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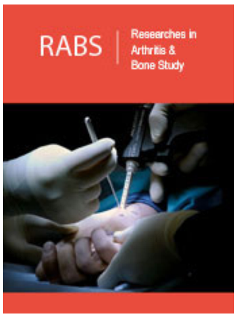
Case Report

The Use of Autologous Tibia Strut Grafts to Enhance Bone Healing of an Infected Long-Bone Nonunion

Reynders-Frederix Peter[1]*, Schiopu Dragos[1] and Reynders-Frederix Cristina[2]

[1]Orthopedic Surgery, University Hospitals Brugmann, Belgium

[2]Revalidation & Physiotherapy, University Hospitals Saint-Pierre, Belgium



***Corresponding author:** Reynders-Frederix Peter, Orthopedic Surgery, University Hospitals Brugmann, Brussels, Belgium

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Abstract

We treated five patients with an infected non-union of the femur and tibia with autologous tibia strut grafts. All patients had bone defects ranging from three to nine centimeters. Three patients suffered for more than seven years from chronic osteitis. Our objective was to describe this grafting technique and its results. We focused on healing time, postoperative complications and functional recovery. We retrospectively studied five patients with an infected non-union of the lower limb who had undergone previous surgeries to overcome the bone healing problem. In this group of patients, we had four femur non-union and one tibia non-union. All of them had a previous infection episode, in which medical and surgical therapy was needed. Of the participants, three were men, and two were females with a mean age of 43.3 years (28-55).

Keywords: Bone healing; Osteogenesis; Antibiotics; Fistula formation; Cortical graft

Introduction

The treatment of an infected lower limb non-union remains a complex therapeutic problem. Several techniques have been developed over time to address it. All these techniques have their positives and negatives. Good results were obtained when using the following: structural allografts [1,2] Masquelet's technique [3], Ilizarov distraction osteogenesis and compression [4-7], free vascularized fibula graft [8], changing the biomechanics of the fracture site [9-12] and recombinant BMP 2 and 7 [13]. These patients often have multiple orthopaedic ailments, such as deep bone infections, bone defects and extensive scarring with reduced local bone vascularization, regardless of whether these ailments are combined with systemic influences that negatively affect the healing process. The influence of diabetes, tobacco abuse, corticoid use, and social deprivation and social isolation negatively affects bone healing [14].

Procuring the Cortical Graft

After preparing the receptor side, the autologous cortical tibial graft is taken from the antero medial surface of the contralateral healthy tibia. The size of the defect determines the length of bone required; however, at least 6cm of proximal and 5cm of distal tibia should be left behind at the donor site. The graft is outlined, and drill holes with a 3.2mm drill are made. The holes are joined together by using an oscillating saw. Cooling of the saw blade with physiologic serum is done to avoid unnecessary heat necrosis of the bone. With the chisel, the graft, with as much bone marrow as possible, is carefully lifted out of the donor bed and immediately implanted in the receptor bed. The donr site tibial bone defect is filled with a cortical tibia allograft. In two cases a press fit between the graft and the donor site was obtained. In these cases, no screws were used.

Case 1

A 52-year-old man was assaulted and sustained a displaced open proximal tibia fracture. His condition was treated by antibiotics, debridement and bone fixation with an external fixator. An infected malunion in valgus occurred. The deep bone infection with fistula formation was treated intermittently with oral antibiotics. After a minor trauma, a new fracture occurred seven years after the initial incident. Spontaneous healing in a plaster cast was not possible because of the fistula and soiling of the plaster cast. Masquelet's technique was used to heal the infected non-union, no bone healing could be obtained. The infected nonunion was accepted by the patient and treated with oral antibiotic administration. Eventually, with long-lasting antibiotic therapy, the deep bone infection came under control, as there were no external infection signs. Because of the increasing varus of the tibia nonunion, another attempt was made to achieve bone healing (Figure 1a & 1b). The external tissue scarring was so extensive that applying a classical surgical approach to the fracture site proved impossible.

