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Impact on periosteal vasculature after dual plating of the distal femur: a cadaveric study

Michael J. Chen, MD*, Lawrence Henry Goodnough, MD, PhD, Brett P. Salazar, BS, Michael J. Gardner, MD

Objectives: Although dual plating of distal femur fractures has been described for injuries at risk of varus displacement, the vascular insult to the medial distal femur utilizing this technique is unknown. The aim of this study was to evaluate the perfusion of the medial distal femoral periosteal arteries after supplemental medial plating of the distal femur.

Methods: Fifteen human fresh-frozen cadaveric femora were thawed and randomized to lateral locked plating alone or with supplemental medial plate fixation. Conventional submuscular medial plating was performed using a 12-hole small fragment plate and multiple cortical screws. The superficial femoral artery was injected with latex dye. Specimens were dissected. The patency of the medial distal femoral periosteal vessels was evaluated.

Results: Four vessels were consistently observed traversing the distal medial femur: the transverse and descending (d-MMPA) branches of the medial metaphyseal periosteal artery, and the transverse and longitudinal branches of the descending geniculate artery. The anterior longitudinal arch (ALA) was present in 13 of 15 specimens and was fed by the d-MMPA. The median number of periosteal arteries occluded by the medial plate was 2 (6 out of 8 specimens). The d-MMPA was occluded in 6 of 8 medially plated femurs, resulting in a complete lack of perfusion of the ALA.

Conclusions: Submuscular medial plating of the distal femur compressed the d-MMPA in the majority of specimens. This vessel gives rise to the ALA, which lacked perfusion in these specimens. This vascular insult could affect the healing of metaphyseal distal femur fractures treated with dual plating.

Keywords: distal femur fractures, dual plate stabilization, minimally invasive plate osteosynthesis (MIPO)

1. Introduction

Lateral locked plating of distal femur fractures preserves the integrity of the medial soft-tissue envelope, and theoretically minimizes disruption of the periosteal blood supply.[1,2] However, distal femur fractures with metaphyseal comminution, medial bone loss, osteoporotic bone, and in patients with an elevated body mass index are prone to varus displacement and implant failure when treated with lateral locked plating alone.[3–6]

Before lateral locked plating became the workhorse of distal femur fixation, Sanders et al[7] had shown that dual plating of distal femur fractures can be an effective method to increase stability and prevent varus collapse. Now that the complications of stand-alone lateral plating are recognized, there has been renewed interest in dual plating of distal femur fractures, with several authors reporting high rates of union utilizing this technique.[8–10] However, there remains concern for biologic insult that results from plating both sides of the femur, even when using a submuscular and minimally invasive technique.

The medial aspect of the distal femur receives its vascular supply from branches from the superficial femoral artery (SFA): the medial metaphyseal periosteal artery (MMPA) and the descending geniculate artery (DGA).[11] The impact on these periosteal arteries after performing nonlocking supplemental medial plate fixation, using a submuscular and minimally invasive technique, is currently unknown.

While previous studies have not reported vascular compromise with medial plating,[7–10] the potential for vascular insult to the medial distal femur with medial plating is not known. The purpose of this anatomic study was to evaluate the perfusion of the distal femoral medial periosteal arteries after submuscular conventional medial plating. We hypothesized that conventional medial plating during dual plate fixation of the distal femur would cause injury to the medial periosteal vessels by compression.

This study used de-identified cadaveric specimens and was therefore considered exempt from IRB review. All research was conducted in accordance with the Declaration of the World Medical Association.

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This study was deemed exempt from IRB or Animal Use Committee review.

