Treatment of femoral shaft fracture with interlocking humeral nail in older children and adolescent

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Treatment of femoral shaft fracture with interlocking humeral nail in older children and adolescent

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ABSTRACT

Treatment of femoral shaft fracture with interlocking humeral nail in older children and adolescent

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Purpose: Rigid interlocking nailing for femoral shaft fracture is ideal to use in adolescent when regarding the fracture stability and patient's convenience. However, numerous authors have reported rigid interlocking nailing has some limitations in this group of age due to the risk of complications. We evaluated the results of intramedullary nailing for femur shaft fractures using rigid interlocking humeral nail through the greater trochanter in older children and adolescent.

Materials and Methods: We retrospectively reviewed records for femoral fractures treated with rigid interlocking humeral nail. Radiographs were examined for proximal femoral change and evidence of osteonecrosis. Outcome were measured by major or minor complication that occurred after operative treatment.

Results: Twenty-four femoral shaft fractures in 23 patients were selected. The mean age at the time of operation was 12 years and 8 months and the mean follow-up period was 21 months. All fractures were healed clinically and radiographically within 8 weeks in average. No patient had developed avascular necrosis of femoral head and coxa valga. There is no change in neck shaft angle (P = 0.29) and articulotrochanteric distance (P = 0.33).

Conclusion: Intramedullary nailing through the greater trochanter using rigid interlocking humeral nail is effective and safe for the treatment of femoral shaft fracture in older children and adolescent.

Key words : children, adolescent, femoral shaft fracture, interlocking humeral nail, greater trochanter

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I. INTRODUCTION

The annual rate of children who present with femoral shaft fracture has been estimated at 19 per 100,000.[1] Diaphyseal femur fractures account for 1.4% [2] to 1.7% [3] of all pediatric fractures. The treatment options are depending on various factors. The management of femoral shaft fractures in the adult population has ceased to be an area of controversy in orthopaedics with rigid intramedullary nailing. But, the treatment in older children and adolescent is greatly different from that in adults and controversial.

In the adolescent period older than the age of 11 years, firm internal fixation is performed generally as in adults. The internal fixation techniques are submuscular plating, flexible intramedullary nail, rigid interlocking nail, etc. Numerous authors widely have performed and extensively have studied the flexible intramedullary nailing in children. For many surgeons, elastic nails have rapidly become the treatment of choice for the pediatric patients ranging from age 5 to 11 years because it allows rapid ambulation of children with

little risk of osteonecrosis, physeal injury or refracture.[4] However, flexible intramedullary nails cannot be locked and so it can lead to problems with loss of length and rotation at the fracture site, particularly in older children who may have more comminuted fractures that are slower to heal.[5]

Therefore, rigid interlocking nail is frequently applied to the treatment of the fracture of the femoral shaft in older children and adolescent, and it has advantages that rapid recovery and ambulation are feasible, hospital stay is short, muscle atrophy is less, and the possibility of improper union and non-union is low.[6]

However, with the rigid interlocking femoral nail in older children and adolescent, avascular necrosis in the femoral head may be developed.[7-8] The rate of this potentially devastating complication is at least 4%.[9] Avascular necrosis of the femoral head is caused by the injury of the blood vessels in the proximal femoral area during the insertion of the rigid interlocking nail through the pyriformis fossa, and it has been reported to be caused by the injury of the medial circumferential femoral artery.[8,10-11] Therefore, it has been reported that the complication was not developed by the insertion of rigid interlocking nail to the greater trochanter tip.[9,12-15]

But, the insertion through the greater trochanter tip causes new complication, which is valgus deformity due to the growth arrest of the proximal femur during the fusion of the physis of the greater trochanter. Gonzalez et al[16] and Raney et al[17] have reported that after the insertion to the greater trochanter tip, complications such as the valgus deformity of the proximal femur and the decrease of the width of femoral head were developed.

It has been reported that as a new surgical technique for such complications, by the use of rigid interlocking humeral nail that has a narrow width and easy to insert, it was inserted to lateral transtrochanter, and complications such as avascular necrosis in the femoral head as well as valgus deformity of proximal femur were not developed.[5,12] Pediatric locking nail system is

commercialized for the adolescent in some countries, but most countries inclusive of South Korea have limited accessibility and availability to the brand new implant.

