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Research article

Mechanical testing of paraosseous clamp-cerclage stabilization compared to interfragmentary wiring and combination technique in L-shape acrylic plate simulate to canine mandibular fracture

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Abstract

The purpose of this research was to comparison of the mechanical strength of the three different stabilization techniques in canine mandibular models. An L-shaped acrylic plate to replicate the mandible of a middle-sized dog was used as a canine mandibular fracture model. The research compared the strength of 3 fixation techniques: interfragmentary wiring, paraosseous clamp-cerclage stabilization, and a combination of both techniques. Each method was tested using 6 acrylic samples and measuring the maximum pressure load on the rostral mandible model using a Hounsfield H50KS testing machine. Statistical analysis was used to summarize the maximum load results from each method. The strengths of the interfragmentary wiring technique and the combination technique were not significantly different, while the paraosseous clamp-cerclage stabilization technique had significantly less strength than the other two techniques. The acrylic samples simulated the mandibular bone in a medium-sized breed dog because there are variable sizes and conformations of the mandible. This method was used to help neutralize other confounding factors associated with using real bone. In conclusion, the combination technique of interfragmentary wiring and paraosseous clamp-cerclage was the best method that can be used for increased stabilization of mandibular fixation. This technique was useful for facilitating stabilization of a mandible at a lower cost compared with the bone plate and screw method.

Keywords: Canine, Dogs, Fixation method, Mandibular fracture

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INTRODUCTION

Mandibular fracture in dogs is a common problem in small animal clinics. Mandibular fracture accounts for 1.5–6% of all bone fractures in small animal clinics (Kitshoff et al., 2013; Umphlet and Johnson, 1990; Wong, 1984). All affected dogs treated at clinics present in pain and with loss of bite function. The most common site of the mandibular fracture is the first molar area (Kitshoff et al., 2013; Schnerer, 2019). The most common of many causes of fractures reported are: dog fights, road traffic accidents, and idiopathic or pathological fracture (Kitshoff et al., 2013).

Many kinds of fixation methods of mandibular fracture have been used, with the most popular being a bone plate and screw, because it provides rigid fixation. However, limitations associated with the bone plate length, contouring, and the hole positions for the bone plate may affect the tooth root and cause inferior alveolar nerve damage, dead tooth, loss of lower lip sensation, and implant failure (Boudrieau, 2012; Boudrieau and Kudisch, 1996; Dover, 1999). In addition, implanting a bone plate requires considerable expertise by the surgeon and may be expensive. Thus, there has been much research to develop a new fixation method to address these problems. Interfragmentary wiring is a favorite method for repairing mandibular fracture as it is simple, easy to apply, and not costly. However, interfragmentary wiring is restricted to simple mandibular fractures (transverse, oblique, or spiral).

Paraosseous clamp-cerclage stabilization was developed in 2001 by an Austrian researcher (Wanivenhaus, 2001). This technique has been of interest to many researchers in treating a long bone fracture (Aumarm, 2012; Manchi, 2017). However, there has been no published study reporting its treatment of mandibular fracture.

The purpose of this study was to compare the interfragmentary wiring technique, paraosseous clamp-cerclage technique, and a combination technique in providing mechanical resistance force for the treatment of mandibular fracture in the site cranial to the first molar region in dogs. An L-shaped piece of acrylic plastic simulating the size of the actual mandible of the dog was used instead of real bone to control confounding factors such as bone density, mandibular size, and limitation due to the unsuitable shape of real bone.

MATERIALS AND METHODS

Sample preparation

A left site of mandibular bone of 20 kg dog were measured the length from rostral part to condyloid process of mandible (13 cm) as horizontal part of L shape and length from top of coronoid process to the mandibular body (8 cm) as vertical part of L shape. A clear piece of 10-millimeter-thick acrylic plate was cut into L shape (8 centimeters in width and 13 centimeters in length) to simulate the shape of the canine mandible. The long side (13 centimeters) of the L shape was cut to simulate a fracture at the site supposed to be the region cranial to the first molar area (6 centimeters from the rostral part) of the acrylic plate.

