Comparing Plate Fixation to Intramedullary Nail Fixation for Unstable Diaphyseal Tibia Fractures

Max Seiter[1], Leonard Buller[1], Abeer Al-Barghouthi[2], Edward Milne[2], Stephen Quinnan[1], Loren Latta[1,2], Francesco Travascio[3]

[1] Dept Orthopaedics, Univ. of Miami, Miami, FL, [2]Max Biedermann Institute for Biomechanics at Mount Sinai, Miami Beach, FL, [3]Dept. Industrial Engr, Univ. of Miami, Coral Gables, FL f.travascio@miami.edu

INTRODUCTION: Surgeons have several choices for internal fixation of diaphyseal tibia fractures. Intramedullary nail fixation (IMN) is the most widely used, and generally preferred, as load-sharing allows for immediate weightbearing; however, intramedullary fixation may not be optimal in certain clinical scenarios or fracture patterns. Minimally invasive plate and screw osteosynthesis (MIPO) has gained popularity as an alternate form of fixation because, unlike traditional plating, it allows for stabilization while minimizing stripping of soft tissues and disruption of blood supply to the healing fracture. Some questions still exists about the optimum rigidity of fixation and motion at the fracture site to facilitate healing. All these issues come to focus in choosing the best surgical fixation for each fracture [1]. Bone repair is highly sensitive to mechanical stimuli in the surrounding tissue [2], influencing cell type differentiation at the repair site [3], which in turn influences how well the damaged area heals – including recovery time, risk of malunion or nonunion, and stiffness of the newly formed bone [4]. Increased interstitial fluid flow occurs in response to mechanical loading and is a crucial factor in cellular excitation [5]. Therefore, many factors must be considered when choosing surgical fixation including: soft tissue stripping, magnitude and type of strain on the healing tissues needed for speedy and efficient bone regeneration [6]. The objective of this study was to investigate how different screw configurations with MIPO compare to IMN in controlling magnitude and type of motion at the fracture site, in a tibia diaphyseal fracture fixed with gapping at the fracture site. A biomechanical test was used to measure the stiffness of the investigated constructs.

Methods: A total of 4 Sawbones Generation IV (Sawbones®, Vashon Island, WA) of a human tibia were transversely cut by a saw at the mid diaphysis, creating a gap of approximately 2 mm and representing a simple, transverse fracture of the tibia. Each bone was fixed with a 4.5 mm 8-hole straight plate applied to the anterior medial surface of the tibia with the cut centered under the plate. The fracture was fixed with approximately 2mm of gapping at the fracture site. All 8 bicortical screws were applied in the locked mode. The tibia bone was subsequently mounted on a MTS 858 Mini Bionix II testing system (MTS Systems Corp., Eden Prairie, MN) for compression and torque testing. For compression, the tibia plateau was put in contact with a femoral total knee implant connected to a universal joint to exert a compressive loading whose magnitude spanned from 200 to 500 N to reproduce a physiological range of tibio-femoral contact loads expected during gait [7]. The distal end of the bone rested upon a spherical pin allowing for rotation in all planes to mimic normal behavior. For torque, both ends of the tibia were clamped in a vise. Specifically, the distal end was aligned to the center of the MTS ram, while the proximal end was mounted on an X-Y linear bearings table to allow the center of rotation to follow the natural rotational axis of the construct in the horizontal plane. The construct was cycled in external-internal rotation in the horizontal plane, from +/- 1 to +/- 3 Nm. After testing of the configuration including all the 8 screws in the holes (C8), the experiments were repeated using two other MIPO configurations and IMN in the following order: 1) keeping screws in holes 1, 4, 5 and 8 (C1458); 2) adding back screws at holes 3 and 6, and removing those at holes 4 and 5 (C1368); 3) removing all the screws and introducing a proximally and distally locked intramedullary nail (IM). The intramedullary fixation was performed with an 8mm nail after reaming the tibia to 9.5mm. The fracture was fixed with 2mm of gapping, and 2 proximal and 2 distal interlocking screws were inserted. During loading, the relative range of motion (ROM) between proximal and distal bone fragments was measured by a motion capture system (MaxPRO, Innovision Systems, Inc., Marietta, GA). Data were reported in terms of rotations in the sagittal, coronal and axial planes.