Therefore, in our study, we evaluated treatment outcomes and the complications in cases using rigid interlocking humeral nails as a treatment method for the femoral shaft fracture in older children and adolescent.

II. MATERIALS AND METHODS

Patients

After obtaining approval from our institutional review board, we conducted a retrospective analysis of all femur fractures treated in our institution between February 2003 and January 2010. Operative reports were reviewed and those managed with undreamed humoral nail were selected for further review. The medical records and radiographs of the patients were reviewed, and a database was constructed. The data that were collected for the study included the age, past history, mechanism of injury, combined injuries, physeal closure, fracture location (proximal, middle, distal) and type (transverse, oblique, spiral), whether the fracture was open or closed, operation time, estimated bloode loss, method and duration of postoperative immobilization, follow-up periods, and major or minor complications.

The subjects were 23 pediatric patients. One pediatric patient has bilateral femoral shaft fracture, and thus the subject was total 24 cases. The mean age of patients at the time of injury was 12 years and 8 months (range, 8 years 11 months ~ 16 years 1 months). The mean weight of patients was 49.4 kg (range, 38 ~ 65 kg). The male was 20 patients in 21 cases, the female was 3 patients in 3 cases. The right side was 14 cases, the left was 8 cases, and both sides were 1 case. The mechanism of injury included traffic accident in 6, falls in 1, and sports injury in 10 cases. Seven patients sustained pathologic fractures

through underlying disease, simple bone cyst in 2, fibrous dysplasia in 1, burkitt lymphoma in 1, osteogenesis imperfecta in 2 patients. As the fracture location, the proximal area was 12 cases (50 %) and the middle area was 12 cases (50 %), and as for the fracture pattern, oblique fracture was 12 cases (50 %), transverse fracture was 7 cases (29%), and spiral fracture was 5 cases (21 %). None of them had complex fracture, and 2 cases had combined injury simultaneously. The mean interval from injury to surgery was average 1.5 days, and among total 24 cases, surgery was performed within 2 days in 23 cases, and 6 days after injury in 1 patient with head injury. (Table I)

Implants

In all cases, internal fixation via the greater trochanter area using the AO titanium humeral rigid interlocking unreamed nail was performed. This nail was flexed by 5 degrees medial proximally without bending distally, so it could be inserted easily from the tip of the greater trochanter (Fig 1). In that place the diameter has two types, 6.7 mm and 7.5 mm which are adequate for pediatric femoral diameter, and the average width of the isthmus of the subject of our study was about 7.9 mm (7.6 - 8.8 mm), therefore in all our cases, 6.7 mm diameter nails were used. The length has four types, 190 mm, 220 mm, 280 mm, and 325 mm, and they were used according to the femoral length of pediatric patients variably.

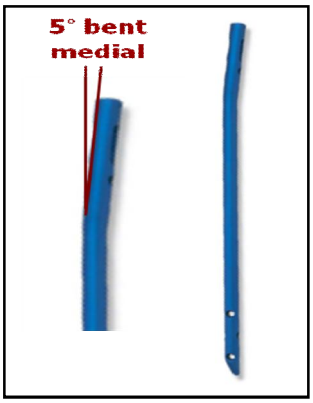

Fig. 1 The design of unreamed humeral nail shows the bending of proximal nail end by 5° medially.

Table 1. Summary of cases.