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Department of Orthopaedic Surgery, Stanford University Medical Center, Stanford, CA

* *Corresponding author. Address: Department of Orthopaedic Surgery, Stanford University, 450 Broadway Street, Pavilion C, 4th Floor, Redwood City, CA 94063-6342. E-mail address: mchen32@stanford.edu (M. J. Chen).*

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2. Methods

2.1. Specimens

Fifteen fresh-frozen cadaveric femora from 8 human donors were used in this study (average age: 64 years (standard deviation ± 4.4 years); age range: 57 to 68 years; sex: all female). Specimens were thawed to room temperature prior to testing. Plate fixation was performed prior to arterial injection of the latex dye in every specimen, as detailed below.

2.2. Plate fixation

Femora from each donor were randomized to lateral locked plating alone, or lateral locked plating with supplemental medial plate fixation. Lateral plate fixation was performed with a 2-incision approach (1 distal to expose the lateral femoral condyle and 1 proximal to center the plate on the lateral femur) in a submuscular fashion using a 10-hole precontoured 4.5 mm lateral distal femur locking plate (Depuy Synthes, West Chester, Pennsylvania). The plate was positioned and compressed to the proximal diaphysis with a 4.5 mm cortical screw inserted into the 2nd to last hole; then the plate was manually compressed to the lateral condyle and secured distally with a 5.0 mm locking screw. Conventional medial plate fixation was performed with a 2-incision approach (1 distal to expose the medial femoral condyle and 1 proximal to center the plate on the medial femur) in a submuscular fashion according to Swentik et al,[9] using a 12-hole 3.5 mm limited contact dynamic compression plate (Depuy Synthes, West Chester, Pennsylvania). The plate was contoured and centered along the medial distal femur. Plate-bone contact was achieved proximally using a 3.5 mm cortical screw inserted into the 2nd to last hole and distally to the medial condyle using a 3.5 mm cortical screw in the 2nd hole. Fluoroscopic imaging was not used during plate application.

2.3. Arterial perfusion

The SFA at the level of the proximal femur and popliteal artery distally were dissected. Warm tap water was injected into the SFA using a 14-gauge angiocatheter until it was running clear out of the popliteal artery. The popliteal artery was then clamped to apply backpressure and additional water was injected. Similar to the previous vascular injection study performed by Gardner et al,[12] black-labeled PMC 780 latex dye (Smooth-On, Inc, Macungie, Pennsylvania) was injected into the SFA again using a 14-gauge angiocatheter until it was seen flowing out of the popliteal artery. The popliteal artery was again clamped to apply backpressure and the syringe was pressurized for 3 additional minutes to fill the arterial system. The SFA was then clamped and specimens were left to rest for 15 minutes prior to dissection to allow the latex time to solidify.

2.4. Dissection

Specimens were meticulously dissected to identify and record the condition of the SFA and its branches to the medial distal femur (Fig. 1). The dissection was continued deeper to identify and preserve the periosteal vessels of the femur (Fig. 1). The location and patency of the medial periosteal vessels were recorded.

2.5. Statistics

Standard descriptive statistics were performed, including determination of the median and range (Excel 2011, Microsoft, Redmond, Washington).

3. Results

Figure 1 demonstrates the vasculature anatomy of the medial distal femur in a specimen that underwent lateral plating alone.

