GABRIEL COUTINHO SILVEIRA

EX VIVO BIOMECHANICAL COMPARISON OF REINFORCED LOCKING PLATE DESIGN AND LOCKING COMPRESSION PLATES APPLIED IN COMMINUTED TIBIAL FRACTURES

Dissertation submitted to the Veterinary Medicine Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of *Magister Scientiae*.

Adviser: Fabiana Azevedo Voorwald

Co-advisers: Thiago André S. de Sá Rocha
Guilherme Gualhardo Franco

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APPROVED: February 28, 2022.

Assent:

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To my parents.

To the Federal University of Viçosa, for the opportunity to complete the postgraduate course.

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ABSTRACT

SILVEIRA, Gabriel C., M.Sc., Universidade Federal de Viçosa, February, 2022. ***Ex vivo* biomechanical comparison of reinforced locking plate design and locking compression plates applied in comminuted tibial fractures.** Adviser: Fabiana Azevedo Voorwald. Co-advisers: Thiago André Salvitti de Sá Rocha and Guilherme Galhardo Franco.

Objectives: The aim of study was to compare four designs of locking plates at biomechanical characteristics for the stabilization of experimentally induced comminuted tibial fractures in dog. **Material and Methods:** Pelvic limbs were harvested from sixteen dog cadavers. Paired tibiae were stripped of all soft tissues, and sub-divided by bone mineral density in four blocks and randomized complete block design (RCBD) in four treatments (T1, T2, T3 and T4). Four configurations of locking plates with fixed angle and 2.7 mm system were tested, locking compression plate (LCP) without filling center holes (T1) (n=4), a LCP filling the center holes within eight screws heads plugs (T2) (n=4), a locking plate (LP) (T3) (n=4) and a reinforced LP (T4) (n=4), were applied to the medial surface of each tibia. Subsequent analysis of variance (F test, ANOVA) and statistical analysis with Tukey's pairwise test ($\alpha = 0.05$) were performed. A 1-cm segment of the tibia was excised centrally beneath the plate. The specimens were potted, then tested in failure and destructive four-point mediolateral bending(n=16), and failure and destructive axial compression(n=16). Bending and axial stiffness, yield load and failure load were calculated for each specimen. **Results:** The LP constructs (T3 and T4) were stiffer than the LCP constructs (T1 and T2) in both tests. Yield load and failure load were not significantly greater for LP constructs compared with LCP constructs in axial test. At bending analysis, yield load and failure load was greater in reinforced LP (T4), with statistical difference between all other treatments. LCP constructs with and without the filling center holes (T1 and T2) did not differs statically at mediolateral bending and axial compression in both tests. **Clinical Significance** Reinforced LP in central width ensure better bending stiffness, yield load and failure load. The screws head plugs had some influence at stiffness in both tests, but not statically differs. The widening of the locked plates, reinforcing the central area, consecutively reducing the forces at comminuted fracture gap. Further cyclic studies of the designs and clinical investigation is recommended. We conclude that the reinforced locking plates with central larger area is the first choice for treatment of comminuted fractures in dogs, ensuring better bending stiffness, yield load and failure load. Using screw head plugs on LCP did not differ statistically when compared to the same plate but without the filling.

Keywords: Comminuted fracture. Static destructive test. Locking plate. Axial compression. Four-point bending.

RESUMO

SILVEIRA, Gabriel C., M.Sc., Universidade Federal de Viçosa, fevereiro de 2022. **Comparação biomecânica *ex vivo* de placa ponte reforçada e placas de compressão bloqueadas aplicadas em fraturas cominutivas da tíbia.** Orientador: Fabiana Azevedo Voorwald. Coorientadores: Thiago André Salvitti de Sá Rocha e Guilherme Galhardo Franco.

Objetivos: Objetivou-se com este estudo comparar as características biomecânicas de quatro configurações de placas bloqueadas utilizadas para a estabilização de fraturas cominutivas de tíbia induzidas experimentalmente em ossos de cães. Material e Métodos: Os membros pélvicos foram obtidos de dezesseis cadáveres de cães. As tíbias pareadas foram separadas de todos os tecidos moles e as amostras foram subdivididas em relação a densidade mineral óssea em quatro blocos e foi aplicado o delineamento em blocos casualizados (DBC) em quatro tratamentos (T1, T2, T3 e T4). Quatro configurações de placas bloqueadas ângulo fixo e com sistema 2,7 mm foram ensaiadas; placa de compressão bloqueada (LCP) sem preenchimento dos orifícios centrais (T1) (n=4), placa de compressão bloqueada com preenchimento dos orifícios centrais com bottons (T2) (n=4), placa bloqueada ponte (LP) (T3) (n=4) e placa bloqueada ponte reforçada (T4) (n=4) foram aplicadas na superfície medial de cada tíbia. Interpretação dos resultados obtidos através de análise de variância (teste F, ANOVA) e análise estatística com o teste de Tukey's pairwise (α = 0,05). Um segmento de 1cm da tíbia foi excisado centralmente abaixo da placa. Os corpos de prova foram acoplados, então testados em falha e flexão mediolateral destrutiva de quatro pontos (n=16), e falha e compressão axial destrutiva (n=16). A rigidez axial e de flexão, a carga de escoamento e a carga máxima foram calculadas para cada corpo de prova. Resultados: Os modelos de placas ponte (T3 e T4) foram mais rígidos que os modelos de placa em ponte bloqueada (T1 e T2) em ambos os testes. A carga de escoamento e a carga máxima não foram significativamente maiores para as construções de placas ponte em comparação com as construções de placas de compressão bloqueada no teste axial. Na análise de flexão, a carga de escoamento e a carga máxima foi maior em placa ponte reforçada (T4), com diferença estatística entre todos os demais tratamentos. Construções de placa de compressão bloqueada com orifícios centrais, preenchidos ou não com bottons (T2 e T1), não diferem estaticamente na flexão mediolateral e compressão axial em ambos os testes.