Patient	Age (years)	Height(cm)/ Weight(Kg)	Side	Past History	Mechanism of injury	Combined injury	Fracture location	Fracture type
1	M/12^{+8}	169/61	Right	No	Pedestrian TA§	No	Proximal 1/3	Spiral
2	M/10^{+1}	145/43	Right	No	Pedestrian TA§	EDH$^{\|\|}$, Skull Fracture	Mid 1/3	Transverse
3	M/11^{+9}	151/45	Right	No	Sports	No	Proximal 1/3	Spiral
4	F/12^{+10}	152/44	Left	No	Sports	No	Proximal 1/3	Oblique
5	M/8^{+11}	136/33	Left	No	Fall	No	Proximal 1/3	Spiral
6	M/9^{+9}	132/37	Right	No	Sports	No	Middle 1/3	Transverse
7	M/15^{+3}	153/48	Left	OI*	Pathologic Fracture	No	Middle 1/3	Transverse
7	M/15^{+7}	153/48	Right	OI*	Pathologic Fracture	No	Middle 1/3	Oblique
8	M/15	158/58	Right	SEP†	Sports	No	Middle 1/3	Transverse
9	M/15^{+6}	169/62	Right	OI*	Pathologic Fracture	No	Proximal 1/3	Transverse
10	M/13^{+1}	160/53	Left	SBC‡	Pathologic Fracture	No	Middle 1/3	Spiral
11	M/14^{+6}	165/65	Right	SEP†	Sports	No	Proximal 1/3	Transverse
12	F/16^{+1}	162/57	Left	No	Sports	No	Middle 1/3	Transverse
13	M/13^{+3}	170/59	Right	FD**	Pathologic Fracture	No	Proximal 1/3	Oblique
14	M/14^{+11}	173/59	Left	No	Motorcylcle TA§	No	Middle 1/3	Spiral
15	M/11^{+4}	146/47	Left	No	Sports	Forearm Fracture	Middle 1/3	Transverse
16	M/10^{+4}	133/40	Right	No	Sports	No	Middle 1/3	Oblique
17	M/10	140/41	Right	No	Pedestrian TA§	No	Proximal 1/3	Oblique
18	M/14^{+3}	165/60	Right	No	Sports	No	Middle 1/3	Oblique
19	M/14^{+5}	167/56	Right	SBC‡	Pathologic Fracture	No	Proximal 1/3	Oblique
20	M/13^{+3}	138/42	Right	BL	Pathologic Fracture	No	Middle 1/3	Oblique
21	M/12	153/49	Left	No	Sports	No	Middle 1/3	Spiral
22	M/10^{+2}	133/40	Left	No	Pedestrian TA§	No	Proximal 1/3	Oblique
23	F/9^{+5}	130/38	Right	No	Pedestrian TA§	No	Proximal 1/3	Oblique

OI*: Osteogenesis imperfect, SEP†: Static encephalopathy, SBC‡: Simple bone cyst
FD**: Fibrous dysplasia, BL : Burkitt Lymphoma, TA§: Traffic accident, EDH$^{\|\|}$: Epidural hematoma,

Surgical Technique

Prior to surgery, long leg splints were used for the temporary immobilization in all the cases, and through the anteroposterior as well as the lateral radiographs of the healthy femur, the minimal internal diameter of the bone marrow cavity was measured. Surgery was performed by one surgeon in our hospital under general anesthesia, in supine position, and on a fracture table

with the foot in a padded boot. The lower extremity was prepared and draped using split sheets to allow access to the hip and thigh. A direct lateral skin incision was made extending proximally from the tip of the greater trochanter, splitting the gluteus maximus muscle, and identifying the tip of the greater trochanter. A curved awl is used to mark the entry point at the tip of the greater trochanter and this position is confirmed on image intensifier. The awl was inserted through the cortex, and a threaded guide wire was drilled through the tip of the greater trochanter into femoral canal. The guide wire was positioned in line with the femoral medullary canal and accurate positioning was verified with image intensifier in both anteroposterior and the lateral projections. The guide wire was advanced into the canal to the level of fracture. The fracture was then reduced and the guide wire was passed down fracture site. The reaming was not performed, and after removing the guide wire, rigid interlocking humeral nails were inserted. The nail is impacted into position until its tip is flush with the tip of the greater trochanter. Proximal interlocking is then carried out with use of the guide, and distal interlocking can be carried out with use of a free-hand technique. Surgery was completed with no cast immobilization. From the next day of surgery, active quadriceps strengthening exercise and range of motion exercise of knee joint was performed, and upon the severity of pain, partial weight loading using crutches was initiated, and upon the confirmation of the union during follow up period, total weight loading was initiated.

