN group was attributed to the longer operation time, the proximal trapezoidal shape mismatch with the reamed cylindrical tunnels, and more bone loss during reaming. Moreover, semi-open reduction procedures affected the results in both groups. No fixation failure or varus deformity was observed in this study, indicating good biomechanical stability with both systems. This is in line with the results reported previously; the anti-bending and anti-torsion abilities of the 2 systems are sufficient to support healing of the fractured bone.\(^{[56]}\)

This study had some limitations. First, the study sample was relatively small, and may have affected the efficacy of statistical analysis. Second, the follow-up period was relatively short. The long-term effect of the 2 surgical managements could not be determined. Third, all surgeries were not conducted by the same surgeon. Fourth and last, blood loss was not precisely calculated, and the measured blood loss represents only the external blood loss, because it was impossible to quantify occult blood loss at the surgical site.

5. Conclusion

Both TGLN and INTERTAN nails are therapeutically effective for the management of Seinsheimer Type V hip fractures in elderly patients, with excellent clinical outcomes. Although the TGLN was superior to INTERTAN in terms of the operative time and intraoperative blood loss, the small sample size affected the strength of this finding.

Author contributions

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