Significado clínico: A placa ponte reforçada em largura central garante melhor rigidez à flexão, carga de escoamento e carga máxima. Os bottons tiveram alguma influência na rigidez em ambos os testes, mas não diferiram estaticamente. O alargamento das placas bloqueadas reforça a área central, reduzindo consecutivamente as forças no foco da fratura cominutiva. Conclui-se que as placas ponte reforçadas em sua largura central (T4), é a primeira escolha para o tratamento de fraturas cominutivas de tíbia em cães, garantindo melhor rigidez a flexão, assim como, melhor limite de escoamento e carga máxima. O uso de bottons na placa de compressão bloqueada não foi estatisticamente superior nos testes estáticos quando comparada a mesma placa sem o preenchimento dos parafusos. Mais estudos cíclicos dos modelos e investigação clínica são recomendados.

Palavras-chave: Fratura cominutiva. Teste estático destrutivo. Placa Bloqueada. Compressão axial. Flexão em quatro pontos.

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LIST OF ACRONYMS AND ABBREVIATIONS

LCP	Locking compression plate
LP	Locking plate
DCP	Dynamic compression plate
ORIF	Open reduction internal fixation
OBDNT	Open but do not touch
Ti	Pure titanium
MIPO	Minimally invasive plate osteosynthesis
DEXA	Double energy absortiometric radiography
BMD	Bone mineral density g/cm2
g/cm^2	gram per square centimeter
N	Newton
C	Celsius
ASTM	Standard specification and test method
RCBD	Randomized complete block design
CV	Coefficient of variation
CCp	Conical couple plate

LIST OF SYMBOLS

% Per cent.

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1. INTRODUCTION

Numerous internal fixation methods to long bone tibial fractures osteosynthesis in dogs have been proposed and are in constant development with advances in implant technology, study of fracture and biomechanics (AUGAT; VON RÜDEN, 2018). Moreover, tibial fractures are common in small animals and represents about 26% of long bones fractures, 38% of which comminuted fractures (BEALE; MCCALLY, 2020; HARASEN, 2003a, 2003b).

Locking compression plates (LCP) are device of extreme rigidity and stability compared to dynamic conventional plates (DCP) (GAUTIER; SOMMER, 2003). LCP was used to stabilize comminuted fractures through open reduction internal fixation (ORIF) for years. However, over the years, indication of ORIF was reduced to only high-strain fractures, where is reconstruct of bone column and interfragmentary compression results in a primary bone healing (HUDSON; POZZI; LEWIS, 2009; ROBINSON et al., 2020).

Bridging plating technique is used to repair low-strain fractures by indirect reduction of mechanical axis and bone length, preventing axial deformity as result of shear or bending forces and promoting secondary bone healing. Stability of this composite system depends on the stiffness of splint and the quality of anchorage of the splint to the bone, because plate is subjected to the full weight-bearing forces. Indirect reduction with bridging plate technique and biological approach creates a mechanical microenvironment which is favorable to clinical union (HUDSON; POZZI; LEWIS, 2009; JOHNSON; HOULTON; VANNINI, 2005; ROBINSON et al., 2020; ROE, 2020).

Biological osteosynthesis, emerged from the understanding of the fracture microenvironment, the need to preserve the fracture site and primordial haematoma, minimizing iatrogenic soft tissue disruption, preserving extra and intraosseous blood supply (AUGAT; VON RÜDEN, 2018; BEALE; MCCALLY, 2012; KLOEN, 2008). Since the biological osteosynthesis concept, LCP has continued to be used to stabilize comminuted long bones fractures. However, the presence of unused central screws holes increases stress and strain build-up, weakening the construction (BELLAPIANTA et al., 2011; FIROOZABADI et al., 2012).

