Is Unicortical Locking Screw Placement Effective For The Torsional Loads in the Distal Radius Fractures? : Biomechanical Study in Cadaver

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Research Article

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Abstract

Background

We aimed to compare biomechanical outcomes of short-length (75%-length) and full-length (100%-length) unicortical distal screws under axial and torsional compression in cadaveric distal radius volar plate model.

Methods

A total of 20 wrists from 10 fresh frozen cadavers were included. 2.5 mm titanium alloy distal radius anatomical plates was placed to the distal radii in full anatomical position, just proximal to the watershed line. Three bicortical screws to the shaft of the radius, followed by unicortical drilling for distal screwing were placed. Measurement by pulling the drill once it reached the opposite cortex was applied. We selected the screw lengths such that they corresponded to the 75% of the measured length (short-length). In the same configuration for each of the cadavers, we delivered six screws from distal radius holes of the anatomical plate. oscillating handsaw was used to create extraarticular distal radius fracture model (AO 23-A3.2). We created dorsal AP model by performing a 1-cm wedge osteotomy from dorsal aspect. Complete separation of the volar cortex was achieved. Potting was performed by embedding the shaft of the prepared radius into the polyurethane medium. We placed aluminum apparatus into the distal end to ensure applying of torsional and axial loading in biomechanistic tests.

Results

No statistically significant difference of stiffness between the short-length and full-length distal screws both under axial compression($p = 0.88$) and torsional compression ($p = 0.82$). Short-length and full-length distal screw groups did not differ in elastic limit under axial compression ($p = 0.71$) and torsional compression ($p = 0.71$). Maximal force on short-length and full-length distal screw groups were also similar under both axial compression ($p = 0.71$) and torsional compression ($p = 0.50$).

Conclusion

It is a safe method under torsional load to avoid drilling of the dorsal cortex and unicortical delivery of 75%-length distal screws could be performed in order to prevent from extensor tendon complications secondary to drilling or screw protrusion.

Introduction

Distal radius fractures are among the most common fractures among orthopedic injuries [1]. While these fractures are usually treated with non-surgical approach in children and adolescents, the need for surgery has recently increased for young adults and elderly, especially for unstable fractures [2, 3]. Allowing for early functional rehabilitation, internal fixation is often more preferred and achieved through various methods, including fragment-specific fixation, dorsal plating, and volar plating [3–6]. Among these, volar plating has become more popular owing to its ease of applicability, strength advantages, and lower rates of extensor tendon problems than in dorsal plating [5].

Potential injuries to extensor tendon may either occur during drilling or postoperatively due to irritation caused by the screw's protrusion into the dorsal surface [7–9]. In order to overcome the latter, unicortical delivery of the distal screws has been suggested. It was reported that the length of the screws advanced into the distal part requires to be 2–4 mm shorter than the calculated length [11]. However, the effect of length of distal screws on fixation remains uncertain in volar plate osteosynthesis. Previous studies reported similar stabilization rates between unicortical distal screws of 75%-length and 100%-length that merely focused on axial compression and bending forces, lacking the impact of torsional forces [4, 10, 12].

Our hypothesis was the short-length (75%-length) unicortical screws may provide the same stability under axial and torsional forces in the treatment of the distal radius fracture compare to the full-length (100%-length) screwing.

In this study, we aimed to compare biomechanistic outcomes of short-length (75%-length) and full-length (100%-length) unicortical distal screws under axial and torsional compression in cadaveric distal radius volar plate model.

Materials And Method

The study was approved by the Medical Research Ethics Committee of Acibadem Mehmet Ali Aydinlar University (Approval No: 2019-10/4). A total of 20 wrists from 10 fresh frozen cadavers were supplied from Acibadem University. The cadavers were eligible if they had had no tumor, bone defect or lesion, osteoarthritis, previous fracture, or osteoporosis. We prepared homogeneous groups according to the dominant and non-dominant wrists of the cadavers.

