Arch Orthop Trauma Surg (1998) 117 : 438–441

ORIGINAL ARTICLE

O. Farouk · C. Krettek · T. Miclau · P. Schandelmaier H. Tscherne

Effects of percutaneous and conventional plating techniques on the blood supply to the femur

Received: 10 July 1997

Abstract A cadaveric arterial injection study was performed to study the effects of percutaneous and conventional surgical plating techniques on femoral vascularity. Sixteen-hole dynamic condylar screw and condylar buttress plates were applied on the proximal and distal shafts, respectively, of intact femora in ten human cadavers. On one side, the plate was inserted using a lateral conventional plate osteosynthesis (CPO) technique with elevation of the vastus lateralis muscle to expose the shaft. On the contralateral side, the plate was inserted percutaneously beneath the muscle using a minimally invasive plate osteosynthesis (MIPPO) technique. After plating, blue silicone dye was injected through the common femoral artery. A dissection was then performed to identify the femoral perforating arteries (PAs). The pattern of periosteal filling of the injected dye was analyzed. The MIPPO technique maintained the integrity of the PAs and exhibited superior periosteal perfusion. The results of this study indicate that the MIPPO technique maintains femoral vascularity and perfusion better than the CPO technique.

Introduction

Displaced subtrochanteric and supracondylar femur fractures have traditionally been treated with open reduction and internal fixation using classic AO principles. In addition, most investigators recommend the use of bone graft when medial comminution or bone loss is present [14, 19]. Several authors, however, have demonstrated that fractures treated with indirect reduction techniques evidence a decreased time to union, rate of nonunion, and need for bone grafting compared with those treated by traditional methods [2, 4, 5, 8, 14, 18]. Developed to avoid direct exposure of the fracture site and minimize soft-tissue stripping, minimally invasive techniques continue to evolve and have been reported, in particular, for the treatment of femoral fractures [2, 4, 5, 8, 13, 20]. The minimally invasive methods reported include the percutaneous insertion of plates which are fixed proximally and distally to the fracture and bridge the fracture site [10, 11, 20].

In order to understand the potential application, success, and risks of these percutaneous plating techniques, an understanding of the potential disruption of the blood supply to the femur with different techniques is necessary. The purpose of this study is to compare the effects of both the percutaneous and traditional plating techniques on the femoral arterial supply using silicone arterial dye injection in human cadavers.

O. Farouk · C. Krettek (✉) · P. Schandelmaier · H. Tscherne
Trauma Department, Hannover Medical School,
D-30623 Hannover, Germany

T. Miclau
University of California, San Francisco,
San Francisco General Hospital,
Department of Orthopaedic Surgery,
San Francisco, CA 94110, USA

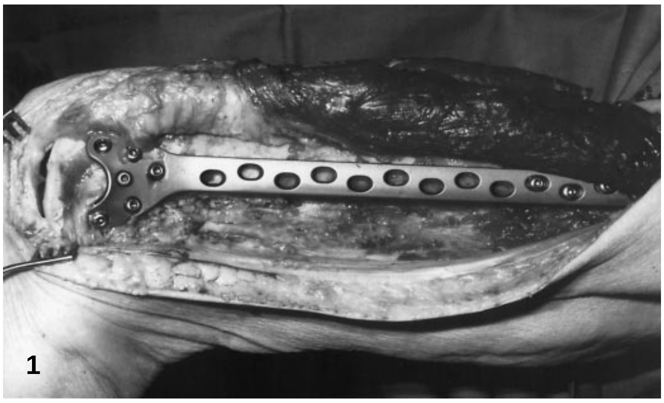
Materials and methods

Ten fresh human cadavers (aged 48–90 years) were obtained for this study. The donors were free of conditions which affect the vascularity of the lower limbs such as diabetes mellitus or ischemic vascular diseases. The experiment was carried out within 48 hours of death, and the cadavers were maintained refrigerated until the start of the procedure.