RESULTS: For compression, the ROM of all constructs was not significantly different (p-value > 0.05) in either sagittal or axial planes. In the axial plane, the ROM with IMN was significantly smaller (p-value < 0.05) than with MIPO configurations when the compressive load was 300 and 500N, see Figure 1. Motion of all constructs with torque was not significantly different (p-value > 0.05) in either sagittal or coronal planes, with the only exception of ROM of the plate configuration C1368 being larger than that of IM at 2Nm in the sagittal plane. In the axial plane, the ROM of IM was significantly larger (p-value < 0.05) than of all the MIPO configurations, see Figure 2. A summary of the ROM of all the constructs for all the loading conditions investigated is reported in Table 1.

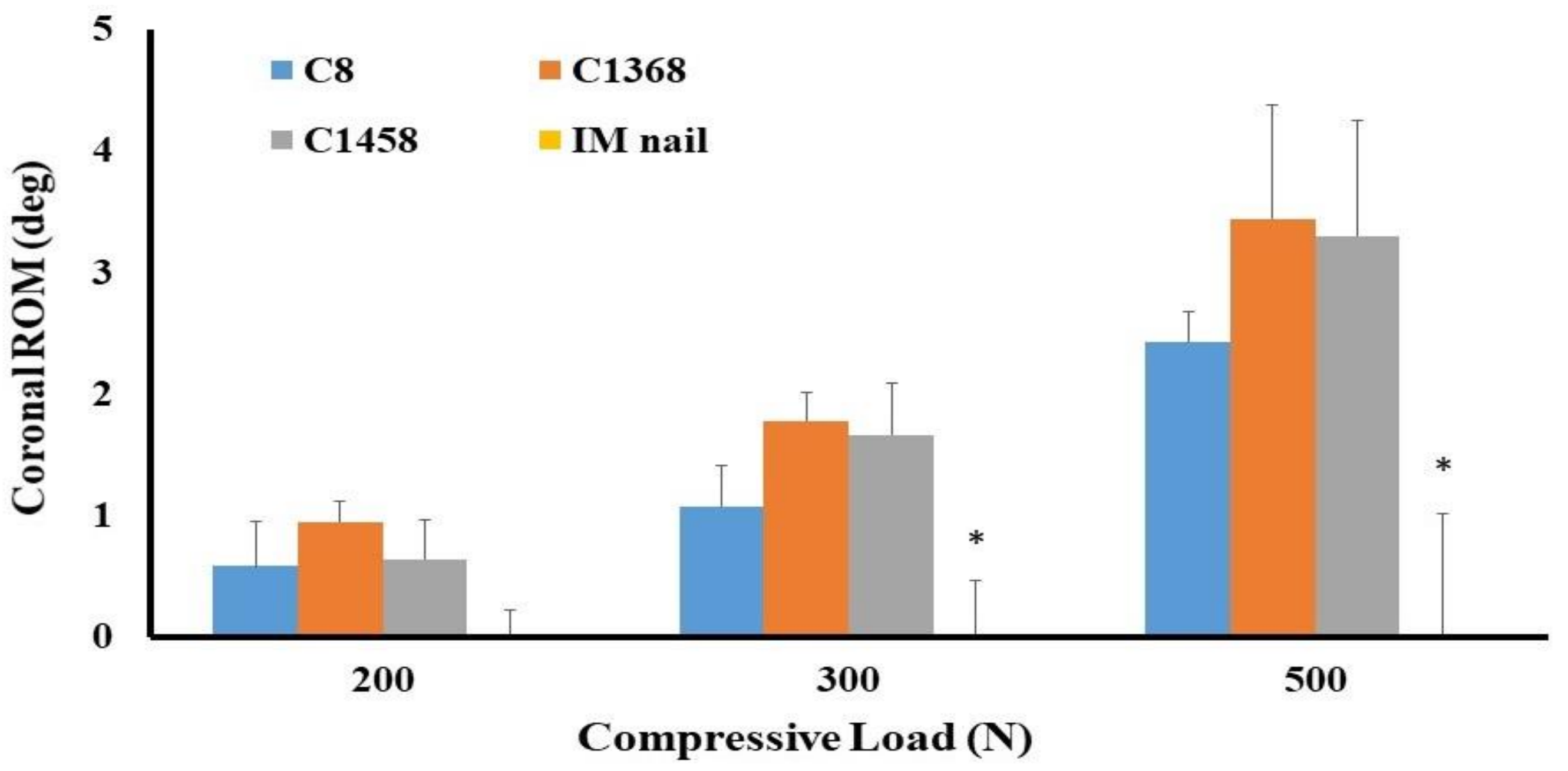

Figure 1. Range of motion of MIP and IM constructs during compression. (*) indicates statistical significance (p-value < 0.05)