The development of screw heads plugs, for coupling in the central holes may reduce stress by increasing the load distribution area, although that, the biomechanical effect of unplugged cortical screws holes on LCP remains undefined, so it may become a fragile area.

Alternative approach is used to apply the central screws heads plugs, a biological simplest osteosynthesis called “open but do not touch” (OBDNT). Moreover, OBDNT is an open fixation method in which the fracture focus and initial hematoma is not manipulated, preserving the microenvironment and growth factors. However, damage to the periosteal vasculature due to surgical access continued to be an undesirable complication (ROBINSON et al., 2020).

Minimally invasive plate osteosynthesis (MIPO) technique is based on reducing the bone segments indirectly, by applying a plate through a periosteal tunnel, created from two small incisions outside of fracture site, allowing the application of locked screws without open access (HUDSON; POZZI; LEWIS, 2009). Locking plates constructs has a solid middle section devoid of screw holes, three screws holes per fragment in both extremities (ILYAS et al., 2020), which increases area moment inertia over fracture gap, and is routinely applied in MIPO.

Since there is a limited number of biomechanical comparisons reports of plates designs available for repair comminuted fractures following the biological principle, this study aimed to compare the axial and bending stiffness, yield load, failure load and the influence of central screws holes and different designs (LCP and LP), on the mechanical behaviour of locking plate constructs applied in canine comminuted fractures of tibia by using mechanical testing.

Our hypothesis was that there would be a difference in flexion and axial stiffness between the constructs, as well as a direct biomechanical influence of the central holes and their filling.

2 MATHERIAL AND METHODS

2.1 Harvesting of Specimens

The methodology used in this study was approved by the Ethics Committee in the Use of Animals, Federal University of Viçosa, protocol number 09/2020.

Sixteen pairs of adult canine tibial bones were collected from routine of small animal sector at Veterinary Hospital of the Federal University of Viçosa, who died for reasons unrelated to bone problems. All were privately owned animals, and a permission for the study was sign from the tutor. The sampling consisted of seven males and nine females, with an average body mass of 18.4 kg (± 1,6 kg). Tibial bones were collected, surrounding muscles and other soft tissues were cleaned off, and radiographed in the craniocaudal and mediolateral views to confirm the absence of bony abnormalities. The length of each femur was measured with magnification in radiographic from the articular surface of the medial condyle to the medial malleolus with average 17,88cm (± 0,86cm). Posteriorly, collected samples were submitted to double energy absorptiometric radiography (DEXA) (figure 1), (GE Medical Systems – LUNAR 8743) to obtain the bone mineral density (BMD) (g/cm²) by measuring the gray scale, calculated by software (enCORE GE Healthcare). All the samples were individually wrapped in gauze soaked in saline solution (0.9% NaCl), placed in plastic bags, labelled in pairs and stored in a freezer at -20 °C until application of the bone plate and biomechanical test application. After defrosting, and during the application of plate all samples were constantly hydrated by saline solution to avoid dryness.

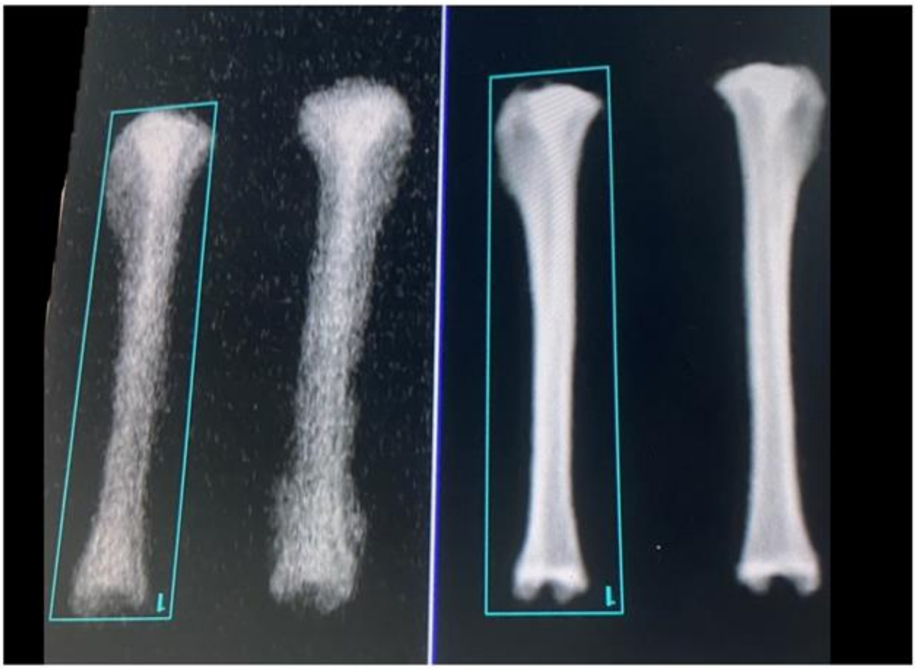

Figure 1 – Measurement area of the gray scale of the specimen with double energy absorptiometric radiography (DEXA) of tibia performed in a sample.