Eighteen L-shaped acrylic samples were divided with 6 in each of 3 groups consisting of interfragmentary wiring (IW), paraosseous clamp-cerclage stabilization (PCS), and a combination technique (CT).

Fixation procedure

For the interfragmentary wiring technique, 4 holes each 1 millimeter in diameter were drilled 5 millimeters away from the cutting site in the proximal and distal parts of the cut line and 5 millimeters from the proximal and distal edges. Two orthopedic wires (American wire gauge, AWG No.20) were inserted into the holes and twisted into the proximal and distal holes to fix the pieces of acrylic together (Figure 1 A and B). The same procedure was used for the other 5 acrylic plates.

For the paraosseous clamp-cerclage stabilization, two holes each 2 millimeters in diameter were drilled in the lateral side of the acrylic plate. The rostral hole was 1.5 centimeters from the rostral edge and the caudal hole was 3.0 centimeters from the caudal edge. A Kirschner wire (K-wire, 2 millimeters in diameter) was bent in a U shape with the arm of U being 10 millimeters long. Two holes (2 millimeters in diameter) were drilled on the distal side of the acrylic plate and the arm of the U-shaped K-wire was inserted into the holes with the two K-wires being perpendicular. Four orthopedic wires (AWG No.20) were inserted into 4 holes drilled proximal to the first K-wire and twisted to clamp-cerclage the K-wires to the acrylic surface (Figure 1 C and D). The same procedure was used for the other 5 acrylic plates.

The combination technique involved both the interfragmentary wiring technique and paraosseous clamp-cerclage stabilization. The interfragmentary wiring was the same as described above. Two holes (2 millimeters in diameter) were drilled in the lateral side of the acrylic plate and the U-shaped K-wire was inserted. In addition, 4 holes were drilled to insert orthopedic wires the same as described for the paraosseous clamp-cerclage technique but without the distal K-wire (Figure 1 E and F). The same procedure was used for the other 5 acrylic plates.

Mechanical testing

A mounting bracket was fabricated to hold the vertical side of the acrylic plate samples. A Hounsfield H50KS testing machine was used for the mechanical test at the Department of Materials Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand. The vertical compression force was loaded onto the rostral part of the samples using a speed of 10 centimeters per minute until the sample collapsed (Figure 2). The mechanical testing was performed on each of the 6 samples in each group. The maximum loading (N) and compressive strength (MPa) data were collected and analyzed using a statistical program.