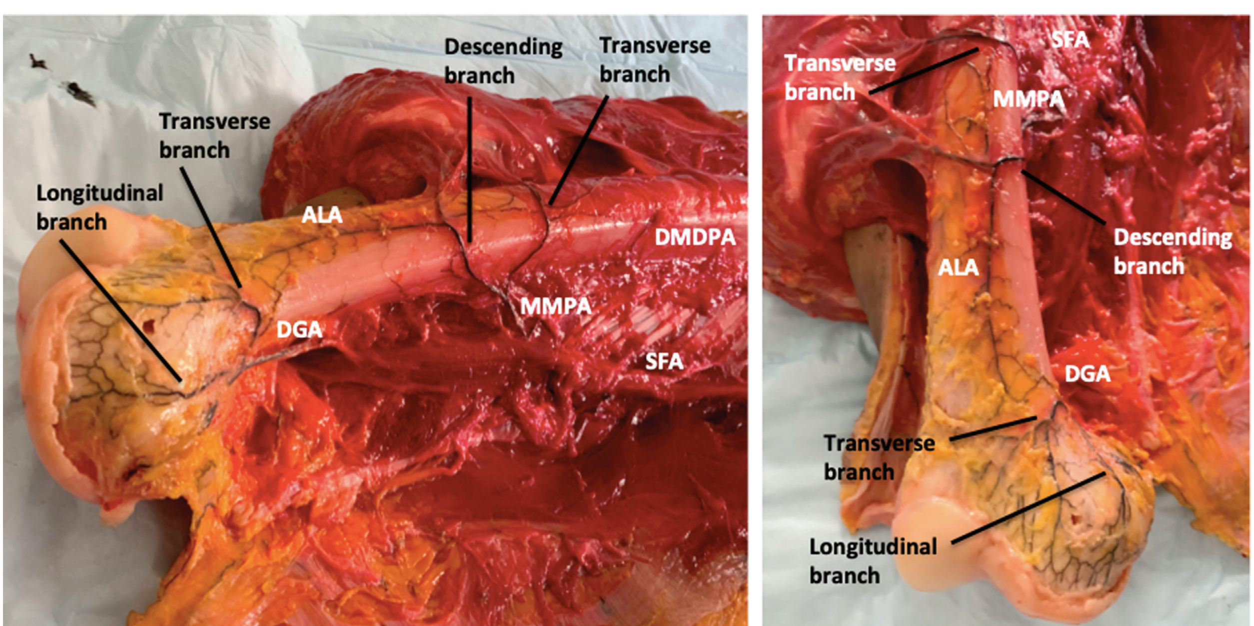

Figure 1. A control specimen demonstrating the medial metaphyseal periosteal artery (MMPA) and descending geniculate artery (DGA) as they originate from the superficial femoral artery (SFA). The distal medial diaphyseal periosteal artery (DMDPA) was present in this specimen. The transverse and descending branches of the MMPA are labeled along with the anterior longitudinal arch (ALA), which is fed by the descending branch. The transverse and longitudinal branches of the DGA are also labeled.