We separated radius bones from the ulna and other soft tissues and cut into specimens of 14-cm in length. Afterwards, we placed TST® titanium alloy distal radius anatomical plates to the distal radii in full anatomical position, just proximal to the watershed line. Considering the count and configuration of the screws suggested by Mehling et al. [13], we sent three bicortical screws to the shaft of the radius, followed by unicortical drilling for distal screwing. We performed measurements by pulling the drill once it reached the opposite cortex.

We selected the screw lengths such that they corresponded to the 75% of the measured length (short-length). In the same configuration for each of the cadavers, we delivered six screws from distal radius holes of the anatomical plate. Afterwards, we used oscillating handsaw to create extraarticular distal radius fracture model (AO 23-A3.2) [4, 14]. We created dorsal ap model by performing a 1-cm wedge osteotomy from dorsal aspect (Fig. 1, 2). Complete separation of the volar cortex was achieved. Potting was performed by embedding the shaft of the prepared radius into the polyurethane medium. We placed aluminum apparatus into the distal end to ensure applying of torsional and axial loading in biomechanistic tests (Fig. 3, 4).

All specimens were placed in the testing machine and tested under axial and torsional loads. Initially, axial and torsional forces were simultaneously applied to each sample, where stiffness and elastic limit measurements were obtained. Afterwards, the magnitude of maximal force that was required to achieve catastrophic failure (fracture of the bone, screw, or plate) were determined for both short-length and full-length groups.

The plated cadaveric radius bones were embedded into the polyvinyl chloride tube from one end via polyester resin, while the other end was fixed to the test device via a miniature vise. This vise ensured both torsional and axial compression by clamping the bone in a plane perpendicular to the plate plane.

A vise was attached to the loading cell (AXIAL-TORSIONAL LOAD TRANSDUCER 25 kN / 25 Nm) of the testing device (MTS 858 Mini Bionix II), and a steel pot was placed in this vise to place the samples. The prepared samples were placed inside the steel pot via PVC tube. The upper part of the bone was attached to the test device through the miniature vise. While the loads applied to the bone were measured via the transducer (AXIAL-TORSIONAL LOAD TRANSDUCER (2500 N / 25 Nm), the displacements and angles were calculated via the displacement transducer (MTS LVDT TRANSDUCER-359/LVDT, Displacement, Serial Number: 10188729) and angle transducer (MTS ADT TRANSDUCER- 359/ADT, Torsional Angle, Serial Number: C11382).

Once the test began after connection of the samples to the device, a torsional load of 0.5 Nm to 5 Nm was applied for 10 cycles simultaneously with an axial compression force between 5 N and 250 N at a frequency of 0.25 Hz to eliminate the gaps in the system and observe the range in which the system operates stably. Afterwards, the loads in the system were reset and the axial and torsional stiffnesses of the system and the maximum loads that the system can carry were determined with static loading. These static tests were performed with an axial speed of 2 mm/min and a rotational speed of 10°/min. The occurrence of closure of the osteotomy line or the loosening of the screws were accepted as damage criteria, upon which the tests were terminated.

Axial and torsional stiffnesses of the samples under static loadings, their elastic limits, as well as the axial compression and torsional moments detected at the moment of fracture were calculated using MATLAB 2018 software.

Statistical analysis

We used Number Cruncher Statistical System 2007 (Kaysville, Utah, USA) software for statistical analysis. Continuous parameters were expressed as mean, standard deviation, median, minimum, and maximum. For the non-normally distributed data, we compared the groups through Mann-Whitney U test. An overall Type-I error level of five percent was used to infer statistical significance.

Results

We detected no statistically significant difference of stiffness between the short-length and full-length unicortical distal screws both under axial compression (415.8 ± 61.9 N/mm and 410.9 ± 54.2 N/mm, respectively; p = 0.88) and torsional compression (465.0 ± 50.9 N/mm and 456.2 ± 23.8 N/mm, respectively; p = 0.82) (Table 1).

Table 1
Comparison of the study groups in stiffness under axial and torsional compression.