2.2 **Preparation of Specimens and Compositions of groups**

Thirty-two 2.7-locking plates made of pure titanium (Ti) grade 2 - Standard Specification and Test Method (ASTM) F67 - were used, each 124 mm long. Of these plates, 16 LCP, designed with 12 holes and those 2 combi-holes (locking and compression) and 3mm thick, 8 locking plates, designed with 6 holes and lesser width center, and 8 experimentally locking plates, designed with 6 holes, reinforced in center width, the same in the entire plate (Figure 2). Locked screws and screws heads were made of titanium alloy – ASTM F136 - and size was chosen based on the bone width where they were applied, exceeding 2mm from the opposite cortex.

Figure 2 – Demonstrative of plates, from left to right, LCP, locking plate, and reinforced locking plate.

Four treatments were assay, a LCP without filling (T1) the center holes (n=4), a LCP filling the center holes (T2) within six screws heads plugs (n=4), a locking plates

(T3) (n=4) and an experimentally and reinforced locking plate (T4) (n=4), all of those, with three proximal and distal bicortical screws per fragment. The samples were randomly distributed (n=16) for the four-point bending test and axial compression.

After thawing in saline solution at room temperature (24°C), the specimens were distributed in four density mineral blocks. Each treatment was assay in each block to quantify and compare the effects of BMD. Each plate was placed on the medial of the tibia middle diaphysis with the aid of clamps and were applied while maintaining a 1mm gap between the plate and the bone by utilizing a spacing device. Tibial middle diaphysis gap osteotomy measuring 10mm was performed using a sagittal saw after the application of the plate, taking care to avoid contact between the blade and the plate. The distance of the plate in relation to the bone was maintained at 2 mm by a custom spacemeter. Correct insertion and subsequent locking of the screws was verified through visual analysis, and screws that had some portion of the locking thread above the surface from the plate were considered as incorrect insertion and were replaced (figure 3).

Figure 3 – Correct insertion of the screws in LCP with all locking screws heads above the surface of the plate.

For axial compression test, to increase of stability of the coupling in the testing machine, two orthogonal 3.0 mm Steimann pins were placed in each epiphysis of tibia, perpendicular to the long axis of the bone, and was placed in a polymethylmethacrylate resin mold (6 cm diameter and 3 cm height), using a custom-made device to ensure the alignment.

Screw holes were drilled through a locking drill guide with a 2.4 mm drill bit, and screws were chosen of the screws was based on depth of the holes which was measured using a depth gauge. The 2.7 mm locking screws were inserted and locked to the plate with a final insertional torque of 0,8N. Moreover, the constructs were photographed at the end of preparation and immediately previously the test (figure 4A-B and 5A-B).

Figure 4 – (A) Pre-testing samples of axial compression in mediolateral view. (B) Pre-testing samples of axial compression in craniocaudal view.