Follow-up

After surgery, through the follow-up clinical examination and anteroposterior and lateral radiographs, the presence of the bony union in the fracture area and deformity was evaluated, and the each deformity of the proximal femur was evaluated by measuring the neck-shaft angle and articulotrochanteric distance [5]. All radiographs were made with the patella

facing straight ahead. Union of the fracture was assessed by standard radiological and clinical criteria. Clinically the bony union was defined as the loss of tenderness and pain, observation of the formation of callus in the upper as well as the lower area of fracture, or the loss of fracture line in the bony trabeculae passing through the fracture area radiologically. Measurements including the neck-shaft angle (NSA) of femur of the affected side and the articulotrochanteric distance (ATD) were performed on both hips in the final standing anteroposterior radiograph. The leg length discrepancy was evaluated by scannogram, and in addition, by physical examination, limping during walking and the presence of the femoral rotation, the pain in the knee joint area and the presence of the restriction of movement were observed for functional outcome.

Statistical Analysis

The Wilcoxon signed-rank test (two-tailed) was used to compare the outcomes of intragroup observations. In all analyses, $p < 0.05$ was considered significant.

III. RESULTS

The mean follow up period was 21 months (range, 12 ~ 37 months). All patients healed at a mean of 8 weeks by secondary healing (range, 6 ~ 9 weeks). No patient developed a nonunion or a delayed union. The mean operation time was 120 minutes (range, 90 ~ 150 minutes), open reduction was performed in none of cases, and none of patients received blood transfusion. Postsurgical nerve injury and blood vessel injury were not detected, and during surgery, additional complications were not developed.

Clinically, from postoperative 8 weeks, all pediatric patients were able to walk with full weight bearing. Limitations of knee joint motion as well as pain were not shown, and limping or gait abnormality was not shown. No patient

had clinically significant malrotation. No clinical sign and symptoms indicative of hip osteonecrosis

Radiologically, in all pediatric patients until the final follow up observation, avascular necrosis in the femoral head was not detected. Radiographic changes in the proximal part of the femur were also minimal. The neck shaft angle of the proximal femur prior to surgery was average 135.8 degrees (range, 128.1° ~ 145.7°), and at the postoperative final follow up observation, it was average 134.8 degrees (range, 123.7° ~ 142.5°). The mean neck shaft angle difference was 1.0° (range, -9.3° ~ 8.3°). The change in the mean neck shaft angle was not significant ($p = 0.29$). None of patients showed varus deformity as well as valgus deformity more than 10 degrees. The initial articulotrochanteric distance was average 22.7 mm (range, 14.5 ~ 31.6 mm) and after surgery it was average 22.1 mm (range, 12.0 ~ 30.0 mm). The mean articulotrochanteric distance difference was 0.6° (range, -8.8° ~ 4.6°). The change in the mean articulotrochanteric distance was not significant ($p = 0.33$), and none of patients showed more than 10 mm change (Table 2). At the final follow up examination, all the patients were taken scannogram, and none of patients showed malalignment. The leg length discrepancy was not detected in any patient(Fig. 2 A-D).

Table 2. Results.

	Mean Preop.	Mean Postop.	Mean change	P value
NSA* (°)	135.8	134.8	1.0	0.29
ATD† (mm)	22.7	22.1	0.6	0.33

NSA*: Neck shaft angle,

ATD†: Articulotrochanteric distance.

Fig.2-A

Fig.2-B

Fig.2-C

Fig.2-D

Fig. 2A-D. An 11+9years old boy (Patient No.3) had a shaft fracture of the femur. Preoperative anteroposterior and lateral radiographs (A) show the proximal 1/3 shaft spiral fracture. Immediate postoperative anteroposterior and lateral radiographs (B) show the internal fixation with unreamed humeral nail via the tip of the greater trochanter. Postoperative 3 months follow-up anteroposterior and lateral radiographs (C) show bony union without complications. The boy has neither subjective nor objective discomfort with full weight bearing gait. Postoperative 15 months Scanogram (D) after hardware removal show no leg length discrepancy deformity and distortion of the proximal femoral area.