		Total	**Short-length unicortical distal screw**	**Full-length unicortical distal screw**	***p-value***
Axial compression	*N/mm, mean ± SD*	*413.3 ± 56.7*	415.8 ± 61.9	410.9 ± 54.2	[a] 0.88
	N/mm, median (min-max)	*409.6 (332.8-535.6)*	421.6 (342-535.6)	400.8 (332.8-503.4)	
Torsional compression	*N/mm, mean ± SD*	*460.6 ± 38.9*	465.0 ± 50.9	456.2 ± 23.8	[a] 0.82
	N/mm, median (min-max)	*455.5 (412.6-583.3)*	455.5 (412.6-583.3)	454.9 (422.3-498.5)	

[a] *Mann Whitney-U Test*

Short-length and full-length unicortical distal screw groups did not differ in elastic limit under axial compression (266.2 ± 42.5 N/mm and 269.4 ± 42.8 N/mm, respectively; p = 0.71) and torsional compression (2632.3 ± 186.5 N/mm and 2649.8 ± 224.8 N/mm, respectively; p = 0.71) (Table 2).

Table 2
Comparison of the study groups in elastic limit under axial and torsional compression.

		Total	Short-length unicortical distal screw	Full-length unicortical distal screw	p-value
Axial compression	*N/mm, mean ± SD*	*267.8 ± 41.5*	266.2 ± 42.5	269.4 ± 42.8	[a] 0.71
	N/mm, median (min-max)	*277.2 (189.0-331.8)*	277.2 (189.0-331.8)	279.2 (198.3-321.9)	
Torsional compression	*N/mm, mean ± SD*	*2641.1 ± 201.2*	2632.3 ± 186.5	2649.8 ± 224.8	[a] 0.71
	N/mm, median (min-max)	*2603 (2367–3126)*	2571 (2442–3083)	2624 (2367–3126)	

[a] *Mann Whitney-U Test*

Maximal force on short-length and full-length unicortical distal screw groups were also similar under both axial compression (503.0 ± 35.0 N/mm and 497.9 ± 41.2 N/mm, respectively; $p = 0.71$) and torsional compression (5312.2 ± 569.1 N/mm and 5344.1 ± 452.3 N/mm, respectively; $p = 0.50$) (Table 3).

Table 3
Comparison of the study groups in maximal force under axial and torsional compression.

		Total	Short-length unicortical distal screw	Full-length unicortical distal screw	p-value
Axial compression	*N/mm, mean ± SD*	*500.5 ± 37.3*	503.0 ± 35.0	497.9 ± 41.2	[a] 0.71
	N/mm, median (min-max)	*502.5 (424.6-567.8)*	511.6 (436.4-556.7)	498.5 (424.6-567.8)	
Torsional compression	*N/mm, mean ± SD*	*5328.2 ± 500.6*	5312.2 ± 569.1	5344.1 ± 452.3	[a] 0.50
	N/mm, median (min-max)	*5213 (4824–6726)*	5133 (4824–6726)	5224 (4986–6532)	

[a] *Mann Whitney-U Test*

Discussion

Our biomechanics study on distal radius fracture model showed that short-length distal screws used in volar plating provided adequate fixation to axial and torsional forces of the wrist. Biomechanistic measurements yielded by the short-length unicortical distal screws were comparable to that of full-length screws both under axial and rotational compression.

Fixation of distal radius fractures via volar plate has recently become more widespread than dorsal plating. The most common complication of volar plate technique, extensor tendon rupture, could be avoided by unicortical delivery of distal screws [11]. This could prevent protrusion of the screw at the dorsal cortex, minimizing the risk of extensor tendon injury by protruded screw. In addition, as drilling does not require penetration of the contralateral cortex, direct injury to extensor tendon by the drill is avoided, further reducing the risk of subsequent complications. While unicortical delivery has its own advantages, concerns has emerged whether it provides adequate stabilization. Wall et al. reported similar stability of 75%-length and 100%-length distal screws in distal radius fracture models [4]. Liu et al and Baumbach et al. also achieved such consistent outcomes in embalmed and fresh cadaver models, respectively [10, 12]. Nevertheless, none of these studies reported the impact of torsional forces on stability, rather on the effects of axial compression and bending forces.