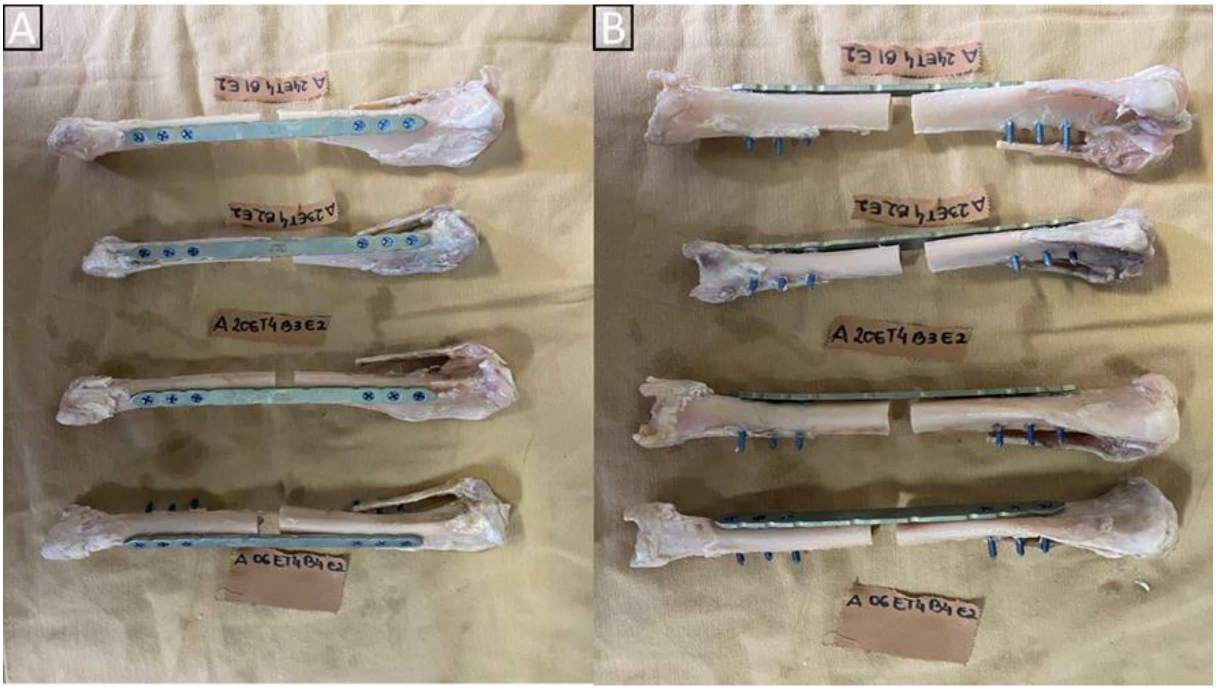

Figure 5 – (A) Pre-testing samples of four-point bending in mediolateral view. (B) Pre-testing samples of four-point bending in craniocaudal view.

2.3 **Mechanical Testing**

The mechanical tests were carried out using a universal testing machine (Shimadzu AGX) with a maximum load capacity of 5000N and a speed range of 5 mm/min, and supplied with TRAPEZIUM software. All tests were performed at a temperature of 22ºC.

For axial compression test, the acrylic resin base was attached to a bench vise fixed to a universal testing machine (Figure 6A-6B). Excluding the bone immerse on acrylic resin, working length was 140mm in all the samples. The axial load was applied on proximal acrylic resin by preloading each sample to 50N. Then, the constructs were further loaded to final failure, which was defined as the maximum load recorded immediately prior to a sudden decrease in sustained load, which coincided with obvious visual construct failure. Yield load (N) was the linear elastic limit of load-deformation curve, as determined using 0,2% slope offset criterion.

Four-point bending test was based and slight adapted of ASTM F382, each specimen was placed within the materials testing machine and applied 50N of preloading to the correct adjust of samples (Figure 6C-6D). Loading and support rollers were positioned to the same distance in all tests, center span distance was 32mm and loading span distance was 34mm. To evaluate mediolateral bending, the load was applied though two loading rollers in lateral surface of tibia, while medial plate applied surface was in contact to the support rollers. Bending stiffness and yield load was defined through the previously standard method. Failure load was defined as axial compression test.

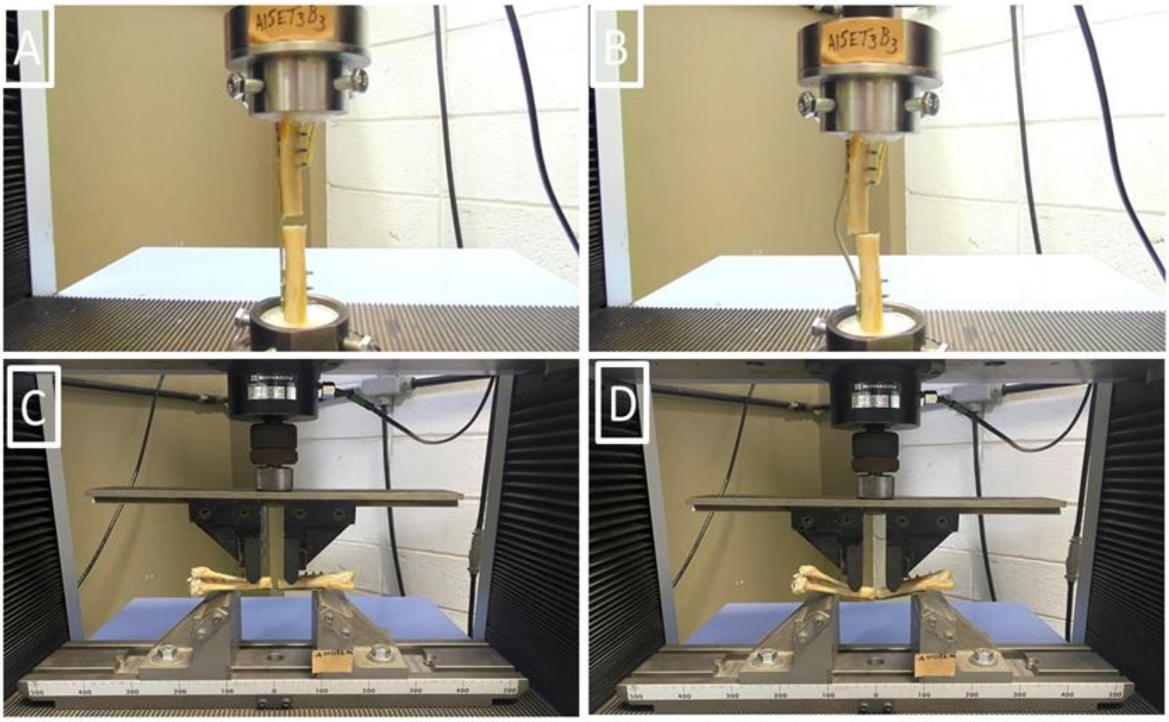

Figure 6 – (A) and (B), shows a potted locking plate in a custom setup for axial compression, (C) and (D) shows a four-point bending setup, positioned in mediolateral plane. (A) and (C) represent the moment before, and (B) and (D) the moment after load application in testing machine.

