



Titanium elastic nail fixation for paediatric femoral and tibial fractures

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The aim of this prospective study was to evaluate the results of treatment of paediatric femoral and/or tibial diaphyseal fractures with titanium elastic nails (TENs).

Sixty six patients with 48 femoral and 25 tibial fractures were followed-up for 15 to 24 months. The outcome rating system proposed by Flynn *et al* was used to evaluate the final results.

Most patients (56.1%) were operated between 2 to 4 days after injury ; a traction table was used in 54.8% of cases. The average operative time was 28 minutes, and the average hospital stay was 5.7 days. Post-operative immobilisation was used in 30% of cases, mostly with femoral fractures. The fractures united in an average time period of 85 days ; 89% had united within 3 months. The nails were removed in 87.8% of cases after an average of 5.9 months. The following complications were noted : soft tissue and skin problem (9.1%) in relation to nail ends at the entry points, limb-length discrepancy (9.1%), malunion (4.5%). Based on Flynn *et al*'s outcome rating system, 75.8% of the results were excellent, 24.2% were satisfactory and there were no poor results.

With good knowledge of the technique of TEN fixation for paediatric femoral and tibial fractures, excellent and satisfactory results were achieved in all cases, with few minor complications. TENs can give stable fixation allowing early mobilisation and shorter hospitalisation with less disruption of patient and family life.

Keywords : titanium elastic nail ; paediatric femoral and tibial fractures.

INTRODUCTION

Treatment of paediatric fractures dramatically changed in 1982, when Métaizeau and the team from Nancy, France, developed the technique of flexible stable intramedullary pinning (FSIMP) using titanium pins (18,19). In the last two decades there was an increased interest in the operative treatment of paediatric fractures, although debate persisted over its indications (1).

There is a little disagreement concerning the treatment of long bone fractures in children less than 6 years (POP cast) and adolescents older than 16 years (locked intramedullary nailing). Controversy persists regarding the age between 6 to 16 years, with several available options : traction followed by hip spica, external fixation, flexible

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stable intramedullary nails (Ender or titanium), plate fixation, and locked intramedullary nailing (2,3,5,16,26).

Whatever the method of treatment, the goals should be to stabilise the fracture, to control length and alignment, to promote bone healing, and to minimise the morbidity and complications for the child and his/her family (20,25).

Orthopaedic surgeons will continue to be challenged to treat this age group with less morbidity at a lower cost, as no clear guidelines have been available until now despite efforts done initially by French surgeons, later on by European surgeons and recently by the Paediatric Orthopaedic Society of North America (POSNA) (1,2,6,9,15,17-19,24,30).

Titanium elastic nail (TEN) fixation was originally meant as an ideal treatment method for femoral fractures, but was gradually applied to other long bone fractures in children, as it represents a compromise between conservative and surgical therapeutic approaches with satisfactory results and minimal complications (2,6,9,15,18,19,24,30).

The aim of this prospective clinical study was to evaluate the results of operative treatment of paediatric femoral and tibial fractures in the age group between 5 to 16 years using titanium elastic nails (TENs), with follow-up of 12 to 24 months.

MATERIALS AND METHODS

This study was designed as a prospective clinical study to assess the results of operative treatment of paediatric femoral and tibial fractures treated in King Saud Hospital, Unaizah, Al-Qseem and King Fahad Specialist Hospital, Al-Madina, Kingdom of Saudi Arabia between December 2005 and December 2007. Inclusion criteria were : age above 5 years and below 16 years with traumatic closed or open femoral and/or tibial fractures at mid-shaft and junctional upper-middle third or lower-middle third. Patients with extreme proximal or distal femoral and/or tibial fractures closer to the epiphyseal plate and patients with grade III C open femoral and/or tibial fractures were excluded from the study. Patients with incomplete clinical and/or radiological data, patients with pathological fracture, and patients with follow-up less than one year were also excluded from the study.

Sixty six patients with 73 fractures (48 femoral and 25 tibial) were included in the study. There were 48 male (72.7%) and 18 female (27.3%) patients. Mean age at time of injury was 9.4 years (range : 5.2 to 15.3 years). Fifty fractures (68.2%) resulted from a road traffic accident, with 10 major and 12 minor associated injuries affecting the head in 9 patients, the mandible in 1, the clavicle in 2, the humerus in 3, the forearm in 3, the pelvis in 1 and a metatarsal in 1. Sixty six fractures were closed ; 7 were open. The fractures were midshaft in the femur or tibia in 47.9% of cases. The most common fracture pattern was transverse or oblique (table I).