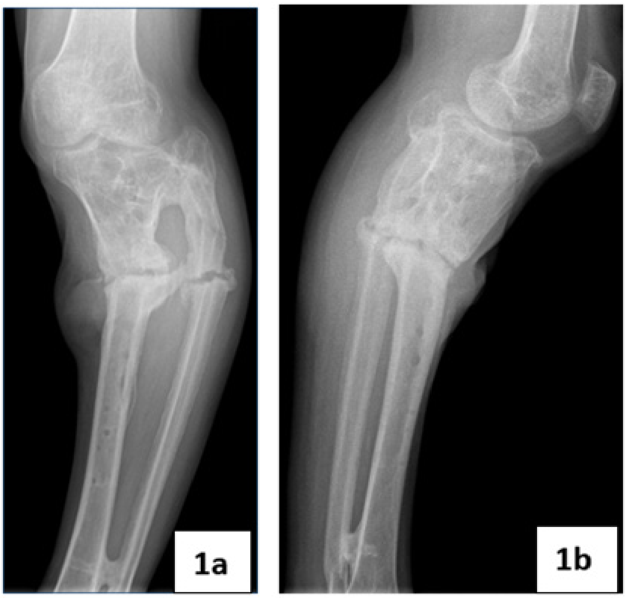

Figure 1a-b: Case n° 1. Radiographs eleven years after the initial fracture. Mobile pseudarthrosis with varus deformity.

Surgical technique

First, a fibula osteotomy was performed to obtain a better alignment of the lower leg. Then, an autologous cortical tibia graft, taken from the other tibia, was inserted intramedullary via a suprapatellar approach (Figure 2a & 2b). The tibia was then stabilized with an external fixator. One week after surgery, the cortical bone graft broke at the level of Herzog's angle. After one year, there was sufficient endosteal bone formation around the intramedullary graft, and the fixator external could be taken off (Figure 3a-3e & 4a-4b), The patient is now walking with a cane for equilibrium reasons.

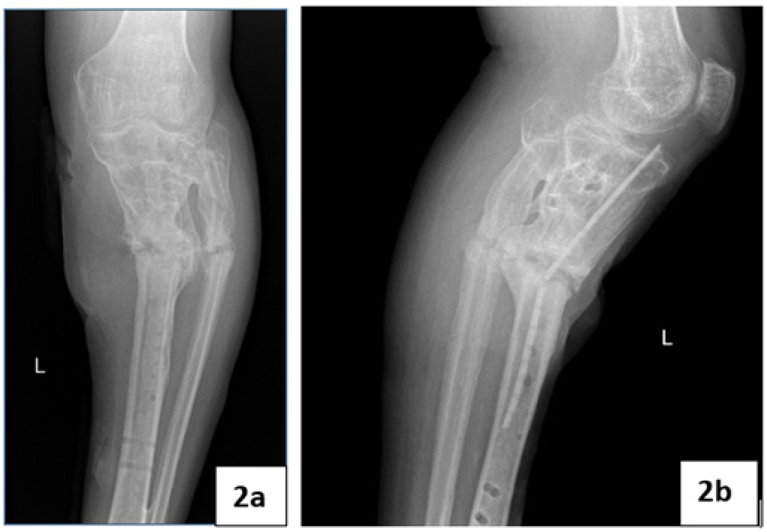

Figure 2a-b: Case n° 1. Radiographs two years after the removal of the external fixator. On profile the broken endosteal located graft is clearly visible.

