

Correlation between the Spanish patient's femoral biometrics and osteosynthesis with a long Gamma nail

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Purpose. To analyze the location of the long Gamma nail in the distal femoral shaft and to assess the possible complications derived from a poor biometric match between the implant and the femur

Materials and methods. Retrospective study of 69 long Gamma nails. To evaluate the position of the distal tip of the implant, a system of coordinates was designed at the distal femoral shaft and the distance from anteroinferior tip of the nail to the X and Y axes measured.

Results. Sixty-five nails (94.2%) were positioned ahead of the theoretical midline of the femoral shaft on the sagittal plane. Of these, 14 (20.2%) were in contact with the anterior cortex and 4 of these (5.7%) had impaled through the anterior cortex giving rise to the formation of a pedestal. Of the 42 shorter (340 mm) nails, 16 (38%) proved too long as they were located at the femoral metaphysis.

Conclusions. There is a clear conflict between the femoral biometry of our population and the length and curvature of the long Gamma nail, with a high incidence of poor implant positioning; nails could adopt an excessively anterior position and even impale through the anterior cortex. We think that long Gamma nail osteosynthesis is appropriate for pertrochanteric, subtrochanteric and trochantero-diaphyseal fractures, although the availability of shorter nails with a curvature adapted to our population's biometry would be desirable.

Key words: *long Gamma nail, proximal femoral fractures, femoral fractures, intramedullary femoral nail.*

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Correlación entre la biometría femoral de pacientes españoles y la osteosíntesis de fémur con clavo Gamma largo

Objetivo. Analizar la localización del enclavado Gamma largo en la diáfisis femoral distal y valorar las posibles complicaciones derivadas de una mala relación biométrica entre implante y fémur.

Material y método. Se realizó un estudio retrospectivo de 69 enclavados tipo Gamma largo. Para evaluar la posición del extremo distal del clavo se diseñó un sistema de coordenadas en la diáfisis femoral distal y se midió la distancia a los ejes X e Y desde la punta anteroinferior del clavo.

Resultados. Hubo 65 clavos (94,2%) colocados por delante de la teórica línea media de la diáfisis femoral. De ellos, 14 (20,2%) contactaban con la cortical anterior, y de éstos en 4 (5,7%) se sobrepasó la misma y hubo efecto pedestal. De los 42 clavos de menor longitud (340 mm), 16 (38%) resultaron excesivamente largos por localizarse distal a la metafisis femoral. Hubo una pérdida posoperatoria de la función para la deambulación, aunque los resultados fueron, en general, muy satisfactorios.

Conclusiones. Existía clara discordancia entre la biometría femoral y la longitud y curvatura del clavo Gamma largo en nuestra muestra, con alta incidencia de posición no deseada del implante, anteriorizándose e incluso rompiendo la cortical anterior. El clavo Gamma largo nos parece una osteosíntesis muy adecuada para las fracturas pertrocantéreas, subtrocantéreas y trocantereodiasfisiarias, pero sería deseable disponer de clavos más cortos y con un radio más adecuado a la morfología femoral de nuestra población.

Palabras clave: *clavo Gamma largo, fractura de fémur proximal, fractura femoral, clavo intramedular femoral.*

The surgical treatment of proximal humeral fractures has become more widespread given the overall increase in

life expectancy and the specific incidence these fractures have in the elderly population. Many intramedullary implants have been developed in recent times, with significant biomechanical differences between them¹⁻³, but since its introduction in 1990, the long Gamma nail has constituted a very good alternative to treat proximal femoral fractures, being specifically indicated for complex trochanteric and subtrochanteric fractures⁴.

In our experience with long Gamma nails, although satisfactory results have been obtained in the osteosynthesis of many pertrochanteric, subtrochanteric and trochantero-diaphyseal fractures, we have often detected the problem that the distal end of the nail ends up in an overly anterior and distal area of the femoral shaft, such that it can at times even fracture the anterior cortex of the distal femur.

Our study aims at evaluating the distal location of the nail with respect to the femoral shaft and at looking into the possible causes for incorrect nail positioning.