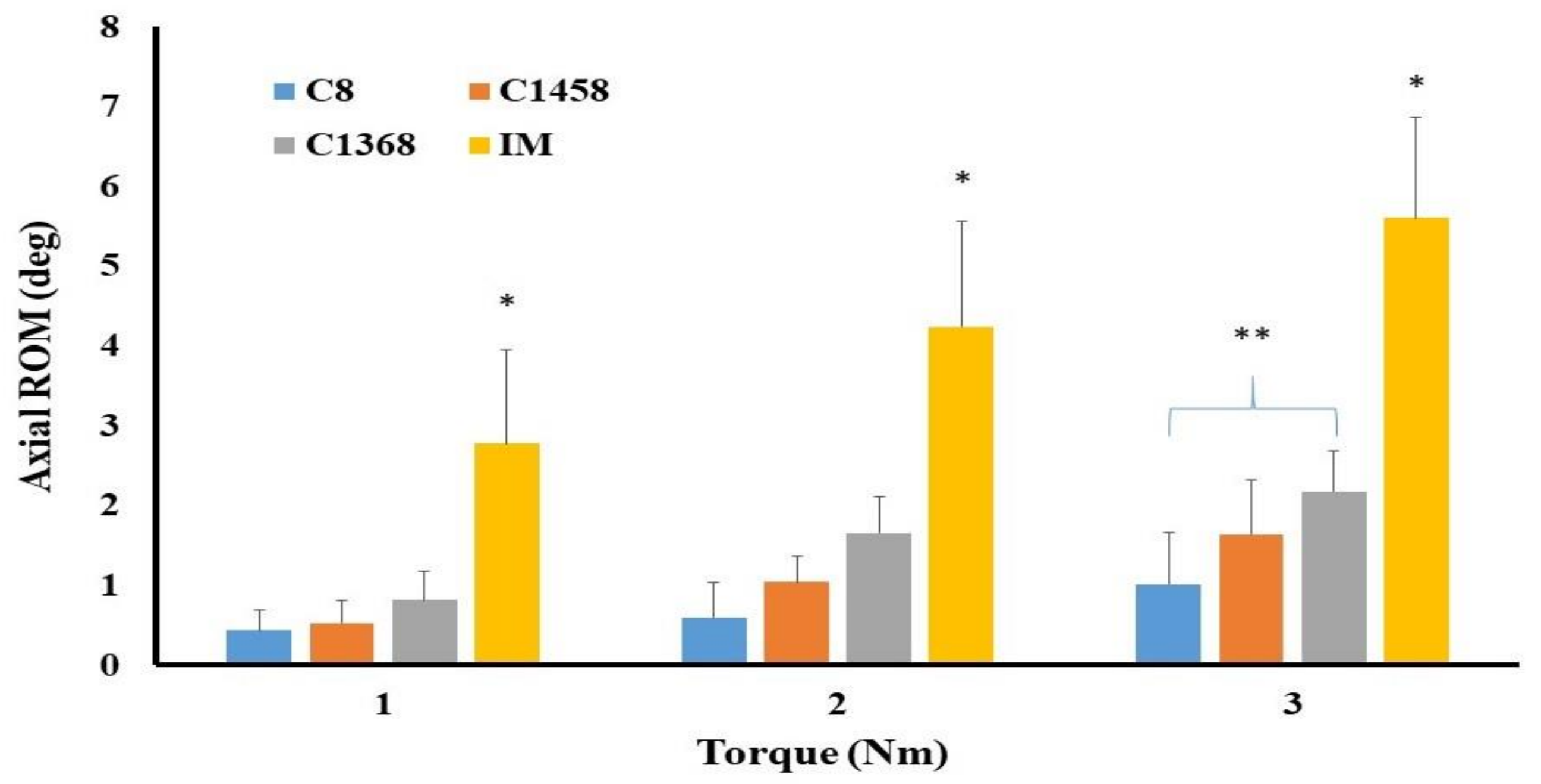

Figure 2. Range of motion of MIP and IM constructs during torque. (*) and (**) indicate statistical significance (p-value < 0.05)

DISCUSSION: Our study demonstrates that in fractures fixed with gapping, the ROM under compression is significantly greater with MIPO than IMN, with the ROM of IMN being essentially 0 within the coronal plane. This indicated that fractures with less rotational stability or those exposed to larger rotational forces, such as transverse fractures or fractures of the upper extremity, may benefit more from plate fixation. In contrast, rotationally stable fractures and those exposed to higher forces in axial loading, such as in the lower extremity, may benefit from intramedullary fixation.

SIGNIFICANCE: Our study demonstrates that in fractures fixed with gapping, the ROM under compression is significantly greater with MIPO than IMN; and that ROM in torque is significantly less with MIPO than IMN. This has implications in choice of fixation as fractures with poor rotational stability, such as transverse fractures, may benefit most from plate fixation. Similarly, fractures of the upper extremity that are subjected primarily to rotational forces may be better treated with MIPO, while lower extremity forces that are subjected to higher forces in axial loading may be best treated with intramedullary fixation.