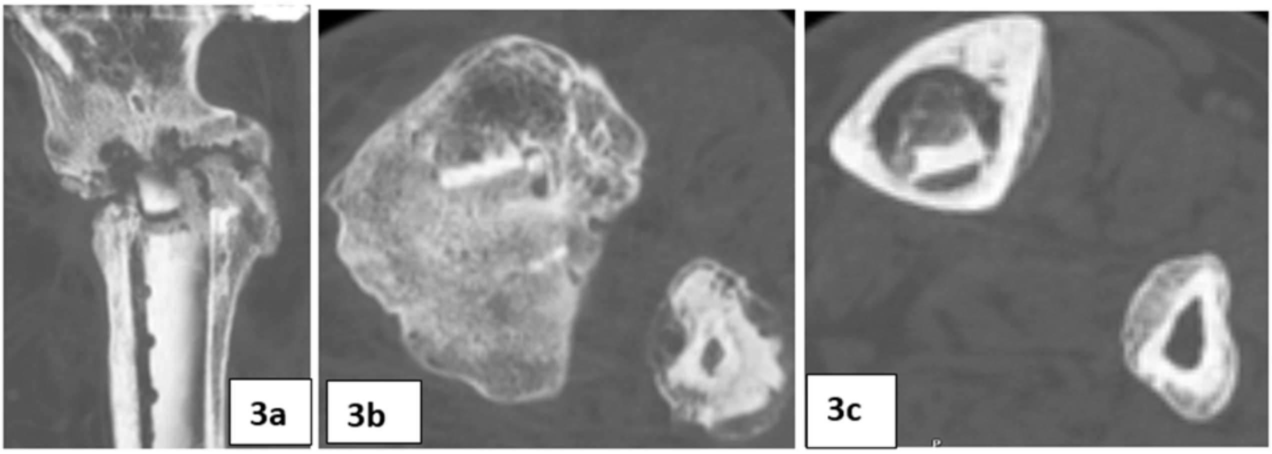

Figure 3a-c: Case n° 1. CT images showing the endosteal bone formation around the broken cortical graft.

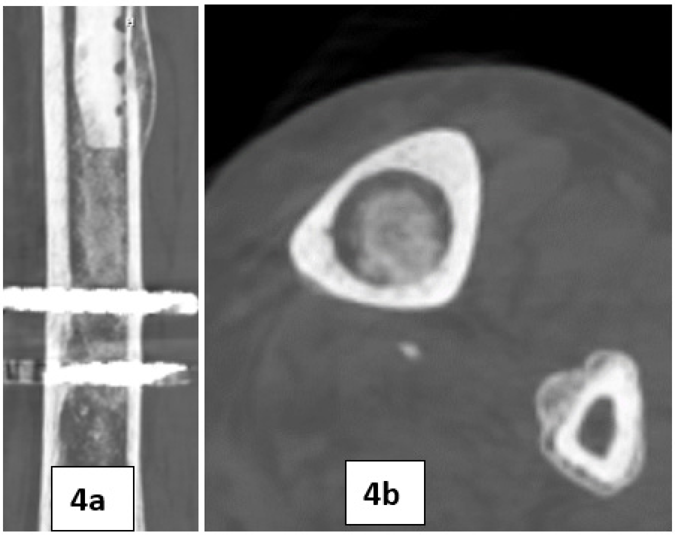

Figure 4a-b: Case n° 1. CT images picturing the extensive endosteal bone formation underneath the autologous cortical graft.

Case 2

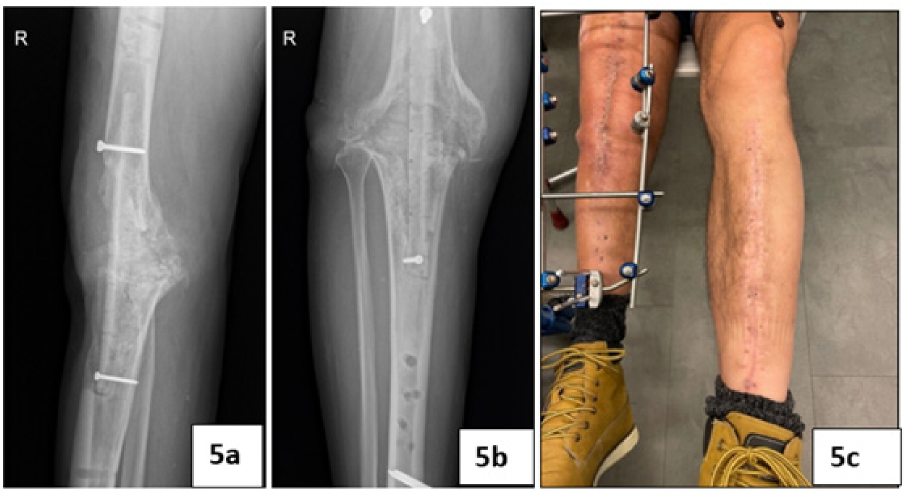

Figure 5a-b: Case n° 2. Radiographs showing the anterior placed grafted spanning the non-union side and fixed with two 4.5mm cortical screws and spanning external fixator. **5c:** Case n° 2. Clinical views of both lower legs with the surgical scar on the left tibia for the graft procurement.