One of the goals in volar plate applications is to provide sufficiently strong stabilization that allows for early rehabilitation. In rehabilitation, wrist and finger movements exert a certain load on the distal radius. While uncertainty exist about the quantity of this load in vivo, studies reported the compression induced by wrist movements as below 100 N, and combined compression by wrist and finger movements as below 250 N [4, 10, 12]. In our study, the mean maximal force on axial loading and torsional loading was 501 N and 5328 N, respectively; suggesting the resistance capacity of plates to be above the assumed physiological load. In addition, these magnitudes were comparable to the findings reported in the relevant studies [4, 10]. Several studies on distal radius fractures suggested assessment of torsional loading to be more determinative than axial compression [6, 15–17]. In a study comparing fixation of sawbones by volar plating via either locked pegs or screws alone, axial loading was reported to have similar outcomes whereas torsional loading showed superiority of the screws over pegs [6]. In another biomechanics study regarding distal radius fractures, modified double plating was reported to perform better in terms of resistance to torsional loading than that in classical double plating and single plating [15, 18]. Our biomechanistic study was the first to assess the impact of torsional loads in volar plating of distal radius fractures via unicortical 75%-length distal screws. We further showed that these short-length screws provided adequate stabilization against physiological torsional loading as well as axial compression.

We performed our study on fresh frozen cadaver specimen, contrary to the Wall et al. studying on synthetic radius models [4]. Moreover, we created standardized fracture models on cadaveric bones. This distal radius fracture model was first described by Baumbach et al. and reported to be more likely to mimic in vivo fractures compared to the former gold-standard distal radius fracture models [19–22]. The setup is an important step of the biomechanistic studies to achieve valid outcomes. The studies evaluating shaft fractures of the long bones could provide sufficient potting area for proximal and distal parts. On the other hand, as in our study, distal or proximal intraarticular fractures or those close to the joint may not allow for fixation by potting both segments if there is not sufficient bone segment exists.

The aluminum apparatus we prepared for the distal bone fragment could have helped us to evaluate rotational loading together with axial loading.

The number of cadavers in our study could be suggested as adequate, considering the sample sizes reported in the literature. Biomechanistic results obtained under axial and torsional loads were assessed in relation to the well-agreed and physiological forces exerting on the distal radius [4, 10, 23, 24].

The findings of our study should be interpreted with its limitations. Our main weakness is the fracture model. While it mimics the mostly encountered distal radius fracture, it could not be appropriate to translated into the outcomes for intraarticular fractures, comminuted distal radius fractures, and those occurring on the coronal plane. Furthermore, the biomechanistic nature of the study warrants confirmation by in vivo clinical trials.

This biomechanistic study showed no difference between short-length and full-length unicortical distal screws in terms of effective physiological forces exerted on extraarticular distal radius fractures managed with volar locking plate osteosynthesis. In particular, the study revealed that unicortical delivery of 75%-length distal screws in volar plating could provide adequate stabilization against physiological axial and torsional loads. This was the first cadaver study that indicated sufficient strength of volar plating of the dorsal radius fractures via unicortical screws against torsional loads.

Conclusion

Our findings could allow us to further suggest that drilling of the dorsal cortex could be avoided and unicortical delivery of 75%-length distal screws could be performed in order to prevent from extensor tendon complications secondary to drilling or screw protrusion.

Declarations

Ethics approval and consent to participate:

After approval by the institutional review board

Consent for publication:

Authors give permission for publication

Availability of data and materials:

May be obtained if requested

Competing Interest:

The authors declare that they have no conflict of interest regarding the submission and publication of this manuscript.

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Authors' contributions:

ATP: Data collection, manuscript writing

YO: Data collecting

RE: Data collecting

BEK: Manuscript writing, correction, editing, study design

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They state that the article is original, has not been submitted for publication in other journals and has not yet been published either wholly or in part. They state that they are responsible for the research that they have designed and carried out; that they have participated in drafting and revising the manuscript submitted, whose contents they approve.

In the case of studies carried out on human beings, the authors confirm that the study was approved by the ethics committee and that the patients gave their informed consent.

They also state that the research reported in the paper was undertaken in compliance with the Helsinki Declaration and the International Principles governing research on animals.