MATERIALS AND METHODS

We performed a descriptive retrospective study to evaluate a total of 122 long Gamma nailing-type procedures carried out between January 2001 and December 2002 at the Department of Orthopedic and Trauma Surgery of the Gregorio Marañón University Hospital. The inclusion criterion was to be in possession of a valid lateral knee x-ray where a previously designed coordinate system could be used to assess the position of the nail. Seventy-four patients met this criterion, of which 5 being excluded for presenting with pathological fractures. Of the 69 cases studied, the proportion of males to females was 3:1, with a mean age of 78 years (range: 50-98). The injury affected the right femur in 32 patients and the left one in 37. Thirty-two cases presented with pertrochanteric fractures, all of them type A3 according to the classification by Müller and Nazarian⁵, another 39 corresponding to subtrochanteric types II, III and IV fractures according to the classification by Seinsheimer⁶. Two patients had been treated previously with a short Gamma nail for a pertrochanteric fracture and sustained a postoperative femoral diaphyseal fracture under the nail and a supracondylar fracture, respectively, for which reason the short Gamma nail was replaced by a long Gamma nail.

The long Gamma nail is an asymmetrical implant available in lengths of 340, 360, 380 and 400 mm. It makes it possible to change the neck shaft angle to adapt it to each patient's anatomy, with 125, 130 and 135° angles being possible. The size of the lag screw varies between 85 and 120 cm and can be decided intraoperatively. The nail can be locked with a distal screw according to the fracture characteristics and the surgeon's preference; this screw is available in lengths from 25 to 50 mm. The length, neck shaft

Table 1. Length, neck-shaft angle and lag screw of the long Gamma nails used

Length	Neck-shaft angle			Total number
	125°	130°	135	
340 mm	38	4		42
360 mm	17	3	1	21
380 mm	4			4
400 mm	2			2

angle and lag screw of the long Gamma nails used in our patients are shown in table 1.

The medullary canal must be opened with an awl half way down the greater trochanter, avoiding an excessively anterior or posterior approach which could lead to the nail's malalignment. We performed a distal nailing procedure in 18 patients, with requiring prophylactic trochanteric cerclage for a displaced persubtrochanteric fracture.

We evaluated loss of ambulating function comparing the patients' pre-fracture score to their postoperative one.

In order to assess the position of the distal end of the nail in relation to the femoral shaft we designed a system of coordinates on the lateral knee radiograph. The X axis of this system corresponded to a line tangent to the anterior femoral cortex and the Y axis to a line perpendicular to the X axis that coincided with the point at which the shaft intersected the femoral condyles. In order to locate the nail within this coordinate system we used the anteroinferior tip of the nail and measured the distance to both axes (X and Y) (fig. 1). This coordinate system gave us information as to what the location of the nail was with respect to the anterior femoral cortex, and thus helped us determine how far anteriorly it lay.

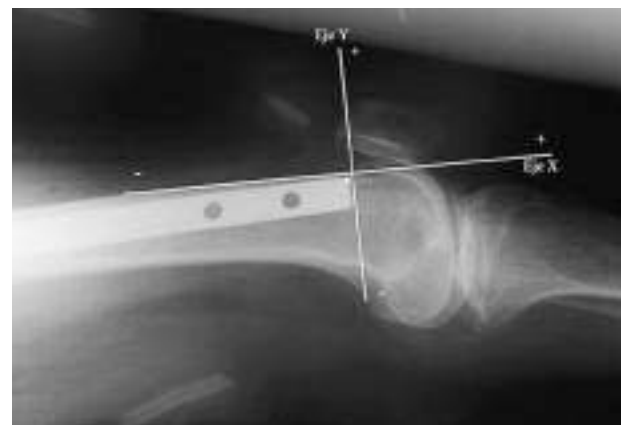


Figure 1. System of coordinates used to locate the anteroinferior end of the nail with respect to the femoral shaft.



Figure 2. Antegrade nail in contact with the anterior femoral cortex.