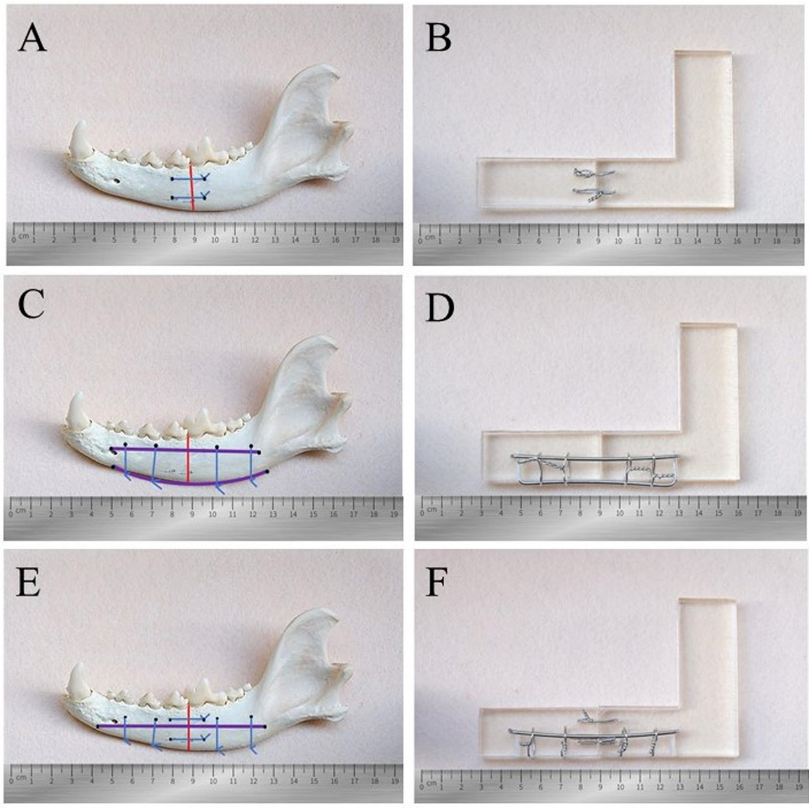

Figure 1 Three types of canine mandibular fixation technique and their respective acrylic models: Interfragmentary wiring technique (A, B); Paraosseous clamp-cerclage stabilization (C, D), and Combination technique (E, F).

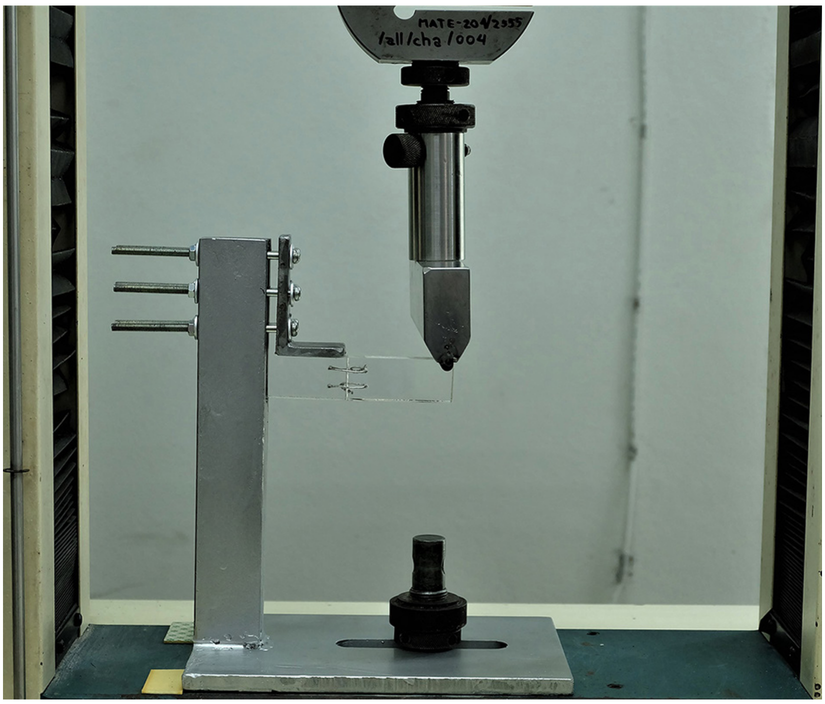

Figure 2 Sample holding method and vertical compression load on rostral part of acrylic L-shaped plate.

Statistical analysis

Maximum load data were used to calculate the mean and standard error (SE) based on the NCSS11 program to analyze the variation in strength of the three mandibular fixation methods using a one-way ANOVA test. Then, the data of mean maximum loads were compared using the Tukey-Kramer multiple comparison test with statistical significance set at $P<0.05$

RESULTS

Figures 3 and 4 present the correlations between the maximum force (N) applied on the acrylic samples and the extension lengths (mm), respectively, for the interfragmentary wiring, paraosseous clamp-cerclage stabilization, and the combination techniques. The mean ultimate forces were CT, 201.7 N; IW, 162.58 N; and PCS, 78.30 N. The stiffness of the CT, IW, and PCS samples were 15.22, 11.65, and 5.88, respectively. The means and standard error of the mean of the maximum forces required to deform the acrylic samples from elastic to plastic are shown in Table 1.