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COMPRESSION

	Coronal			Axial			Sagittal		
	200 N	300 N	500 N	200 N	300 N	500 N	200 N	300 N	500 N
C8	0.58±0.37	1.07±0.34	2.43±0.25	-0.20±0.12	-0.17±0.11	-0.15±0.07	0.78±1.73	0.73±1.77	0.55±1.72
C1368	0.95±0.16	1.78±0.23	3.44±0.93	-0.14±0.36	0.03±0.40	0.10±0.37	-0.18±0.20	-0.32±0.13	-0.50±0.46
C1458	0.64±0.32	1.67±0.42	3.30±0.95	0.05±0.04	-0.17±0.04	-0.13±0.20	0.13±0.07	0.11±0.14	0.04±0.05
IM	0.00±0.23	-0.03±0.49	0.01±1.00	-0.15±0.33	-0.15±0.37	-0.49±0.49	0.32±0.18	0.71±0.43	1.19±0.82

TORQUE

	Coronal			Axial			Sagittal		
	1 Nm	2 Nm	3 Nm	1 Nm	2 Nm	3 Nm	1 Nm	2 Nm	3 Nm
C8	-0.01±0.07	0.00±0.01	0.01±0.03	0.43±0.40	0.61±0.39	1.02±0.78	0.21±0.19	0.19±023	0.30±0.31
C1368	0.09±0.13	0.01±0.15	0.03±0.04	0.53±0.40	1.05±0.45	1.64±0.61	0.14±0.24	0.36±0.36	0.60±0.60
C1458	0.04±0.06	0.02±0.03	0.00±0.01	0.82±0.38	1.66±0.44	2.18±0.62	0.36±0.42	0.66±0.70	0.40±0.39
IM	0.03±0.08	0.00±0.01	-0.02±0.09	2.78±1.12	4.24±1.36	5.61±1.29	0.14±0.17	0.09±0.13	0.12±0.09

Table 1. Summary of range of motion (mean±SD) of MIP and IM constructs during compression and torque

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