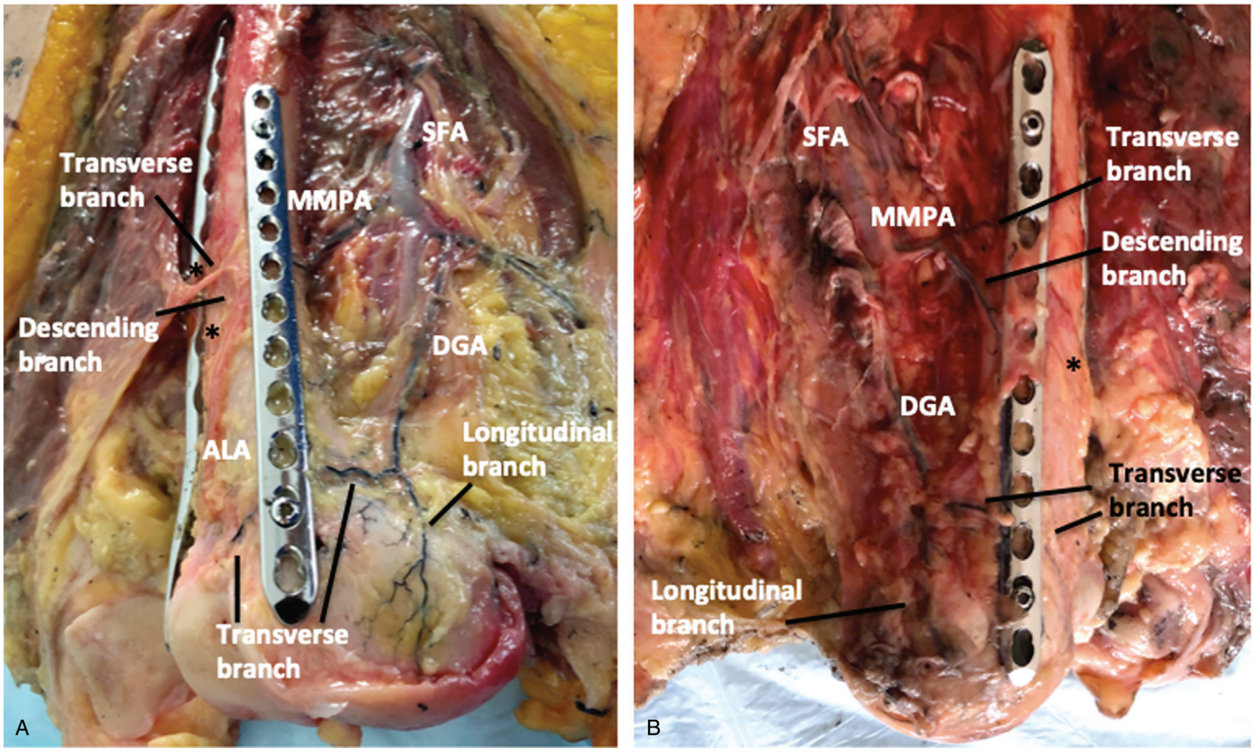

Figure 2. (A) A dual plated specimen demonstrating occlusion (*) of the transverse and descending branches of the medial metaphyseal periosteal artery (MMPA). The anterior longitudinal arch (ALA) is not perfused. The transverse branch of the descending geniculate artery (DGA) is running underneath the plate but is not compressed. The longitudinal branch of the DGA is posterior to the plate and unharmed. The superficial femoral artery (SFA) is labeled. (B) A different dual plated specimen demonstrating occlusion (*) of the descending branch of the MMPA. There was no ALA in this specimen.

All specimens (15 of 15) had an MMPA that bifurcated into transverse (t-MMPA) and descending (d-MMPA) branches, and a DGA that bifurcated into transverse (t-DGA) and longitudinal (l-DGA) branches. The anterior longitudinal arch (ALA) of the distal femur [13,14] was present in all (13 of 15) but 2 specimens, which came from the same donor. The d-MMPA consistently gave rise to the ALA (13 of 13 specimens). A separate unnamed transverse periosteal artery immediately proximal to the MMPA was present in 7 of 15 specimens. We named this vessel the distal medial diaphyseal periosteal artery.

Figure 2 demonstrates the occlusion of certain periosteal arteries after medial plating of the distal femur. When present, the distal medial diaphyseal periosteal artery was compressed in 3 of 3 (100%) medially plated specimens. The t-MMPA and d-MMPA were both compressed in 6 of 8 (75%) medially plated specimens. The t-DGA was compressed in only 1 of 8 (12.5%) medially plated specimens. The l-DGA was compressed in 2 of 8 (25%) medially plated specimens if the plate was placed posteriorly along the medial femoral condyle (note the anterior location of the medial distal femoral plate in Figure 2A with preservation of the l-DGA). The ALA was never perfused if the d-MMPA was occluded, and never received contributions from the lateral periosteal arteries. Lateral plating had no impact on the anterior and medial arterial anastomotic networks of the distal femur.

The median number of medial periosteal arteries occluded by the plate in medially plated femurs was 2 (6 of 8 specimens). There was no injury to the SFA in any of the medially plated specimens.

4. Discussion

The aim of this cadaveric injection study was to test the hypothesis that supplemental medial plate fixation of the distal femur alters bone vascularity via compression of the medial periosteal arteries, even when performed in a minimally invasive and submuscular fashion. The results of this study support our hypothesis, as at least 1 medial periosteal artery was occluded in all medially plated femurs.