Figure 3. The nail fractures the anterior cortex.

RESULTS

Of the total 69 nails studied, 65 (94.2%) were placed, on the sagittal plane, over the theoretical midline of the femoral shaft. Of these 65 nails in an overly anterior position, 14 (20.2% of total) came into contact with the anterior cortex (fig. 2), and 4 of these (5.7%) exceeded the level of the anterior cortex, which resulted in an x-ray pedestal effect (figs. 3 and 4). Of the 42 shortest-length available nails (340 mm), 16 (38%) turned out to be too long, taking up a position distally to the femoral metaphysis. Figure 5 shows the location of the different nails with respect to the above mentioned coordinate system.

Table 2 shows the data of the patients' preoperative ambulation and their level of ambulation at the last follow-up session. As can be observed, there is a generalized loss of function postoperatively, although results are highly satisfactory.

DISCUSSION

The long Gamma nail has a radius of 3,000 mm⁷ while, according to morphometric studies by Casteleiro^{8,9}, the mean radius of the diaphysis taken at the midpoint of the maximum anatomical length of the femur at the level of its anterior aspect is $1,381.28 \pm 118.626$ mm for the Spanish population. This biometric discrepancy between implant and femur appears clinically as a trend for the nail to migrate anteriorly, impinging on or even fracturing the anterior femoral cortex in its distal-most portion (5.7% of long Gamma nails in our series).

As regards the length of the long Gamma nail, there are different sizes available, the shortest being 340 mm. In his biometric study, Casteleiro found that femoral length in Spanish individuals ranges between 367 and 467 mm. These values contrast with those in the study by Trotter y



Figure 4. Pedestal effect caused by a Gamma nail placed too anteriorly.

Gleser¹⁰ of a multi-ethnic population in the United States, whose values ranged between 381-574 mm for males and 348-526 mm for females. Of this it can be inferred that the Spaniards have shorter femora than North-Americans, and that in Spain even the shortest of the long mails could be too long. Our study shows that in 38% of the cases in which it was used, the shortest nail exceeded the level of the femoral metaphysis.

In our series, all fractures went on to heal, although 3 patients had to be reoperated, 2 because of fracture site impaction with the nail subsiding to the joint (fig. 6) and the other because of poor orientation of the lag screw, which had to be reoriented in the immediate post-op.

Being a relatively new implant, there are no long series of this nail and its complications. The papers we found in the literature report, in general, highly satisfactory results with few complications. Pervez et al¹¹ studied 35 patients all of whom went on to heal with 4 complications (2 instances of nail breakage in patients with delayed healing, one intra-operative femoral fracture at the distal locking point and a