Most fractures (56.1%) were operated between two and four days after injury. A traction table was used in 54.8% of cases, only with femoral fractures. All nails were inserted using a retrograde technique for femoral fractures whereas most of the tibial nails were inserted using the antegrade technique.

Surgical technique

A. Femoral fractures

Two retrograde TENs were used in all femoral fractures. A traction table was used in 40 cases ; an ordinary table was used in 8 patients, especially younger patients with transverse or short oblique fractures or in cases with open fractures with exposed bone ends. Intra-operatively full access to the x-ray image intensifier was ensured. Straight not preformed TENs of adequate size (not less than 40% of the narrowest diameter of the diaphysis) were used.

A 1-2-cm longitudinal skin incision was made over the medial and lateral surface of the distal femur, starting 2 cm proximal to the distal femoral epiphyseal plate ; a haemostat was used to split the soft tissue down to the bone, following which a 3.2 mm drill bit was used at a point 2.5 cm proximal to the distal femoral growth plate to open the cortex at a right angle ; the drill was then inclined 10° to the distal femoral cortex. A nail was introduced with a T-handle by rotation movements of the wrist. Under image intensifier control, the nail was driven with rotatory movement or with a hammer to the fracture site which was aligned to anatomical or near anatomical position with proper attention to limb rotation and length. By rotation movements of the T-handle with or without limb manipulation, the nail was directed to the proximal fragment which was pushed into better alignment by the nail. At the same time the second nail was advanced to enter the proximal fragment and in the meantime any traction was released to avoid any

Table I. — Fracture characteristics

Femoral Fractures		Tibial Fractures		
%	N°	%	N°	
88	22	91.6	44	<i>Fracture type</i>
12	3	8.3	4	– Closed
				– Open
60	15	41.6	20	<i>Fracture Level</i>
20	5	31.3	15	– Mid shaft
20	5	27.1	13	– Upper / middle 1/ 3 rd
				– Lower / middle 1/ 3 rd
40	10	33.4	16	<i>Fracture Pattern</i>
24	6	29.2	14	– Oblique
20	5	18.7	9	– Transverse
12	3	18.7	9	– Spiral
4	1	-	-	– Comminuted
				– Segmental



Fig. 1. — A : Closed fracture of the upper third of the right femur. B-C : radiographs showing full radiological union 13 weeks after retrograde TENs fixation. D-E : radiographs after TENs removal 25 weeks later.

distraction, and both nails were pushed further till their tips became fixed into the cancellous bone of the proximal femoral metaphysis without reaching the epiphyseal plate. The tips of the nail that entered the lateral femoral cortex should come to rest just distal to the trochanteric

epiphysis. The opposite nail should be at the same level towards the calcar region ; too short nails should be avoided. The two-nail construct should be in a symmetrical alignment face to face with the maximum curvature of the nails at the level of the fracture (fig 1, 2).