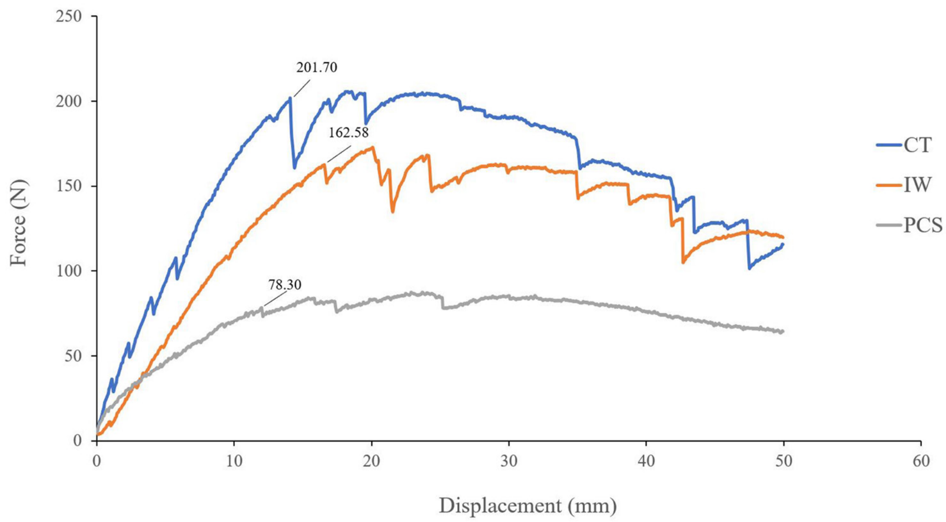

Figure 3 Mean vertical load curves for samples of interfragmentary wiring (IW), paraosseous clamp-cerclage stabilization (PCS), and combination technique (CT), showing ultimate force values for each curve.

Table 1 Comparison of maximum force between interfragmentary wire fixation, paraosseous clamp-cerclage stabilization, and combination technique in acrylic samples

Number of L-shape acrylic plate	Maximum load (N/mm)		
	Interfragmentary wiring technique	Paraosseous clamp-cerclage stabilization	Combination technique
1	220	105	201.5
2	196.5	88.5	268.5
3	183.5	93.5	213.5
4	226.5	88.5	193.5
5	133.5	125	258.5
6	155	98.5	181.5
Mean±SE	185.33±13.57	99.83±5.16*	219.50±13.33

Based on one-way ANOVA, the paraosseous clamp-cerclage stabilization could withstand a significantly lower mean force of up to 99.83 N than interfragmentary wiring and combination technique (185 N and 219.50 N, respectively). However, there was no statistical difference between the interfragmentary wiring and the combination technique.

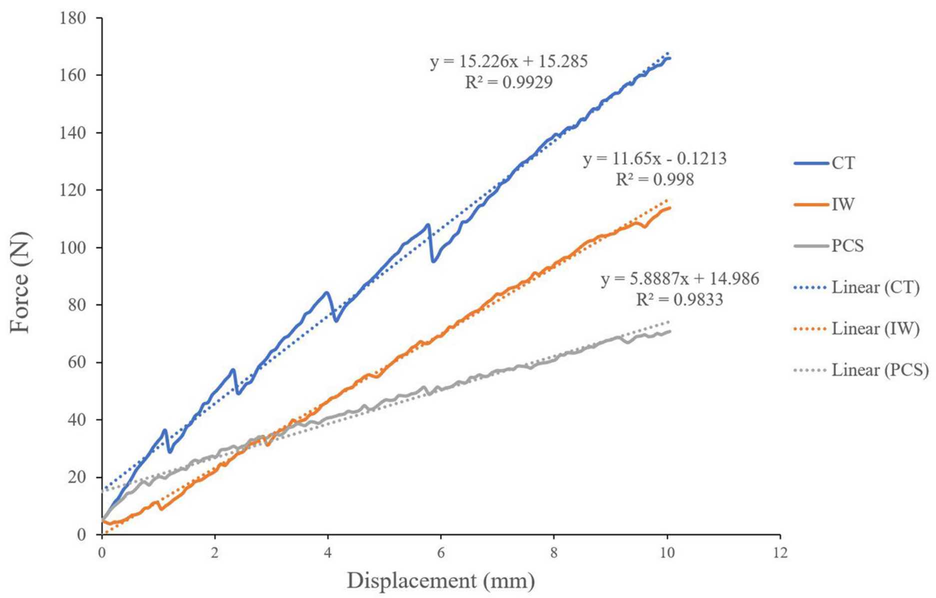

Figure 4 Actual and linear models of data for interfragmentary wiring (IW), paraosseous clamp-cerclage stabilization (PCS), and combination technique (CT), where R2 is coefficient of determination for each equation.