IV. DISCUSSION

For the treatment of pediatric femoral shaft fracture, treatment method is determined generally by the age of patient, weight, the presence or absence of injury in other areas, the condition of the skin and soft tissues, the location and displacement of fracture, the experience or preference of clinician, etc. Within these factors, the age of patient is the most important variable for the choice of treatment method, and for the adolescent age group older than 11 years, similar to adults, firm internal fixation using intramedullary nailing has been generally performed. Cuttica[18] concluded that the use of elastic nails in children over the age of 8 years lead to greater incidence of both malunion and implant irritation. Considering these, we included our patients over the age of 8 years in this study. Although the range of patients' age was wide (range, 8 years 11 months ~ 16 years 1 months), five of 8 patients over the age of 14 years had pathologic fracture due to underlying disease and the remaining 3 patients had thin feature and low weight. So, they were not appropriate for treatment with intramedullary nail for adults. The recent studies have suggested that complications are more common in heavier patients (> 40 Kg) treated with flexible[18]. The mean weight of patients was 49.4 kg. Therefore, most of all patients were treated by rigid humeral nail. Although some patients (3 cases) in this study had a lower weight than 40 kg, we included these patients in our study because we thought rigid humeral nail led to firm fixation for fracture and had more advantages when compared flexible nail.

The procedure of internal fixation with the flexible intramedullary nail is relatively simple, and the one of the most important cause to the surgeons who prefers this implant is that the blood supply in the fracture area is preserved. Because flexible intramedullary nail can be simply inserted in the narrow canal, it is usually no harm to the growth plate and important blood supply.[19-21] And at the same time, bony union is fast, and early weight bearing

is possible.[22] On the other hand, in comparison with rigid interlocking nail, postoperative fixation immediately after surgery is less firm, the angular and rotational deformity may be developed, and after complications, incorrect alignment in approximately 12 % has been reported, and approximately 3 % develops the discrepancy of the lower extremities**.** In addition, the flexible technique-related complications were about 12% in many articles with flexible nailing.[23-25] Rigid interlocking nailing shows early bony union and a high union rate, early weight bearing is possible, and firm fixation could be obtained by the insertion of screws to the proximal area and the distal area, and the malalignment complication could be resolved, these things mean that the shortcomings of flexible intramedullary nails could be compensated.[26] Moreover, rigid intramedullary nailing is useful for unstable shaft fracture patterns with comminution, shortening, or locations difficult to treat by other means.[9]

Basically there are major historical drawbacks in rigid intramedullary nailing since Kuntscher et al[27] have reported that in children, the blood vessel injury was developed in the femoral neck area after rigid interlocking intramedullary nailing, and according to the recent reports, the incidence was 0-5 %.[24,28-29] Mani et al[30] even reported that reamed intramedullary nails have fallen out of favor because of their association with growth arrests of the greater trochanter apophysis and avascular necrosis of the capital femoral epiphysis. Nail insertion into the pyriformis fossa causes the medial femoral circumflex arterial injury that supplies the blood of the femoral head, and as additional causes, while performing reaming, the impairment of the blood supply to the femoral head is caused. Moreover regarding the insertion of nail through the pyriformis fossa in the axis of the femur, it has been reported to be difficult to approach, particularly in obese pediatric patients. Although the insertion through the greater trochanter may injure the gluteus medius muscle attached to the greater trochanter, it has advantages that it could be reached

through even a small surgical incision, and it means that operation time could be shortened. For this, Townsend et al[15] have reported that by the application of rigid interlocking nails to the greater trochanter instead of the pyriformis fossa, avascular necrosis in the femoral head could be prevented. However, by the application of the greater trochanter as the entry point, the coxa valga deformity developed secondarily due to the growth arrest of the physis of the greater trochanter.[28] Though this new complication was suggested by some authors, the growth of the greater trochanter and the femoral neck is not significantly influenced by the insertion of rigid interlocking screws or rigid interlocking nails to the proximal area through the physis of the greater trochanter. The physis of the greater trochanter has been reported to affect the growth of the greater trochanter as well as the varus and valgus of the femoral neck, nevertheless, even if the growth of greater trochanter were ceased, it does not mediates a great influence clinically. Momberger et al[13] reported 48 patients (average 13.2 years old) with femoral shaft fractures treated with various intramedullary rigid nailing and no patient developed significant proximal femoral deformity. On the other hand, Ziv et al[29] have reported that in 4 among 17 patients, Kuntscher nails through the greater trochanter made the articulotrochanteric distance slightly increased about 0.5-1 cm in younger age relatively. However, in pediatric patients older than 8 years, some authors reported that the fusion of the apophysis was performed for the correction of coxa valga, though more than 50 % growth of the greater trochanter was progressed already, and it was not effective to coxa valga deformity.[31] This means trochanteric arrest have little clinical significance even it happens. The tip of the greater trochanteric as entry in our study is more supportive by these recent studies rather than lateral entry with commercialized pediatric femoral nail in adolescent patients. Technical modification is also very important in choosing the entry portal around the greater trochanter and the trochanter-pyriformis junction by avoiding any dissection medially and

posteriorly along the femoral neck. Technique related complications should be avoided by all means.