Surgical approaches and plate application

Sixteen-hole dynamic condylar screw (DCS) and condylar buttress plates (CBP) (Stratec Medical, Oberdorf, Switzerland) were applied to the proximal and distal femoral shafts of intact human cadaveric femora, respectively, using one of two different surgical plating techniques. The lateral conventional plate osteosynthesis (CPO) was performed on one side, and a minimally invasive percutaneous plate osteosynthesis (MIPPO) was done on the contralateral side. The approaches were alternated right and left.

The CPO was performed proximally and distally through a standard lateral approach [7, 14, 15, 18] by dissecting posterolaterally between the vastus lateralis muscle and the lateral intermuscular septum (Fig. 1). The vastus lateralis was elevated subperiosteally from its attachment to the linea aspera as needed for plate placement on the lateral femur. The perforating vessels encountered during the dissection were ligated and incised. The application of



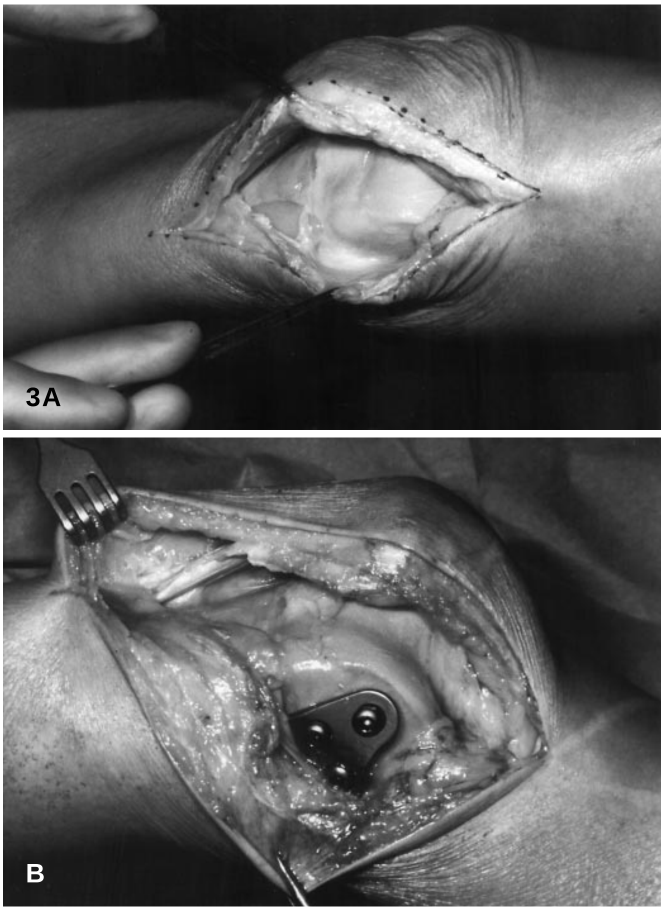


Fig. 1 Lateral conventional approach to the distal femur

Fig. 2 A, B Minimally invasive percutaneous insertion of the dynamic compression screw plate on the proximal femur

Fig. 3 A, B Transarticular condylar buttress plate insertion on the distal femur

the DCS plate on the proximal femur was achieved on the CPO side by extending the lateral approach proximally with transverse division and ventral retraction of the vastus lateralis muscle origin at the lower border of the greater trochanter [15, 18]. The plate was fixed with four screws distally. The placement of the condylar buttress plate was performed on the CPO side through a lateral approach to the distal femur as described by Rüedi [18] with distal extension of the incision to Gerdy's tubercle. The fascia lata was split in line with its fibers, and the knee joint capsule was entered in line with the incision anterior to the superior attachment of the lateral collateral ligament.

On the MIPPO side, DCS plate application was performed in the proximal femur (case 1 to 3) through a 3-cm incision through which the condylar screw was inserted (Fig. 2 A), and the plate was introduced submuscularly beneath the vastus lateralis and fixed with four distal percutaneously inserted screws (Fig. 2 B). The CBP plate was applied to the distal femur (case 4 to 10) on the MIPPO side through a lateral knee arthrotomy as described by Krettek et al. [9, 11] with proximal extension of the incision between the rectus femoris and vastus lateralis muscles (Fig. 3).