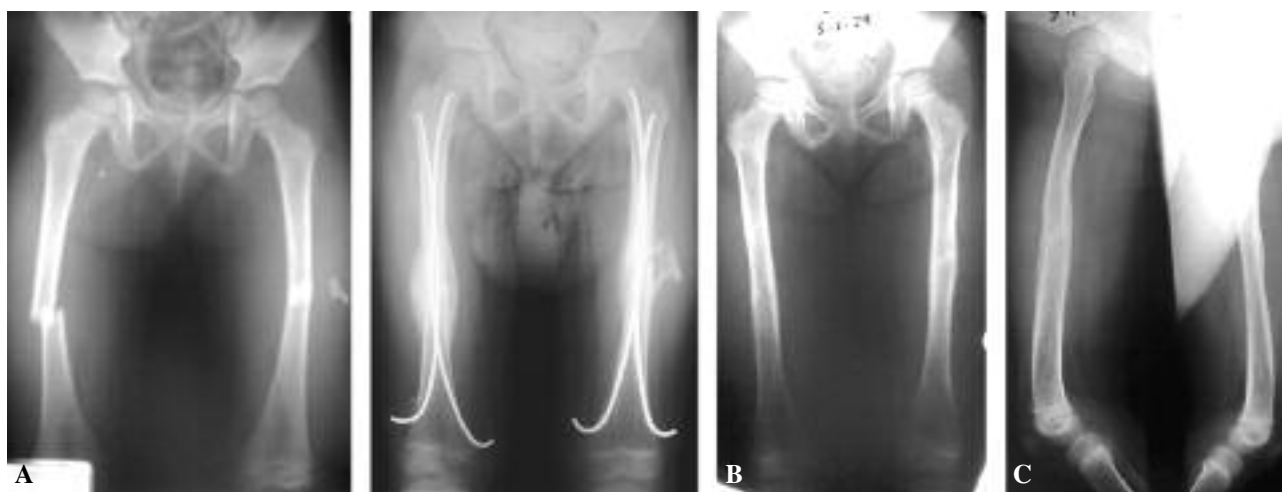


Fig. 2. — A : bilateral closed midshaft fracture of the femur. B : radiographs showing full radiological union 15 weeks after retrograde TENs fixation. C : radiographs after TENs removal 30 weeks later.

Distally the nails were cut leaving only 1-2 cm outside the cortex. The extra osseous portion of the nails was kept as it was or slightly bent away from the bone to facilitate removal later on. In all cases care was taken to use nails with similar diameters, to use the largest possible diameter, and to use the double C construct to ensure 3-point fixation. This allowed early mobilisation with touch weight-bearing, then partial followed by full weight-bearing once incipient callus formation was seen. This elastic fixation can to some extent allow anatomic correction of any distraction or translation during early limb loading.

The nails were inserted in a closed fashion in all cases except in one patient with a comminuted open junctional middle/lower third femoral fracture, in which an interposed bone fragment blocked the passage of the nail into the proximal fragment.

B. Tibial fractures

Two TENs were used in all cases using the double-C construct in antegrade fashion in most cases (fig 3) or retrograde in some cases. All nails were inserted on an ordinary operating table with full access to image intensifier. In children with ipsilateral femoral and tibial fractures, the tibial nails were inserted after femoral nails insertion.

The technique of TENs insertion was essentially similar to femoral nail insertion. Cases with tibial fracture associated with distal 1/3 fibular fracture were also fixed with antegrade TENs for the fibula before TENs fixation of the tibial fracture.

Postoperative care

Antibiotic prophylactic with cefuroxime was given to all patients for 2 days except in open fractures, where cefotaxime, cloxacilline, and metronidazole was administered for 5 to 7 days, followed by oral cefuroxime for another 2 weeks unless result of the swab culture taken on admission was different.

Depending on the age of the patient, patient compliance, fracture patterns, and quality of fixation, postoperative immobilisation ranged from no immobilisation to knee immobiliser, hip knee ankle foot orthosis (HKAFO), knee ankle foot orthosis (KAFO), hip spica, skin traction on a Thomas splint, or below knee cast with a bar. Postoperative immobilisation was advised for patients with femoral and/or tibial fractures either due to concerns about fracture pattern stability, fixation stability, non compliance of the patient, or in patients with low pain threshold. Post operative immobilisation was used for 3 to 6 weeks to support the limb with a weak quadriceps, to decrease postoperative pain, and to decrease soft tissue irritation at the entry points especially at the distal femur.

Documentation and follow-up

Special records were kept for every patient with all details related to the patient, the fracture, the surgical treatment, the postoperative evolution including complications such as malunion or limb-length discrepancy and pain.