Although clinically coxa valga does not appear to be significant, Gordon et al[5,12] attempted to prevent coxa valga deformity by the insertion of humeral rigid interlocking nails to the greater trochanter. The nail used in this study has a 10° apex medial, proximal bend 4.5 mm from proximal end of the nail, so the insertion was easy. In addition, the internal lumen was narrow, therefore, even if it were inserted to the greater trochanter, it did not influence the physis, and attempts were made to minimize injury by inserting intramedullary nail to the more lateral side than the greater trochanter.

Considering such complications, the diameter of the humeral rigid interlocking nails used in our experiment was 6.7 mm, which was thought to be appropriate for the femoral shaft of the subject pediatric patients, and efforts were made to reduce the possibility of injury to the physis of the greater trochanter. The greater trochanter instead of the pyriformis fossa was selected as the entry point, and it appears that femoral avascular necrosis did not occur since reaming was not performed to minimize the injury of the endosteal blood flow. The proximal portion of nail was flexed medially by 5 degrees, and thus it was difficult to insert to the lateral greater trochanter area, and the apex of greater trochanter was used as the entry point, however, in all patients, the alteration of the femoral neck shaft angle was less than 10 degrees, and that of articulotrochanteric distance difference was also less than 10 mm on average, and the development of coxa valga was not detected in any case. In addition to such problems, the ideal entry point for rigid interlocking nails is still controversial.

In these days, pediatric femoral nail is commercialized in some countries. This nail is especially appropriate for the preadolescent age group, however, many countries including the South Korea is not accessible to use this nail. In this study we used humeral nail for the pediatric femur fracture, and the

anatomical advantage in figure is fit for it, but it has some limitations. Though there are no complications like nail breakage or failure in long term follow-up in this study, humeral nail itself is not appropriate for the weight bearing bone. Because humeral intramedullary nail was initially designed for the non-weight bearing bone, further study is required for using axial loading bone.[32] In our study, we use the entry via the tip of greater trochanter and all cases are over 8 years old with the easy, readily accessible implant, so these preconditions make no major complication finally during follow-up.

There are no previous studies with rigid humeral unreamed interlocking intramedullary nailing on the pediatric femoral fracture through the tip of the greater trochanter in vivo, and we present easy way by the familiar implant with safety. Gordon et al[5] use humeral nail via rather lateral entry for protecting proximal femoral area, however it can run the risk of eccentric reaming, nail jamming, comminution of proximal fractures, and postoperative varus deformity.[33] Major strong point of the implantation should endanger neither the physis nor the blood supply to the femoral head especially in pediatric patient group.[4,34] This make many surgeons prefer flexible nails than rigid ones. If rigid nail is also free from the injury of the physis or the blood supply, we have to consider the better implant as a original object for the fracture itself because the flexible nails have a lot of problem like nail tip pain about 7% to 40%.[19]

This study has some limitations. Our study design was retrospective, the number of patients was small. There was surgeon's selection bias in selecting patients for this study. In addition, we did not have a comparison group. Therefore, the comparative assessment between patients treated with and without interlocking humeral nail was not possible.

V. CONCLUSION

In conclusion, for the treatment of femoral shaft fracture in older children and adolescent, by the use of humeral rigid interlocking nails, and inserted to the tip of the greater trochanter, bony union could be obtained without the major complications like avascular necrosis in the femoral head or coxa valga deformity of the proximal femoral area. Use of rigid humeral nail for the femoral fractures in older children and adolescent is thought to be a safe and effective method especially for the condition that the pediatric femoral nail is unavailable.