The d-MMPA was occluded in 75% of medially plated specimens, which compromised perfusion of the ALA in every instance. Although this was striking, it remains unknown if this is the dominant periosteal artery of the distal femoral metaphysis. Compression of the t-MMPA occurred frequently, as this branch was immediately proximal to the d-MMPA and was frequently adjacent to the site of the proximal screw insertion. The t-DGA was never compressed, as it was located along the concavity of the metaphyseal flare and was protected from plate-bone compression. The l-DGA, a more posterior structure on the medial femoral condyle, was only compressed if the plate was applied posteriorly in reference to the mid-sagittal femoral diaphysis. If the surgeon chooses to plate the medial distal femur, consideration should be given to positioning the plate distally along the anteromedial surface of the medial femoral condyle, as demonstrated in Figure 2A, to preserve the l-DGA. However, the clinical benefit for preserving the l-DGA is unknown.

Plating the lateral distal femur in a submuscular fashion allows for the preservation of the lateral perforating arteries and minimizes the vascular insult at the periosteal level compared with open plating techniques.[15] Although the distal half of the femur poses minimal risk of injury to the SFA when using submuscular medial plating techniques,[16] the impact on periosteal perfusion has not been studied. Our study similarly found no injury to the SFA with the use of submuscular plate insertion in combination with our 12-hole plate length, but did find occlusion of certain medial periosteal arteries using the plating technique we employed; specifically the use of nonlocking screws proximally and distally, which rely on plate–bone contact.[17,18] Given that several authors have reported high rates of union with dual plating, it is likely that the impact on the periosteal vasculature is offset by the biomechanical benefits of stabilization.[7–10] A more biologically friendly technique to consider in an effort to avoid periosteal vessel compression would be to use locking screw fixation of the medial plate to minimize plate–bone contact. In addition, an alternative technique to dual plating that increases construct stability in osteoporotic bone is combining a retrograde femoral nail with a lateral distal femoral locking plate.[19,20] While this method limits exposure and avoids plating of the medial distal femur, there is still a potential for vascular insult to the endosteal blood supply if reaming of the intramedullary canal is performed.[21] This treatment strategy may also not be feasible in certain fracture patterns that are too distal for a retrograde nail, or in cases of periprosthetic fracture where the femoral prosthesis has a closed intercondylar box.

This study has the limitations inherent to using cadavers. While not observed, it is possible that the occluded periosteal arteries could receive retrograde perfusion from adjacent arteries that are patent. We also did not perform plating and injection in a fracture model, which might better represent the pre-existing periosteal vascular compromise that occurs at the time of injury. Medial plating may be less of a biological concern in the setting of pre-existing medial periosteal vessel disruption. It remains uncertain if the occluded periosteal arteries observed in our study would have a negative effect on healing in vivo. Biomechanical studies have demonstrated the efficacy of several supplemental medial implants.[20,22,23] The vascular implications of precontoured locking or large fragment compression plates on the medial distal femur as described in those studies remain uncertain, but the larger footprint may contribute a greater insult than small fragment plating. On the other hand, the biomechanical efficacy of supplemental medial distal femur fixation with small fragment plating is unknown. In addition, our lack of fluoroscopy use during plate positioning and fixation may be seen as a limitation. However, all plates were introduced and positioned through distal and proximal incisions, respectively, using established minimally invasive submuscular plating techniques on an intact bone model without a fracture. Furthermore, screw placement was only performed under direct visualization through the distal and proximal incisions to limit additional soft-tissue trauma. Fluoroscopy would not have provided an additional benefit to the study given our methods and aims.

5. Conclusions

In conclusion, medial plating of the distal femur using a submuscular conventional plating technique compressed the d-MMPA in the majority of specimens. This vessel gives rise to the ALA of the distal femur, which lacks perfusion in these specimens when the d-MMPA was occluded. On average, 2 of the medial periosteal arteries were compressed in medially plated specimens. This vascular insult could potentially affect the healing of distal femur fractures treated with dual plate stabilization. Further research investigating the clinical impact of supplemental medial distal femoral plating is warranted.

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