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Figures

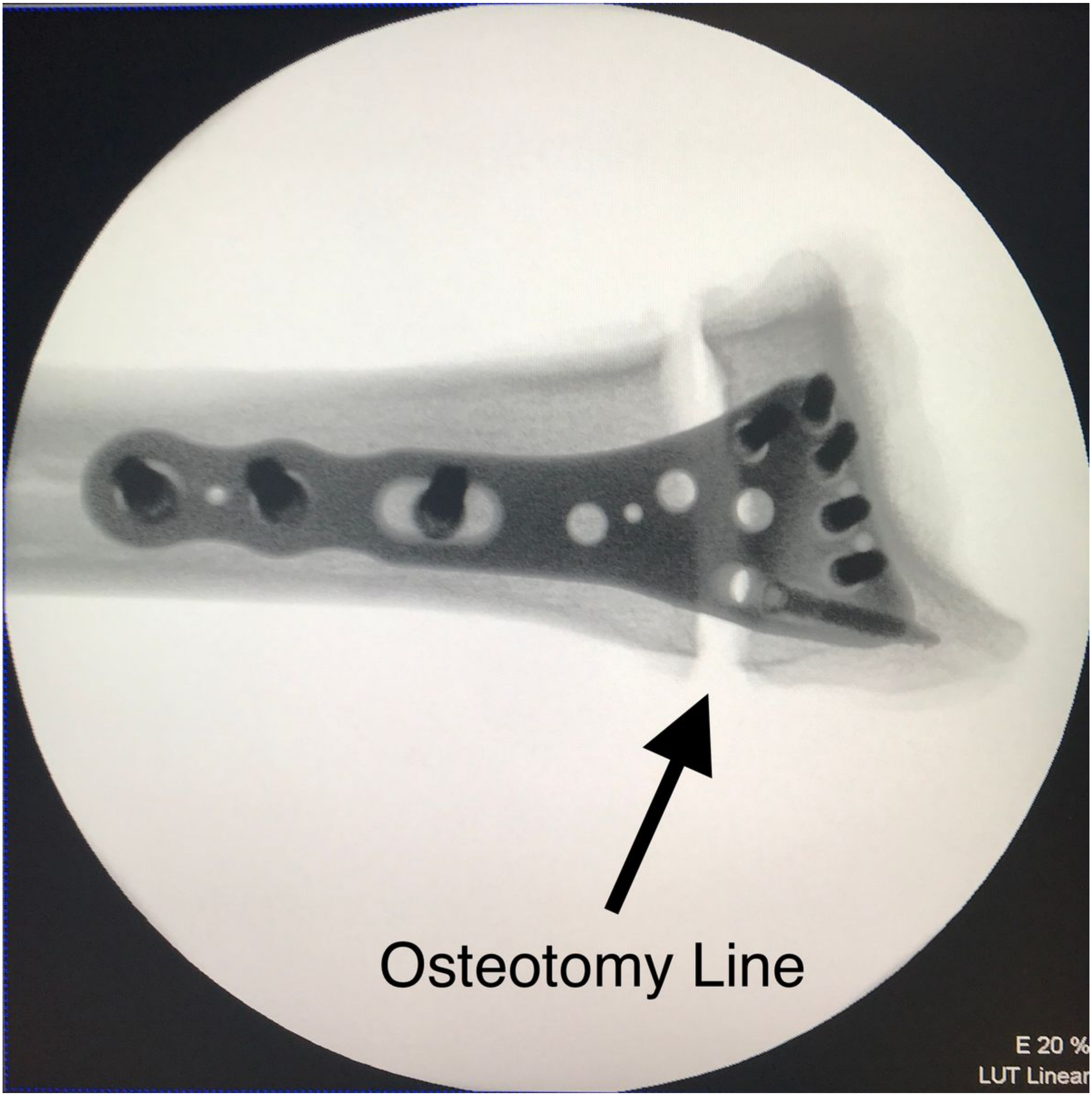

Figure 1

Antero-posterior view of the osteotomized radius with applied plate

Figure 2