At completion of destructive testing, the yield load, failure load, stiffness was achieved in each test. Constructs were photographed, and each failure was documented for each construct.

2.4 **Statistical Analyses**

The design of the experiment was carried out from randomized complete block design (RCBD) with 4 treatments, namely: T1, T2, T3 and T4. In turn, the blocks were determined considering the reflection of the bone density of the samples (Table 1). This division was carried out to maintain the heterogeneity of the sampled block between the blocks while there is homogeneity of the samples presented in each one, as can be observed through the Coefficient of Variation (CV%) presented in Table 1.

Table 1- Samples divided into blocks, coefficient of variation (%) of bone mineral density(g/cm²) in axial compression and four-point bending tests.

Blocks	BMD – Axial compression	CV% - Axial compression	BMD - Bending	CV% - Bending
B1	< 0,615 g/cm²	2,5%	< 0,609 g/cm²	6,9%
B2	0,615 a 0,685 g/cm²	5,3%	0,609 a 0,677 g/cm²	1,83%
B3	0,786 a 0,788 g/cm²	3,5%	0,678 a 0,774 g/cm²	5,9%
B4	> 0,788 g/cm²	6,1%	> 0,774 g/cm²	7,7%

The data sampled for the Stiffness, yield load and failure load tests of both groups were submitted to analysis of variance (F test, ANOVA) at a significance level of 5% ($\alpha = 0.05$). Confirming the alternative hypothesis (H1 = There are significant differences between treatments), Tukey's pairwise test ($\alpha = 0.05$) was performed to compare the means of treatments. Statistical procedures were performed using the software R v.4.1.2 (https://www.r-project.org/).

3 RESULTS

Regarding the four-point bending test, at failure load, the reinforced locking plate (T4), was significantly greater in mediolateral plane than other treatments, moreover, locking plate (T3) not differs to LCP with filling the center screws (T2), and the last one (T2) not differs to LCP without filling the center screws (T1). At bending stiffness, T4 was significantly greater than all other treatments, T3 was significantly greater than T2 and T1, which, had no statistical difference between them. Additionally, yield load in four-point bending test, T4 was significantly greater than all other treatments, T3 was significantly greater than T1, and T2 and T1 in terms of bending stiffness did not differs between then (table 2 and figure 7). Failure mode of all constructs were plate bending.

Table 2. Mean ± standard deviation of treatments submitted to four-point bending test Failure load (N), Stiffness (N/mm) and Yield load (N). Different lowercase letters represent significant differences to Tukey's pairwise at the 5% significance level.

Treatments	Failure load (N)	Stiffness (N/mm)	Yield load (N)
T1	230,25±22,40cd	81,50±7,55c	168,75±7,18cd
T2	272,14±32,15bd	92,25±10,56c	202,50±17,41bd
T3	314,00±47,24b	110,25±12,09b	250,25±42,63b
T4	454,75±17,46a	132,00±19,71a	354,00±23,86a

LCP without filling the center holes (T1); LCP filling the center holes within eight screws heads plugs (T2); locking plate (T3) and reinforced locking plate (T4).