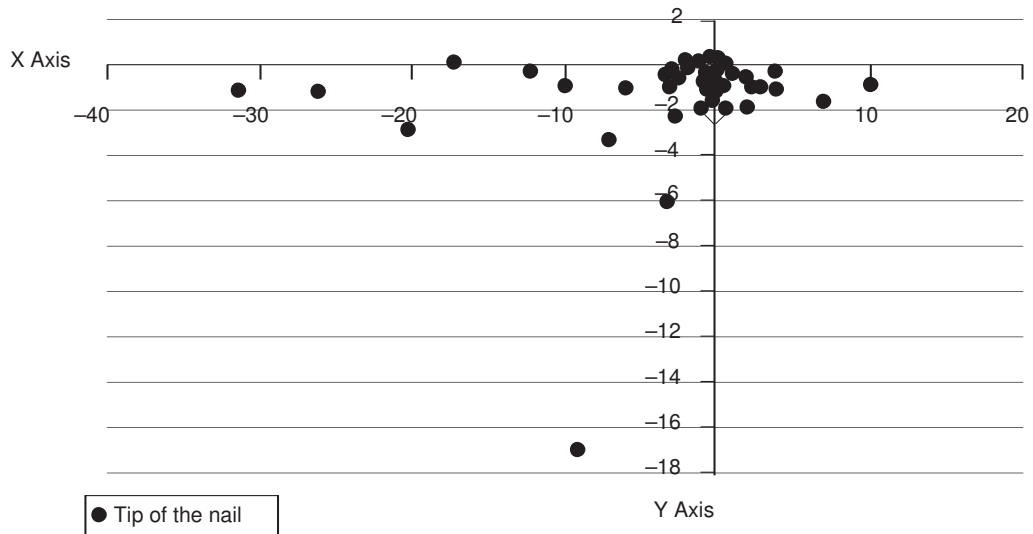


Figure 5. Representation of the antero-inferior end of the nail as seen on the system of coordinates used for locating it.

Table 2. Number of patients classified according to their pre-op and post-op ambulation levels

	Preoperative ambulation	Postoperative ambulation
With no support	48	40
With one walking stick	11	9
With one walking stick and a relative	4	0
With 2 walking sticks	0	8
Occasional ambulation (or with walker)	6	6
Wheelchair	0	3

late fracture at the tip of the nail after a fall. Barquet et al¹² studied 43 patients and observed a breakage of the distal locking screw and several instances of disruptive healing with varus deformities and shortening. Hotz et al¹³ found mechanical problems in 4 patients out of a series of 32, 2 of whom presented with shortening and external malrotation.

D'Angelo et al¹⁴ studied 43 patients and had high rates of poor healing, with 10 patients presenting with leg length discrepancy, 7 torsion deficit and one instance of healing in varus. Edwards et al¹⁵ studied 51 cases and reported an impacted subcapital fracture on introducing the nail, a medial cortical fracture on introducing the distal locking screw and a migration of the nail to the knee resulting from the collapse of a pathological fracture. Sehat et al¹⁶ authored the longest and most recent of the studies we reviewed. In 100 cases they obtained 85% satisfactory results, but had 7 complications: 4 cases of *cut out* of the lag screw, one case of implant fatigue, one infected pseudoarthrosis and a periprosthetic fracture. Of this last complication they say



Figure 6. Distal migration of the nail resulting from the collapse of the fracture site.

that it occurred as a result of the nail being in an overly anterior position in the distal shaft, adding that this was quite a common occurrence in the patients reviewed, but without specifying the actual percentage.

None of the studies referred to above brings up the discrepancy between the biometrics of the femur and that of the nail, or the complications that this poor biometric match could give rise to. The only authors who do so are Anchueta et al¹⁷, who studied a series of 170 long Gamma nailing procedures (one of the largest in the literature) and concluded that it is a highly appropriate implant not only for its current indications, i.e. subtrochanteric, trochantero-diaphyseal and pathological fractures¹⁸⁻²¹, but also for all pertrochanteric fractures, thus obviating the need to use distal locking in short Gamma nailing procedures, which has provoked so many complications in the past, and contributing to the stabilization of any fractures that could arise intraoperatively. However, they encountered difficulties derived from implant design and implant size since even the shortest nail available (340 mm), turned out too long in 95% of their cases.

The problems of the short Gamma nail were made worse by the fact that the nail's curvature was not congruent with the femoral radius of the Spanish elderly population, which provoked a distal radiological impaction of the nail in 45% of cases and even caused incomplete fractures of the distal cortex in 4% of cases (although this did not have significant clinical repercussions)¹⁹. These results can be easily compared to those in our own series, where distal radiological impaction occurred in 20.2% of cases and anterior cortical fractures in 5.7% of cases.

To conclude, there is a clear discordance between femoral biometrics and the length and curvature of the long Gamma nail in our population. This means that, in a high percentage of cases, the implant ends up in an undesired position, getting into the femoral shaft and even fracturing the anterior cortex. In spite of this biometric problem, Gamma nail fixation seems to us a highly beneficial fixation system, not only for subtrochanteric or trochantero-diaphyseal fractures, but for many cases of pertrochanteric fractures. Nevertheless, it would be a good idea to have shorter nails available, whose radius as better adapted to the femoral morphology of our population.

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Conflict of interests

The authors have declared to have no conflict of interests.