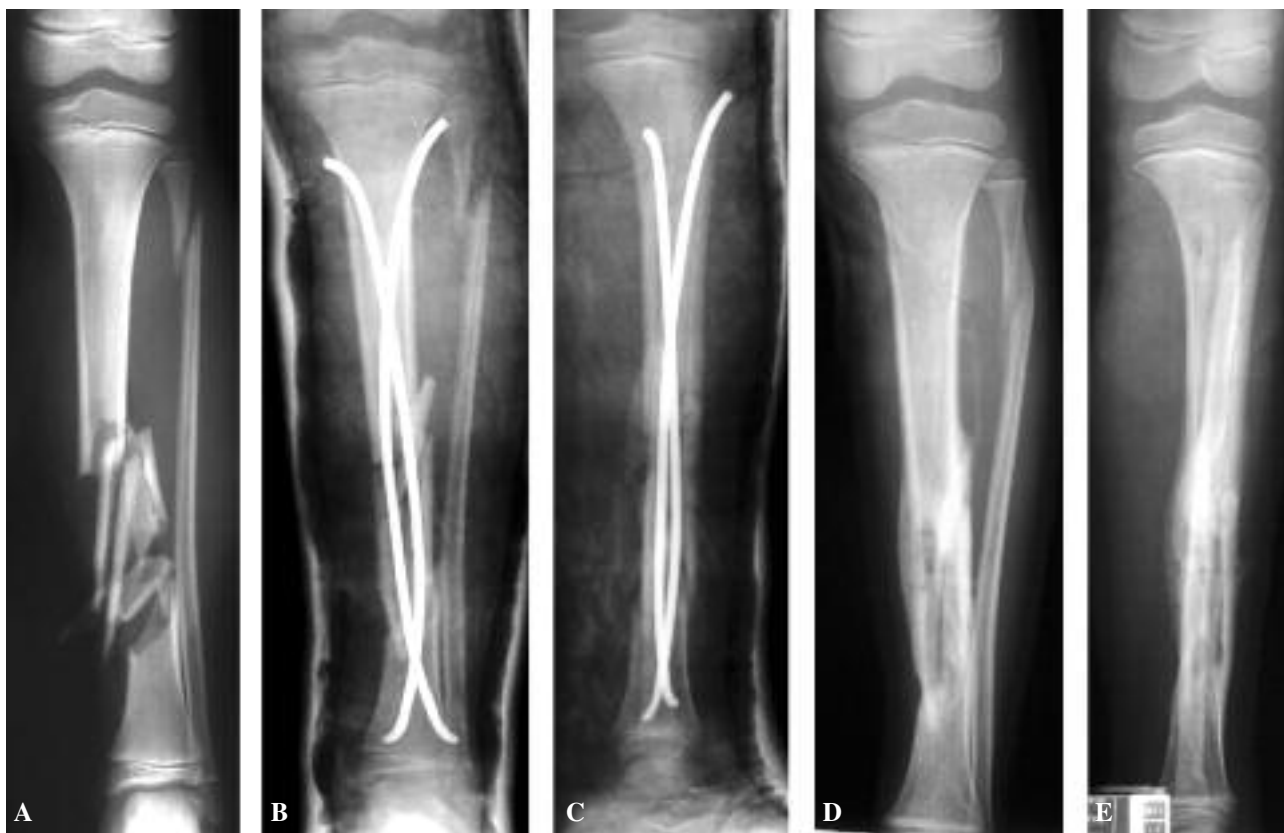


Fig. 3. – A : open (grade 3A) segmental fracture of both bones of the left leg. B-C : radiograph showing full radiological union 17 weeks after debridement, lavage and TENs fixation. D-E : radiographs after TENs removal 27 weeks later.

All patients were followed-up clinically every 2 to 3 weeks for assessment of hip, knee and ankle range of motion and any complications till complete bone healing, then every 3 months till the end of the follow-up period, which was at least 12 months.

Radiological follow-up included full-length antero-posterior and lateral radiographs at every clinic visit to check alignment, any loss of reduction, bone healing, and any implant related complications.

In cases with clinically detected limb-length discrepancy, a CT scanogram was done at the end of the follow-up. The TENs were removed after clinical and radiological union.

Assessment

At the end of the follow-up period, all patients were assessed clinically for any residual pain, limping, hip-knee-ankle range of motion, activity level, limb-length discrepancy, and any rotational malalignment of the involved extremity.

Radiological assessment was also done to assess the quality of bone healing, any malunion, and to measure limb-length discrepancy using plain radiographs and a CT scanogram. The outcome rating system proposed by Flynn *et al* (6) was used to evaluate the final clinical and radiological results (table II).

Statistical analysis

All data regarding the patient, fracture, operation, postoperative care, complication and results in the TENs outcome evaluation system were subjected to descriptive parametric statistical analysis.