A 55-year-old man, who smokes heavily, received a total knee prosthesis for severe gonarthrosis. Unfortunately, a deep infection occurred. The patient was given antibiotics as the only treatment because he refused further surgery. He sought surgical advice five years after the initial placement of the knee prosthesis. A bone scan with marked white blood cells showed profound osteomyelitis of the distal femur and proximal tibia. A cemented spacer was used and then changed after three months by a hinged knee prosthesis. Within a year, the deep infection reoccurred, necessitating the removal of the knee prosthesis. An attempt to perform an arthrodesis of his knee with a bridging external fixator failed. After one year with an external fixator, the bone union did not occur, and a cortical autologous strut graft was placed anteriorly, spanning the arthrodesis site. The graft was fixed with two 4.5mm cortical screws, one above and one below the arthrodesis site. A new spanning external fixator was placed to secure the knee arthrodesis (Figure 5a-5c).

Three months after the last surgery, the patient fell on the street, breaking his strut graft with a skin laceration in front of his knee. The skin abrasion became infected. Antibiotics were given, and the anteriorly located wound was debrided. After six weeks, the wound became clean, and a posteriorly placed large fragment femoral plate was placed covering the former knee joint. This patient had poorly vascularized, scarred-down and immobile tissue in the front of his knee. No attempt was made to remove the anteriorly located broken cortical strut graft. At the same time, a cortical strip of bone from the posterior side of the proximal tibia was taken and shifted proximally to bridge the fracture site. Removal of dead bone tissue was done with the same procedure. After the last surgery, the anteriorly located infected wound healed. The anteriorly (broken) and posteriorly cortical bone grafts were integrated after one year. Full weight-bearing activities were possible at that time.

Two years later, the posteriorly located plate broke (Figure 6a). The broken implant was replaced by two cannulated crossing screws of 7.3mm screws to secure the former knee joint together with a solid femur allograft which spans the non-union side. This graft was secured to the femur with six 4.5mm cortical screws: three screws above and three screws below the non-union site (Figure 6a-6b). It took another two years post-surgery to see the bony union and integration of the allograft. The patient is now pain free and can walk with one elbow crutch.

Figure 6a: Case n° 2. CT scan depicting the broken cortical graft. **6b:** Case n° 2 Radiograph after the broken plate removal and posterior strut allograft placement. Two crossing 7.3mm crossing screws were used to stabilize the knee joint.

Case 3

A 28-year-old female was involved in a car crash. An isolated closed femur fracture was diagnosed and treated with open femoral nailing and cerclage wiring. One year later, there was a painful mobile pseudarthrosis with a leg shortening of three centimetres on the same site (Figure 7a-7b). She did not experience any infection after her initial treatment. The clover leaf nail was replaced by a locking femoral nail. At the same time, an allograft was placed at the lateral side of the femur, bridging the non-union fracture side. Unfortunately, the deep tissue samples came back positive for *Enterobacter cloacae*, *Streptococcus oralis* and *Escherichia coli*. All the implants and allograft were removed, and her leg was put in a spanning external fixator, spanning her hip as well as her knee joint.

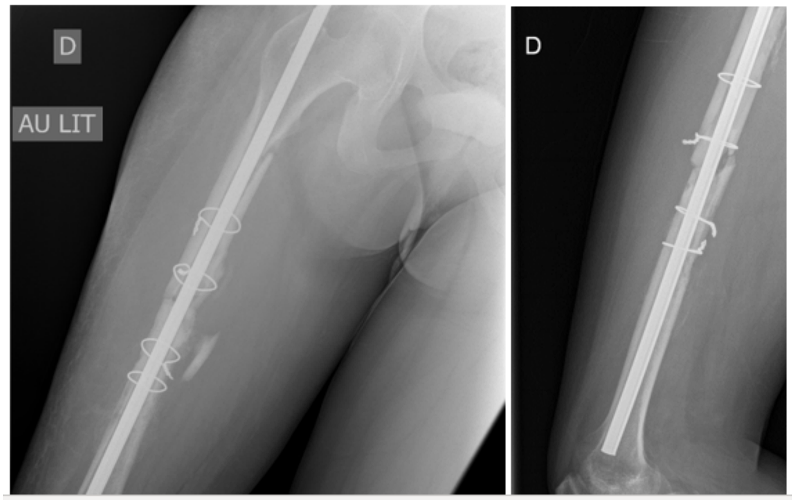

Figure 7a-b: Case n° 3. Radiographs, two years after open nailing of a closed femur fracture.