Injection of blue silicone

The common femoral vessels were exposed bilaterally in the femoral triangle through a 10-cm longitudinal incision. The vessels were then secured with two non-occlusive silk ties [1]. The clotted blood was cleared from the femoral vessels by flushing the common femoral artery with 1000 ml of warm saline which exited from the common femoral vein. Blue silicone (mixture of Biodur S14 red with blue pigment powder and hardener 5% S1, Dr. Andrea Whalley, Heidelberg, Germany) was then injected through the catheterized common femoral artery. The vascular injection continued until the dye became apparent in the venous cathether.

Cadaver dissection and vascular analysis

After overnight refrigeration to allow the dye to harden, the cadaver was placed in the supine position with a sandbag beneath the buttock on the dissected side. The posterolateral approach was deepened and, after longitudinal incision of the lateral intermuscular septum, the dissection was continued posterolaterally between

Table 1 The incidence of perforating artery division with the conventional plate osteosynthesis (CPO) and minimally invasive plate osteosynthesis (MIPPO) (*DCS:* Dynamic condylar screw plate in case 1 to 3, *CBP:* condylar buttress plate in case 4 to 10). The difference in periosteal perfusion of the conventional specimens (with variable perforating artery division) compared with that of the minimally invasive specimens (100% intact perforating arteries) is also tabulated

Case number	Plate applied	Approach	1st perforator	2nd perforator	3rd perforator	4th perforator	Interrupted (Total)	Difference of periosteal filling
1	DCS	CPO	Intact	Intact	Intact	Incised	1/4	Moderate
		MIPPO	Intact	Intact	Intact	Intact	0/4	
2	DCS	CPO	Intact	Intact	Incised	Incised	2/4	Moderate
		MIPPO	Intact	Intact	Intact	Intact	0/4	
3	DCS	CPO	Incised	Incised	Intact	Intact	2/4	Moderate
		MIPPO	Intact	Intact	Intact	Intact	0/4	
4	CBP	CPO	Intact	Incised	Incised	Incised	3/4	Moderate
		MIPPO	Intact	Intact	Intact	Intact	0/4	
5	CBP	CPO	Intact	Incised	Incised	Incised	3/4	Moderate
		MIPPO	Intact	Intact	Intact	Intact	0/4	
6	CBP	CPO	Intact	Incised	Incised	Incised	3/4	Mild
		MIPPO	Intact	Intact	Intact	Intact	0/4	
7	CBP	CPO	Intact	Incised	Incised	Intact	2/4	Mild
		MIPPO	Intact	Intact	Intact	Intact	0/4	
8	CBP	CPO	Intact	Incised	Incised	Intact	2/4	Mild
		MIPPO	Intact	Intact	Intact	Intact	0/4	
9	CBP	CPO	Intact	Intact	Incised	Intact	1/4	No difference
		MIPPO	Intact	Intact	Intact	Intact	0/4	
10	CBP	CPO	Incised	Incised	Incised	Incised	4/4	Marked
		MIPPO	Intact	Intact	Intact	Intact	0/4	
Incised (total)		CPO	2/10	7/10	8/10	6/10	23/40	9/10
		MIPPO	0/10	0/10	0/10	0/10	0/10	

the vastus lateralis and the short head of biceps femoris [21]. The perforating arteries of the profunda femoris were identified as they crossed the tendinous insertion of the adductor magnus. The perforating arteries, filled with blue silicone, were then inspected for their integrity.

Analysis of periosteal perfusion

The femora were harvested to evaluate periosteal vessel filling with the blue silicone. The perfusion of the vessels with dye was analyzed and rated based on a 12-point score. Each of the paired femurs was divided into four zones (area of bone at the proximally fixed portion of the plate, at the bridging portion of the plate, at the distally fixed portion of the plate, and proximal or distal to the plate). Each zone was scored from 0–3 based on the degree of periosteal staining (none, mild, moderate, marked). The 12-point scores were then compared between the paired femurs. Differences of 9–12 points, 5–8 points, 2–4 points, and 0–1 point were regarded as marked, moderate, mild, and none/equal, respectively.