RESULTS

Most fractures (56.1%) were operated between the second and the fourth day after admission. A traction table was used in 54.8% of cases (only with

Table II. — TENS outcome score (Flynn *et al* (6))

Poor results	Satisfactory results	Excellent results	
> 2.0 cm	< 2.0 cm	< 1.0 cm	* Limb-length inequality
> 10 degrees	10 degrees	5 degrees	* Malalignment
present	none	none	* Pain
Major and lasting morbidity	Minor and resolved	none	* Complication

Table III. — Operation details

%	N°	
20.6	15	<i>Time to Fixation :</i> – 1 st day
56.1	41	– 2 nd day – 4 th day
13.7	10	– 5 th day – 7 th day
9.6	7	– > 7 th day
54.8	40 (femoral)	<i>Traction table :</i> – yes
45.2	25 tibial + 8 femoral	– no
65.7	48 (femoral)	<i>Nailing Technique :</i> – Retrograde
30.1	22 (tibial)	– Antegrade
4.1	3 (tibia+fibula)	– Antegrade + Retrograde
97.2	47 femoral + 24 tibial	– Closed
2.8	1 femoral + 1 tibial	– Open
–	–	<i>Operation time :</i> – range : 15 minutes – 75 minutes
–	–	– mean : 28 minutes
–	–	<i>Radiation exposure time :</i> – range : (30 seconds – 135 seconds)
–	–	– mean : 69 seconds

femoral fractures). All nails were inserted using a retrograde technique for femoral fractures whereas most of the tibial nails were inserted using the antegrade technique (88%).

All nails were inserted in a closed fashion under fluoroscopy guidance, except in one open comminuted fracture of the distal femur and one open segmental mid-shaft tibial fracture. The average operative time for nail insertion was 28 minutes with a range of 15 to 75 minutes and the average time of radiation exposure was 69 seconds with a range of 30 to 135 seconds (table III).

The average hospital stay was 5.7 days with a range of 2 to 28 days. Twenty patients (33.3%) were given postoperative immobilisation ; a knee

immobiliser was the most commonly used method (50%). Most of the fractures united within 3 months (89%), and only 4.1% required 5 months to unite. Mean time to bone healing was 85 days, with a range between 42 to 140 days. The TENs were removed in 87.8% of patients, on average 5.9 months after operation (range, 3 to 9 months).

Sixteen complications were noted in 16.6% of patients. Most of these complications were transient and resolved completely without affecting the functional outcome and without requiring any surgical interference or readmission.

Soft tissue irritation in relation to the ends of the TENs at the entry points was reported in 9.1% of patients.

Limb lengthening was noted in 6% of patients with transverse or short oblique femoral fractures with an average of 1.1 cm lengthening (range : 0.8 to 2 cm). Limb-shortening was seen in two patients with an average of 0.7 cm (range : 0.4 to 1.2), one with a comminuted femoral fracture and the other with a spiral femoral fracture.

One comminuted femoral fracture healed with an 8° varus angulation, and another comminuted femoral fracture with a 10° valgus angulation. Another comminuted femoral fracture healed with a 5° flexion angulation .

There were no instances of osteitis or septic arthritis, rotational deformity, or pulmonary embolism ; there was also no refracture after nail removal and no need for any secondary surgical action or readmission after discharge, except for nail removal.

According to the outcome scoring system developed by Flynn *et al* (6), 75.8% of results were excellent and 24.2% were satisfactory. No poor results were noted in this study.

DISCUSSION

The decision regarding the best line of treatment of paediatric lower limb fractures is based on several factors : age of the patients, nature of the injury (isolated or combined), fracture type (open or closed), fracture pattern (stable or unstable), patient and family compliance, social, psychological and economic status, and finally the surgeon's preference (3,20,24-26).

Over the past 20 years, paediatric orthopaedists have tried a variety of methods to treat paediatric lower limb fractures to avoid prolonged immobilisation and complications. Each method has had its own complications : spica cast immobilisation alone or following traction had resulted in limb-length discrepancy, angulations, rotational deformity, psychological and economic complications (16,24,28). External fixation had resulted in pin-tract infection, loss of knee range of motion, delayed union, non-union, and refracture after fixator removal (5,20,26). Solid antegrade intramedullary nailing had resulted in avascular necrosis of the femoral head, trochanteric epiphysiodesis, and coxa valga (1,7,26).