The patient wore the external fixator for three months while receiving intravenous antibiotics. After this period, the external fixator was removed and replaced by a 4.5mm locking plate, which protected a 25cm long autologous tibia on lay graft (Figure 8a-8c). The contralateral tibia served as the donor side. Full weight-bearing activities were possible six months after the last surgery. During this period, she received oral antibiotics. Full integration of the cortical graft was visible one year after the last surgery. Five years after her last surgery, she remains infection free but does walk with a slight limb. She has a shortening of 2.5cm, which compensates with inlay shoe soles. Her knee flexion is 110° for a full extension, and hip function is normal.

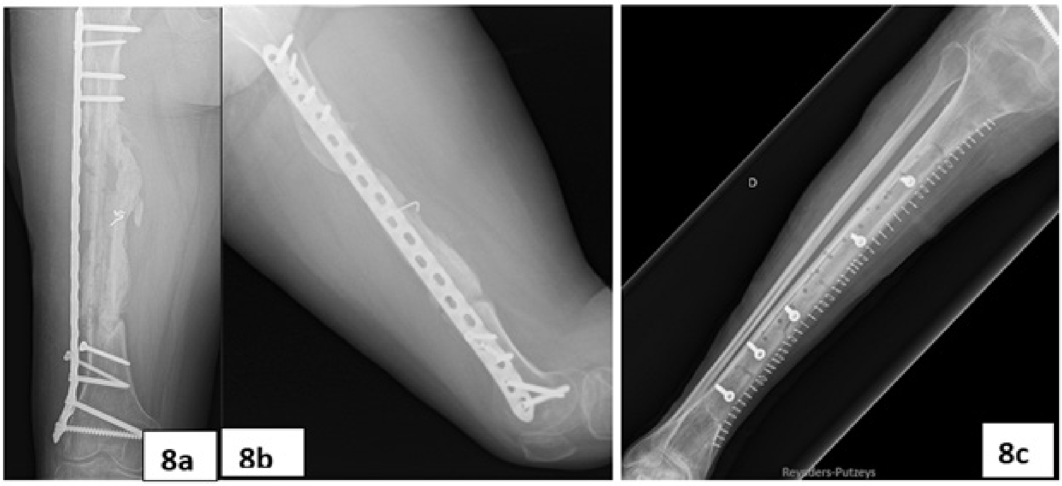

Figure 8a-b: Case n° 3. Radiographs, two years after cortical bone graft transplantation. **8c:** Case n° 3. Radiograph of the donor site two years after surgery. Allograft is held in the donor defect with 4.5mm cortical screws.

Case 4

A 54-year-old man was involved in a motorcycle accident abroad. He sustained an open bifocal femur fracture and a closed base-cervical femur fracture on the same side-the cloverleaf nail protracted from his knee when he returned to Europe. Pus was pouring out the level of the bone segment and his knee joint. The intertrochanteric fracture went unnoticed and was not stabilized. A mixed flora of *Escherichia coli*, Actinobacteria baumanii and a multi resistant Proteus mirabilis was found after deep tissue sampling. The nail and allograft were removed, and his leg was placed in an external fixator, spanning his hip and knee. After three months, an autologous tibial cortical graft was placed inside the bone gap, and the bone was stabilized with an external fixator. Reinfection then occurred, which was treated with antibiotics. Spontaneous breakage of the cortical graft was noted two months after the placement. An oncological resection of the infected bone and soft tissue was carried out, and a mega prosthesis was done, including his hip and knee joints, at another institution.