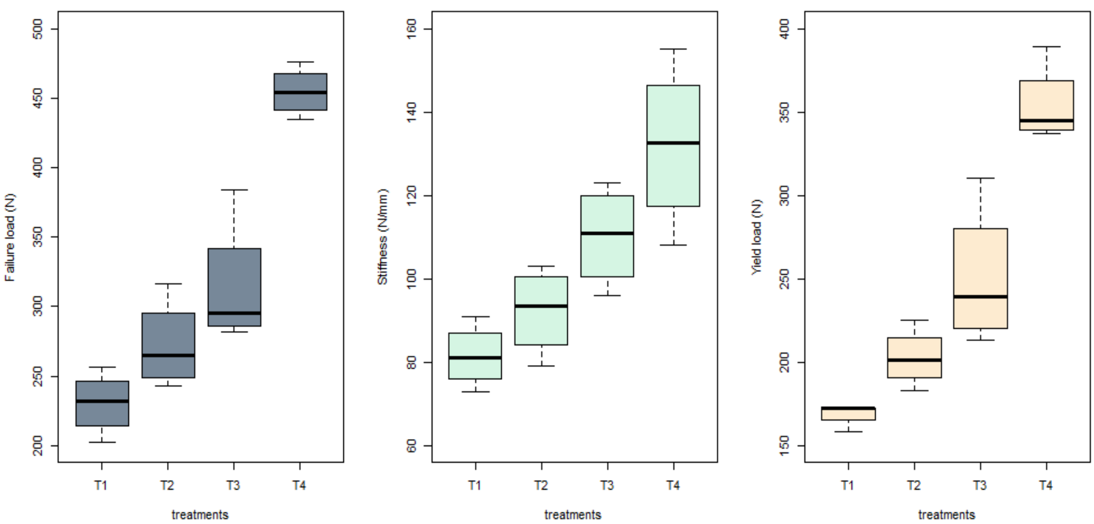

Figure 7 – Boxplots of the Four-point bending test group for the Failure load (N), Stiffness (N/mm) and Yield load (N).

The block analysis demonstrated in the four-point bending test, regarding yield load and bending stiffness, density was an interference factor in the results. However, it was not shown to influence the failure load.

During the destructive axial compression test, both yield load and failure load were not different in any construction. The axial stiffness of the two locking plates (T3 and T4) was significantly greater than the LCP plates (T1 and T2). However, when comparing T3 and T4, there was no significant difference, as well as between T1 and T2 (table 3 and figure 8). Failure mode of all construct were plate bending, however a sample of T3 presented an avulsion of two screws heads plugs. At block analysis, density was determinant factor of difference only in axial stiffness.

Table 3. Mean ± standard deviation of treatments submitted axial compression test. Failure load (N), Stiffness (N/mm) and Yield load (N). Different lowercase letters represent significant differences to Tukey's pairwise at the 5% significance level.

Treatments	Failure load (N)	Stiffness (N/mm)	Yield load (N)
T1	1700,00±192,10a	477,00±93,09b	1498,00±117,04a
T2	1652,42±459,56a	521,07±97,61b	1474,86±421,18a
T3	1706,00±247,76a	672,00±141,03a	1568,00±286,41a
T4	1843,75±604,57a	724,50±178,40a	1575,41±599,93a

LCP without filling the center holes (T1); LCP filling the center holes within eight screws heads plugs (T2); locking plate (T3) and reinforced locking plate (T4).

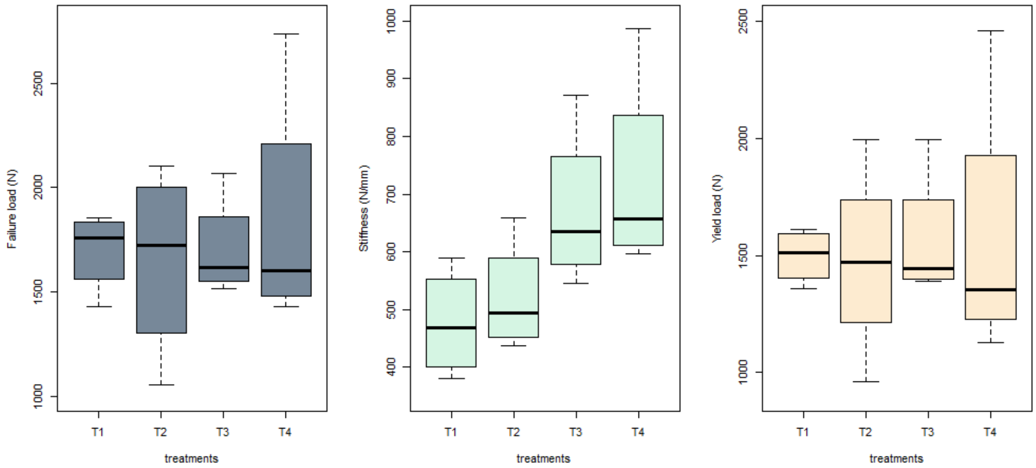

Figure 8. Boxplots of the axial compression test for the Failure load (N), Stiffness (N/mm) and Yield load (N).

4 DISCUSSION

We accepted our hypothesis that there would be a difference in the axial stiffness and bending of the proposed treatments. We also accept the hypothesis of the direct influence of central holes on stiffness and reject that filling the central holes with head plugs ensure greater stiffness.

The study design showed that mineral density is an important bias when *ex vivo* assays were performed, however, can be minimized, but not exclude by a randomized block analysis ensure better understand of *ex vivo* biomechanical results.

We chose to compare four designs of plates routinely applied in bridging function to biological reconstruct of tibial fractures due to the stability of this composite system depends almost exclusively to the stiffness of the splint and the quality of anchorage of the splint to the bone (GAUTIER; SOMMER, 2003; MUIR; JOHNSON; MARKEL, 1995). The choice of the same plate configuration, screw insertion position, implant material, on this study was purposeful, to assess the biomechanical comparison between the plate designs.