The ideal device to treat paediatric femoral and/or tibial fractures should be a simple, load sharing internal splint, allowing early mobilisation while maintaining length and alignment for several weeks until bridging callus forms, without endangering the blood supply to the epiphysis (2,6,9, 15,18,19,24,30).

Ender nails are stainless steel implants that proved to be inadequate for adult femoral and tibial fractures but may be effective for paediatric fractures although they may be not elastic enough as their modulus of elasticity is higher than titanium nails.

TENs are more elastic, thus limiting the amount of permanent deformation during nail insertion ; they promote healing by limiting stress shielding in addition to their biocompatibility without metal sensitivity reactions (6,10-12,15,24).

The principle of Ender nail fixation is canal filling with the nails, while TENs work by balancing the forces between the two opposing flexible implants. To achieve this balance, the nail diameter should be 40% of the narrowest canal diameter or more ; the nails should assume a double-C construct. They should have similar smooth curve and same level entry points (14,15).

This study was designed to allow for a critical analysis of our experience with TENs for paediatric lower limb fractures after reviewing the theoretical background and other published data regarding this technique to master it first and to avoid all possible technical errors.

The retrograde femoral nailing technique was adopted in this study as it is easier, provides mechanical stability, and avoids the risk of fracture at the proximal entry points near the trochanteric region. Use of the antegrade technique was not required in our cases, which may be related to the fact that extreme distal femoral fractures close to the epiphyseal plate were excluded from this study. These fractures are indeed considered as non ideal indications, while extreme proximal femoral fractures are considered as non ideal indications for retrograde nailing due to the risk of complications such as loss of reduction, malunion, and rotational deformity (2,6,22,27,30).

In our opinion, the exact value of TENs fixation of extreme proximal or distal femoral fractures should be evaluated on a large scale.

Tibial nailing can be performed retrograde or antegrade, although the antegrade technique is easier and mechanically more stable with less soft tissue irritation, but in general there has been no difference in outcome.

Three fractures of the distal 1/3 of the fibula associated with tibial fractures were fixed with one antegrade TENs through a small incision in the middle or upper third before fixing the tibial fractures, without any complications.

Our average operative time, radiation exposure, hospital stay, bone healing time, and nail removal time were similar to other data in literature (2,6,9-11,14-15,17-19,25,30).

The development of the TENs fixation method has put an end to criticism of the surgical treatment of paediatric long bone fractures, as it avoids any growth disturbance by preserving the epiphyseal growth plate, it avoids bone damage or weakening through the elasticity of the construct, which provides a load sharing, biocompatible internal splint, and finally it entails a minimal risk of bone infection.

The low incidence of complications reported in this study especially for malunion and limb-length discrepancy may be related to exclusion of extreme proximal and distal femoral fractures, meticulous adhesion to all technical requirements of the technique, and the use of postoperative immobilisation in cases with concern about stability.

Although TENs fixation was used as early as 1982 by French surgeons, one of the main critics was the cost of treatment (4,21). Buechsenschuetz *et al* (2) have shown that TEN fixation of paediatric femoral fractures was associated with lower cost and comparable or even better clinical outcome in comparison to traction and casting.

Rotational malalignment was not noted in this study due to utmost care being taken during intra-operative limb positioning. Ligier *et al* (15) and Flynn *et al* (6) have reported a similar finding, supporting the concept that TENs can give rotational stability if good care is taken intra-operatively during nail insertion and postoperatively, especially for comminuted, spiral, and long oblique fractures.

It appears from this study that all cases with malunion and shortening were related to the latter

fracture types. Lengthening was associated with transverse fractures, which may be inevitable, but these complications need a longer follow-up to determine their persistence or correction. All complications noted in this study were related to femoral fractures. This observation is similar to O'Brien *et al* (22), Salem *et al* (23), and Vallamshetla *et al* (29); Goodwin *et al* (8) have reported minor complications in 26% of cases with TENs fixation for tibial fractures.

In conclusion, titanium elastic nail fixation is a simple, easy, rapid, reliable and effective method for management of paediatric femoral and tibial fractures between the age of 5 to 16 years, with shorter operative time, lesser blood loss, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing.

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