Case 5

A 28-year-old man fell on slippery ice and broke the distal third of his femur. It was a closed fracture. A locked plate (LISS DePuy-Synthes) was used to stabilize the distal femur fracture. Unfortunately, the plate had to be removed two months later because of a deep infection (*Staphylococcus aureus*). The femoral fracture was stabilized by an external fixator, and antibiotics were given. After eight months, the external fixator was removed because of an ongoing pin tract infection. Thirteen months after the initial trauma, revision surgery was performed using a contralateral autologous cortical tibia graft. The cortical strut graft was brought into the medullary cavity by the retrograde way (from his knee on) and stabilized by a lateral placed locked plate. Six months after the last surgery, graft integration was also seen with fracture healing. However, some function of his knee was lost: 20° of flexion. At his follow up at three years, no infection was seen. The patient refused further surgery. He now walks with a cane.

Discussion

In these five patients, an autologous tibial strut graft was used to enhance bone healing. Autologous cortical grafts are notorious for their slow integration in the surrounding bone tissue of the host when compared to autologous cancellous bone grafts. Cortical bone is dense and contains less than 10% soft tissue. Cancellous bone is more porous and interspersed between bone marrow, which represents more than 75% of its volume. Cancellous bone is four times more active than cortical bone [15]. The primary healing mechanism of autogenous cortical bone grafts is osteoconductive (scaffolding). Autologous cortical bone has nearly no biologic active cells (fewer osteogenic properties) compared to cancellous bone. Cortical bone is less porous and has less surface area and less cellular matrix than cancellous bone. Therefore, cortical bone grafts take longer to revascularise. Cortical bone grafts are a good choice when there is need to span a bone defect. Cortical grafts need to be resorbed by osteoclasts and progressively replaced by mesenchymal cells and eventually new viable bone in a process called creeping substitution, which can take many years. Fatigue fractures of these grafts are seen in 25% of the cases [16].

The surgical technique of using autologous cortical strut graft was popularized by the Slovak surgeon J. Zahradnicek in 1939, by M. Lange in 1951 and by A.N, Witt 1952 [17]. Probably due to the Iron Curtain, which divided Europe in two after World War II, this technique found little acceptance in Western European countries. In this series of five patients, this technique was used to enhance bone healing by biological means while increasing the mechanical support of the nonunion. In all the patients, multiple surgical interventions were needed because of recurrent deep bone infections. In three cases, a structural failure of the cortical graft was seen. In these three cases, the stability of the bone construct was given by an externa fixator. Mechanical stability, good vascularization and intimate contact between the graft and the recipient bone are essential [17]. In one case, the mechanical failure of the graft together with an uncontrollable bone infection was the cause of total failure. An oncological resection of all infected bone was necessary as was the placement of a tumour prosthesis on his hip, femur and knee joint.

In the two cases with the intramedullary placement of the cortical graft, there was an intense endosteal integration of the cortical graft. In part, endo-medullary reaming could possibly explain this endosteal bone formation. But this is not in concordance with endosteal reaming in trauma cases of long bones, where such an endosteal bone formation is rarely seen. Nor is this endosteal bone formation seen after harvesting intra-medullary bone graft by the Reamer Irrigator Aspirator system (RIA: DePuy-Synthes) [4,18]. This robust endosteal reaction around the graft was seen early in the healing process, which contradicts the creeping substitution theory as a mechanism for graft integration. In one of these two cases, the broken graft healed with endosteal cancellous bone formation. The continuity of the cortex of the broken side of the graft was however not restored. The two weaknesses of this paper are the lack of a control group and its small size. The ideal approach would be to compare this technique with the use of cortical strut allografts. However, the described lesions are rare and heterogeneous in nature, which makes comparison with other treatment protocols difficult.

Conclusion

The use of an autologous cortical strut graft is a possible technique to enhance the biological process of the nonunion healing of a long bone of the lower limb. All the grafts stabilized with an external fixator failed (fatigue fracture), underlining the importance of a solid stabilization of the nonunion with a plate. Creeping substitutions is the mechanism for integration and remodeling of the graft when used as an on lay graft. When the graft is used as a biological nail (endo-medullary position), an early and extensive endo-medullary bone formation is seen around the graft. The latter gives the impression of a different and faster bone integration and remodeling mechanism when placing the cortical graft in the endo-medullary cavity.

Ethics Approval

The study was approved by the local ethical committee, CE2023/108 and have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments, including applicable ethic regulation of the Free University of Brussels, Belgium.

Competing Interests

The authors whose names are listed certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants, membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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