Additionally, engineering principles reports that unplugged screw holes concentrated stress and the initiation growth of cracks design of locking plate (ANDERSON, 2017). Presence of central screw holes without filling, cause stress and strain buildup, leading plastic deformation and eventual mechanical failure, as well as bridging design plates without central screw holes led to increased ultimate load values and fatigue strengths (ILYAS et al., 2020).

Area moment of inertia is a mathematical representation of the distribution of area about an axis through the center of an object's cross-section. The fully knowledge of this concept, avoid surgeon to choose an inappropriate implant to the patient, because area moment of inertia and elastic modulus had a great influence in stability of orthopedics constructs, increasing stiffness (MACARTHUR; JOHNSON; LEWIS, 2020; MUIR; JOHNSON; MARKEL, 1995). Locking plate reinforced in center breadth (T4) had an increase area moment of inertia, such as stiffness, due to the presence of this multiplicate factor in mathematical representation and absence of central holes, which decreases stress and strain build-up in a construct, explaining the greater values of axial and bending stiffness achieved on this treatment. Therefore, suggests that T4 may be better suited to bear greater loads which would be expected if applied in a bridging function. A study using conical couple plate (CCP) reinforced around most central screw holes, applied in feline tibia, was previously performed and obtained similar results (MACARTHUR; JOHNSON; LEWIS, 2020).

Locking plate (T3) presents a lesser wide center and consecutively less area moment of inertia than other treatments, however, also presents absence of central screw holes which increase stability. Stiffness was greater in T3 than T2 and T1 in both tests, and can be associated with the absence of tension accumulating areas due to central area (ILYAS et al., 2020). Furthermore, despite greater values of stiffness in destructive axial test, T4 does not differ statically from T3, although they differ in the bending analysis, this may be explained by different direction of force in two tests. Additionally, bending stiffness is most clinically relevant analysis, due to many constructs are weakest in bending (ROE, 2020).

Also, T3 smaller center decrease area moment of inertia and may result in lesser bending loading bearing than T4. Bending failure load and yield load was greater in T3 than T1 and T2, but only statically different than T1, suggesting that the absence of central screws holes on plate, can result in greater failure load and yield load(ILYAS et al., 2020; ROE, 2020). Even as, reducing width center of plate can be biomechanically comparable to filling the center screws holes with screw head plugs regarding failure load and yield load, but reduces of central width of plate remains superior than unfilled holes at bending analysis.

Comparing the LCP (T1 and T2) results obtained in this study and previously reports, reinforces the lack of significantly effect of screw head plugs in axial and bending stiffness showing absence of statistically difference (BELLAPIANTA et al., 2011; FIROOZABADI et al., 2012; HUNG et al., 2018; MARIANI, 2010). Our study corroborates with previously data, where mechanical behavior of screw head plugs and your interface is complex, and it does not substantially alter the elastic properties of the plate. Despite of that, recent study suggests the screw plugs could increase the fatigue strength of stainless-steel plates, but not of titanium plates (HUNG et al., 2018), however this paper was not able to agree with increase of fatigue strength due to not performed cyclic test, and encourage further studies to better understanding.

Screw head plugs avulsion related to axial compression test in one sample, at inner central screw combi-hole, may be correlated with an increase of load conditions and deformation in an unfilled compressive hole, or incorrect coupling of the plate. Although that, the presence of a lower stiffness value could not have influenced statistical results obtained in the test in relation to the other treatments, due to the analysis of the average of the other groups, even if we had 100% higher values, still, nothing would change in treatment statistical relevance.

Failure load and yield load results at axial compression test demonstrated high values of standard deviation and absence of statically difference to all treatments, we hypothesized that these variations may be explained to two factors, different movement of samples during the test, which can be cause by incorrect alignment or sample full-composition behaviour.

5 CONCLUSION

The present study suggests that locking plate reinforced in central width has a better biomechanical behavior to treatment for comminuted tibial fractures in dogs. The middle region of the plate in fracture gap are most susceptible to deformation, enlargement in this region direct reflects in gain of biomechanical characteristics, reducing stress and strain build-up. We also conclude that locking plate design with a smaller central width, ensure a good bending stiffness and yield load which turn it better than LCP, but is more susceptible to deformation on fracture site when comparing with reinforced locking plate.

The presence of central unused holes on LCP weakens the construct, due to smaller load distribution areas. Use of screw head plugs in locked holes increases bending and axial stiffness, but not statistic significantly, however, a yield load higher values assembling locking plate with smaller middle region, suggest some biomechanical interaction of these screws head plugs on construct and more complex behaviors mechanism can be involved.

Limitations of this study are inherent to cadaveric studies not resemble a clinical condition and was not performed cyclic test. Bone mineral density can be an important factor of bias in cadaveric studies, however can be controlled using a correct statically design. Further studies may be conducing to better elucidate the cyclic biomechanical characteristics of the designs and a clinical application to access clinical conditions.

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