REFERENCES

1. Rewers A, Hedegaard H, Lezotte D, Meng K, Battan FK, Emery K, et al. Childhood femur fractures, associated injuries, and sociodemographic risk factors: a population-based study. Pediatrics 2005;115:e543-52.
2. Sahlin Y. Occurrence of fractures in a defined population: a 1-year study. Injury 1990;21:158-60.
3. McCartney D, Hinton A, Heinrich SD. Operative stabilization of pediatric femur fractures. Orthop Clin North Am 1994;25:635-50.
4. Flynn JM, Luedtke L, Ganley TJ, Pill SG. Titanium elastic nails for pediatric femur fractures: lessons from the learning curve. Am J Orthop 2002;31:71-4.
5. Gordon JE, Khanna N, Luhmann SJ, Dobbs MB, Ortman MR, Schoenecker PL. Intramedullary nailing of femoral fractures in children through the lateral aspect of the greater trochanter using a modified rigid humeral intramedullary nail: preliminary results of a new technique in 15 children. J Orthop Trauma 2004;18:416-22; discussion 23-4.
6. Kraus R, Schiefer U, Schafer C, Meyer C, Schnettler R. Elastic stable intramedullary nailing in pediatric femur and lower leg shaft fractures: intraoperative radiation load. J Pediatr Orthop 2008;28:14-6.
7. Astion DJ, Wilber JH, Scoles PV. Avascular necrosis of the capital

femoral epiphysis after intramedullary nailing for a fracture of the femoral shaft. A case report. J Bone Joint Surg Am 1995;77:1092-4.

8. Beaty JH, Austin SM, Warner WC, Canale ST, Nichols L. Interlocking intramedullary nailing of femoral-shaft fractures in adolescents: preliminary results and complications. J Pediatr Orthop 1994;14:178-83.
9. Buford D, Jr., Christensen K, Weatherall P. Intramedullary nailing of femoral fractures in adolescents. Clin Orthop Relat Res 1998:85-9.
10. Mileski RA, Garvin KL, Huurman WW. Avascular necrosis of the femoral head after closed intramedullary shortening in an adolescent. J Pediatr Orthop 1995;15:24-6.
11. O'Malley DE, Mazur JM, Cummings RJ. Femoral head avascular necrosis associated with intramedullary nailing in an adolescent. J Pediatr Orthop 1995;15:21-3.
12. Gordon JE, Swenning TA, Burd TA, Szymanski DA, Schoenecker PL. Proximal femoral radiographic changes after lateral transtrochanteric intramedullary nail placement in children. J Bone Joint Surg Am 2003;85-A:1295-301.
13. Momberger N, Stevens P, Smith J, Santora S, Scott S, Anderson J. Intramedullary nailing of femoral fractures in adolescents. J Pediatr Orthop 2000;20:482-4.
14. Timmerman LA, Rab GT. Intramedullary nailing of femoral shaft fractures in adolescents. J Orthop Trauma 1993;7:331-7.
15. Townsend DR, Hoffinger S. Intramedullary nailing of femoral shaft fractures in children via the trochanter tip. Clin Orthop Relat Res 2000:113-8.
16. Gonzalez-Herranz P, Burgos-Flores J, Rapariz JM, Lopez-Mondejar JA, Ocete JG, Amaya S. Intramedullary nailing of the femur in children. Effects on its proximal end. J Bone Joint Surg Br 1995;77:262-6.
17. Raney EM, Ogden JA, Grogan DP. Premature greater trochanteric

epiphysiodesis secondary to intramedullary femoral rodding. J Pediatr Orthop 1993;13:516-20.