Table 2 The difference in periosteal perfusion between the conventional (CPO) and minimally invasive (MIPPO) techniques

Cases		Degree of periosteal perfusion		Difference of periosteal perfusion
Number	(%)	CPO	MIPPO	
1	10 %	+	++++	+++
5	50 %	++	++++	++
3	30 %	+++	++++	+
1	10 %	++++	++++	0

Results

The perforating arteries (PAs) were intact in all of the MIPPO specimens and were divided into variable incidences in the CPO specimens (Table 1).

The MIPPO group specimens demonstrated superior periosteal filling (90%) compared with those of the CPO group (Table 2, Fig. 4). The difference in periosteal filling between the two approaches was marked in one case (10%), moderate in five (50%), mild in three (30%), and equal in one (10%).

Discussion

Fractures of the femur, particularly those of the proximal and distal femur, have traditionally been treated with open reduction and plate fixation through a standard lateral approach [14, 15]. However, new internal fixation techniques which minimize exposure of the fracture site have

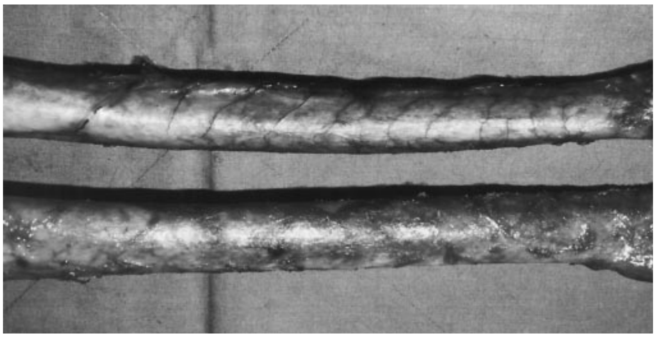


Fig. 4 Photograph illustrating the difference in periosteal perfusion between femurs plated with the minimally invasive (*top*) and conventional techniques (*bottom*)

been developed to improve fracture healing [2, 4, 5, 8, 13, 20]. Among these "biologic", minimally invasive techniques, percutaneous plating of femur fractures has a place [9, 10, 20].

This study was designed to minimize potential differences between the groups. Long 16-hole dynamic condylar screw and condylar buttress plates were selected for their appropriate size for comminuted femoral fractures. The plates, inserted using either the conventional or minimally invasive techniques, were applied on intact femora to avoid the variable disruption of the femoral vascular supply created by a fracture. The techniques were randomized to right and left femora to control for any differences between the limbs.

The results of this study demonstrate that the percutaneous technique better preserved the perforating arteries and subsequently the periosteal perfusion than did the conventional method. These findings support the recent clinical success reported using such techniques [9, 10, 20] for complex femoral fractures. While the perforating arteries have been considered as discrete blood vessels that should be ligated during the surgical approach [7, 14, 15, 18], their biological significance may be greater than initially appreciated. The perforating arteries provide essential vascular anastomoses along the femur, the primary arterial supply to the muscles of the thigh [3], and the blood supply to the nutrient artery of the femur [6, 10]. According to Rhinelander [17], the blood supply to long bones arises from the periosteal, metaphyseal, and nutrient arteries. The nutrient artery usually arises from the second perforator [6, 12] and is the main source of blood for the inner two-thirds of the cortex. The periosteal vessels supply the outer third. During the healing of closed, undisplaced fractures, the medullary circulation remains intact and provides the majority of the blood supply to the fracture. However, with displaced fractures, an enhanced periosteal circulation, derived from the surrounding muscles supplied by the perforating arteries [3, 16], becomes the early primary source of blood supply to the fracture site.