Lateral view of the osteotomized radius with applied plate

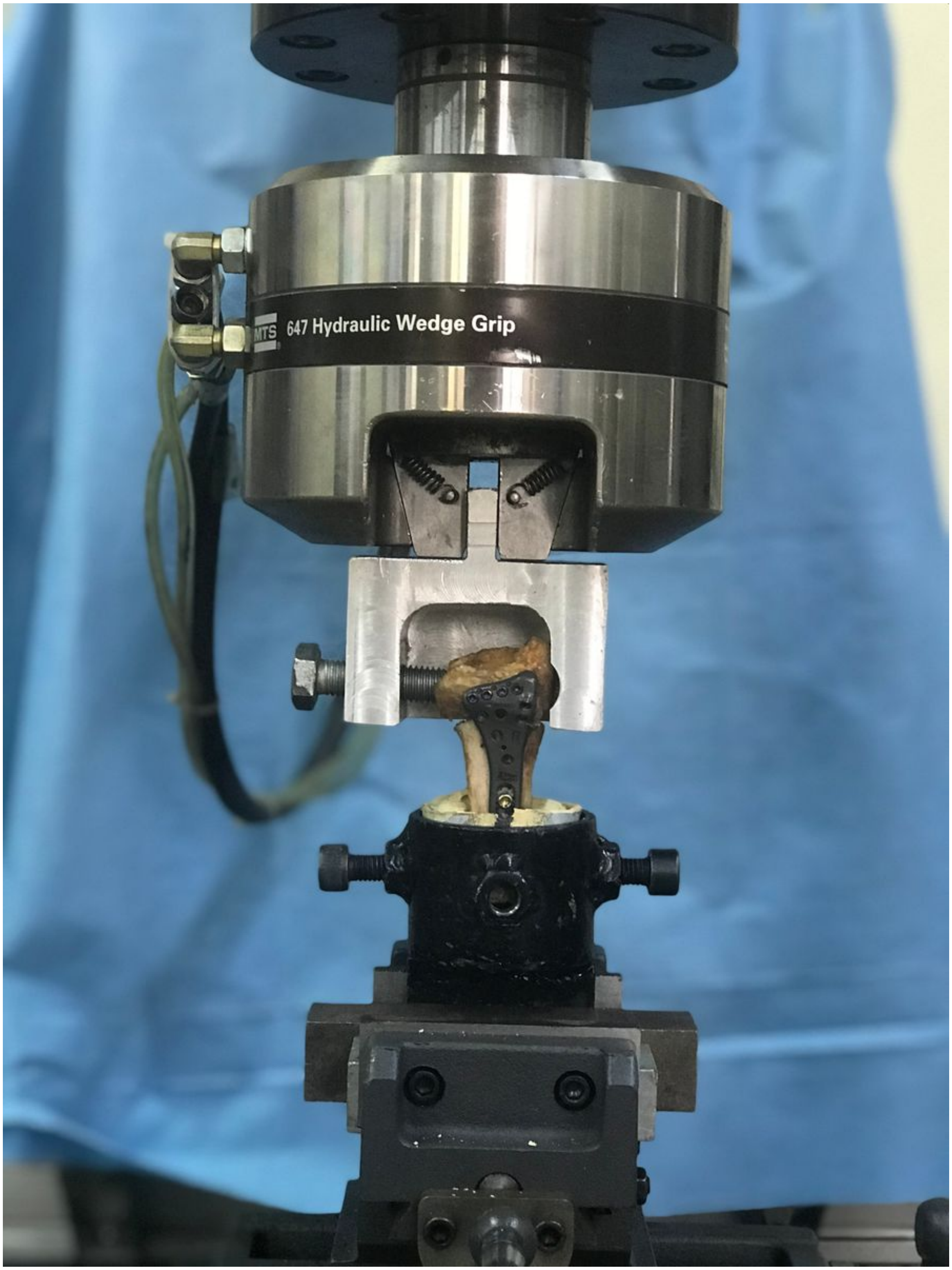

Figure 3

Antero-posterior view of biomechanic test application

Figure 4

Lateral view of biomechanic test application