18. Cuttica D, Klingele K. Pediatric diaphyseal femur fractures ; a comparison of outcomes between flexible intramedullary nailing versus rigid intramedullary nailing. POSNA, Boston 2009;May 2.
19. Aksoy MC, Caglar O, Ayvaz M, Yazici M, Alpaslan AM. Treatment of complicated pediatric femoral fractures with titanium elastic nail. J Pediatr Orthop B 2008;17:7-10.
20. Kanellopoulos AD, Yiannakopoulos CK, Soucacos PN. Closed, locked intramedullary nailing of pediatric femoral shaft fractures through the tip of the greater trochanter. J Trauma 2006;60:217-22; discussion 22-3.
21. Mehlman CT, Nemeth NM, Glos DL. Antegrade versus retrograde titanium elastic nail fixation of pediatric distal-third femoral-shaft fractures: a mechanical study. J Orthop Trauma 2006;20:608-12.
22. Corry IS, Nicol RO. Limb length after fracture of the femoral shaft in children. J Pediatr Orthop 1995;15:217-9.
23. Bopst L, Reinberg O, Lutz N. Femur fracture in preschool children: experience with flexible intramedullary nailing in 72 children. J Pediatr Orthop 2007;27:299-303.
24. Carey TP, Galpin RD. Flexible intramedullary nail fixation of pediatric femoral fractures. Clin Orthop Relat Res 1996:110-8.
25. Gardner MJ, Lawrence BD, Griffith MH. Surgical treatment of pediatric femoral shaft fractures. Curr Opin Pediatr 2004;16:51-7.
26. Winquist RA, Hansen ST, Jr., Clawson DK. Closed intramedullary nailing of femoral fractures. A report of five hundred and twenty cases. 1984. J Bone Joint Surg Am 2001;83-A:1912.
27. Kuntscher G. [Intramedullary nailing of comminuted fractures]. Langenbecks Arch Chir 1968;322:1063-9.
28. Galpin RD, Willis RB, Sabano N. Intramedullary nailing of pediatric

femoral fractures. J Pediatr Orthop 1994;14:184-9.

29. Ziv I, Blackburn N, Rang M. Femoral intramedullary nailing in the growing child. J Trauma 1984;24:432-4.
30. Mani US, Sabatino CT, Sabharwal S, Svach DJ, Suslak A, Behrens FF. Biomechanical comparison of flexible stainless steel and titanium nails with external fixation using a femur fracture model. J Pediatr Orthop 2006;26:182-7.
31. Litt R, Albassir A, Willems S, Debry R. [Coxa vara. Isolated growth of the greater trochanter. Prevention-treatment]. Acta Orthop Belg 1990;56:301-6.
32. Bienkowski P, Harvey EJ, Reindl R, Berry GK, Benaroch TE, Ouellet JA. The locked flexible intramedullary humerus nail in pediatric femur and tibia shaft fractures: a feasibility study. J Pediatr Orthop 2004;24:634-7.
33. Georgiadis GM, Olexa TA, Ebraheim NA. Entry sites for antegrade femoral nailing. Clin Orthop Relat Res 1996:281-7.
34. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. J Pediatr Orthop 2001;21:4-8.

ABSTRACT(IN KOREAN)

상완골 교합성 골수정을 이용한 소아 및 청소년의 대퇴골 간부 골절의 치료

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박 훈

목 적: 청소년에 있어서는 견고한 내고정술을 시행하는 것이 일반적이다. 하지만 많은 저자들이 대퇴골 교합성 내고정술을 시행한 후에 합병증이 나타났다고 하였다. 이에 소아 및 청소년의 대퇴골 간부 골절에서 상완골용 교합성 골수정을 이용한 치료에 대하여 보고하고자 한다.

대상 및 방법: 상완골용 교합성 골수정을 이용하여 대퇴골 간부 골절을 치료 받은 환아를 대상으로 한 후향적 연구로, 방사선 사진의 추적 관찰을 통하여 골절부의 합병증 유무를 평가하였다.

결 과: 23명의 환자, 24예의 환자를 대상으로 수상 당시 평균 연령은 12세 8개월이었으며, 술 후 추시 기간은 평균 21개월이었다. 수술 후 감염이나 불유합, 하지 부동, 내고정물 파손과 같은 합병증은 발생하지 않았으며, 전 예에서 평균 8주안에 골 유합을 얻을 수

있었다. 근위 대퇴부의 외반 변형이나 대퇴골 두의 무혈성 괴사는 관찰 되지 않았다. 수술 전후의 대퇴경부 간부 각도(P = 0.29) 및 대퇴골두 대전자간 거리(P = 0.33)의 변화는 없었다.

결 론: 소아 및 청소년의 대퇴골 골절에서 상완골용 교합성 골수정을 대전자부에서 삽입하여 고정하는 것이 효과적이고 안전한 치료가 될 수 있다.

핵심되는 말 : 소아, 청소년, 대퇴골 간부 골절, 상완골용 교합성 골수정, 대전자부