In conclusion, the lateral conventional plating technique disrupts the femoral blood supply essential for fracture healing more than a minimally invasive approach using a percutaneously inserted plate. This improved blood supply may result in improved union and reduced complication rates. The superior periosteal perfusion seen with the percutaneous plating technique compared with that of the conventional technique suggests that minimally invasive plate osteosynthesis may be more biologically advantageous.

References

1. Anous MM (1988) A clean technique for cadaver injection studies (letter). Plast Reconstr Surg 82 : 199
2. Baumgärtel F, Gotzen L (1994) Die 'biologische' Plattenosteosynthese bei Mehrfragmentfrakturen des gelenknahen Femur. Eine prospektive Studie. Unfallchirurg 97 : 78–84
3. Colborn GL, Mattar SG, Taylor B, Skandalakis JE, Lumsden AB (1995) The surgical anatomy of the deep femoral artery. Am Surg 61 : 336–346
4. Gerber C, Mast JW, Ganz R (1990) Biological internal fixation of fractures. Arch Orthop Trauma Surg 109 : 295–303
5. Heitemeyer U, Hierholzer G (1985) Die überbrückende Osteosynthese bei geschlossenen Stückfrakturen des Femurschaftes. Akt Traumatol 15 : 205–209
6. Hollinshead WH (1982) Anatomy for surgeons. The back and limbs, 3rd edn, Vol 3. Harper & Row, Philadelphia, pp 702–732
7. Hoppenfeld S, deBoer P (1984) Surgical exposures in orthopaedics. The anatomic approach. Lippincott, Philadelphia, pp 357–387
8. Kinast C, Bolhofner BR, Mast JW, Ganz R (1989) Subtrochanteric fractures of the femur. Clin Orthop 238 : 122–130
9. Krettek C, Schandelmaier P, Tscherne H (1996) Distale Femurfrakturen: transartikuläre Rekonstruktion, perkutane Plattenosteosynthese und retrograde Nagelung. Unfallchirurg 99 : 2–10
10. Krettek C, Schandelmaier P, Miclau T, Tscherne H (1997) Minimally invasive percutaneous plate osteosynthesis (MIPPO) using the DCS in proximal and distal femoral fractures. Injury 28 [Suppl I] : 20–30
11. Krettek C, Schandelmaier P, Miclau T, Bertram R, Holmes W, Tscherne H (1997) Transarticular joint reconstruction and indirect plate osteosynthesis for complex distal supracondylar femoral fractures. Injury 28 [Suppl I] : 31–41
12. Laing PG (1953) The blood supply of the femoral shaft: an anatomical study. J Bone Joint Surg [Br] 35 : 462–466
13. Mast J, Jakob R, Ganz R (1989) Planning and reduction technique in fracture surgery. Springer, Berlin Heidelberg New York
14. Müller ME, Allgöwer M, Schneider R, Willenegger H (1977) Manual der Osteosynthese – AO Technik 2nd edn. Springer, Berlin Heidelberg New York
15. Müller ME, Allgöwer M, Schneider R, Willenegger H (1991) Manual of internal fixation, 3rd edn. Springer, Berlin Heidelberg New York
16. O'Sullivan ME, Chao EYS, Kelly PJ (1989) Current concepts review: the effects of fixation on fracture healing. J Bone Joint Surg [Am] 71 : 306–310
17. Rhinelander FW (1968) The normal microcirculation of diaphyseal cortex and its response to fracture. J Bone Joint Surg [Am] 50 : 784–800
18. Rüedi T (1996) Operative Zugänge der Osteosynthese. Springer, Berlin Heidelberg New York pp, 123–137
19. Trentz O, Tscherne H, Oestern H-J (1977) Operationstechnik und Ergebnisse bei distalen Femurfrakturen. Unfallheilkunde 80 : 441–448
20. Wenda K, Runkel M, Rudig L (1995) Die "durchgeschobene" Kondylenplatte. Unfallchirurgie 21 : 77–82
21. Yamamoto Y, Ohura T, Sughihara T (1995) An anatomic study for a vascularized bone flap of femur. Plast Reconstr Surg 95 : 520–525