DISCUSSION

The bite force is generated from the interaction of masticatory muscle, structure of the maxillae and mandible, the temporomandibular joint, and the teeth (Kim et al., 2018). In humans, the jaw's movement vertically and laterally, there is a need to measure bite force three-dimensionally. However, in dog, the jaws are mainly movement vertically and rarely laterally (Kim et al., 2018). For this reason, this research focuses on the force resistance to the vertical force on the acrylic plate that acts as the model of mandibular fracture in dogs. A study of bite force in dogs showed the biting force in normal 22 dogs weighing between 7 to 55 kg found that the rang of biting forces were from 13 to 1,394 N, with mean value of 256 N. However, in the same study showed the result of bite force in dogs body weight range between 11-23 kg had the mean bite force 168 N (range 66-340 N). This study also subjective categories the chewing enthusiasm to 3 levels (+, ++, and +++) and found that the mean of chewing enthusiasm + = 78 N, ++ = 146 N, and +++ = 451 N respectively (Lineder et al., 1995). From our study, the combination technique group and interfragmentary wiring technique group could tolerate the bite force in dogs that had body weight below 23 kg with a medium level of chewing enthusiasm while the paraosseous clamp-cerclage stabilization group is too weak for bone stabilization during healing. Three prediction equations were presented in Figure 4. The stiffness values from highness to lowest were combination technique, interfragmentary wiring technique, and paraosseous clamp-cerclage stabilization. This result showed the combination technique is the most stable technique for maintaining the acrylic plate. All prediction equations had R2 of more than 98% showed the equations have high predictability.

This research simulated the fracture site in the cranial part of the first molar because most fractures sites of the canine mandibular bones occur at premolar (31%), molar (18%), symphysis (15%), or in other parts (Umphlet and Johnson, 1990). In general, causes of fracture are automobile trauma, falling, fighting, and idiopathic (Kitshoff et al., 2013). The clinical signs are acute or per-acute. These causes can affect other parts of the body resulting in life-threatening conditions such as internal hemorrhage or respiratory compromise (Chongphaibulpatana, 2016). For these reasons, mandibular fractures need to be diagnosed and treated as soon as possible. However, the patient should be stabilized before repairing the bone fracture.

Other studies have reported that severe periodontal disease, tumor, cancer, and abnormal bone metabolism can lead to mandibular fracture. Fracture caused by these chronic diseases, compared with acute and traumatic causes, will take a longer time to heal (Chongphaibulpatana, 2016). In some cases, with periodontal disease or chronic problems, the teeth need to be removed or treated before surgery to avoid possible complications in further treatment. The alveolar surface of the mandible is the main area for fixation. Therefore, the surgeon needs to consider the surface tension which influences the post-surgical strength of the mandible. While there are several methods of surgery such as interfragmentary wiring, plate and screw fixation, and external skeletal fixation, the complications from these techniques include destroying tissue, blood vessels, nerves, and the roots of teeth near the surgical area

(Kitshoff et al., 2013) and common complications following mandibular surgical treatment are malunion, malocclusion, asymmetry, tooth root disruption, surrounding neurovascular structure disruption, delayed union, nonunion, infection, osteomyelitis, delayed return to normal functions, accumulation of food particles surrounding fixation materials, gingival sulcus, stomatitis, gingivitis, and abnormal facial conformation (Bilgili and Kurum, 2003).

In normal dogs, when the mouth is closing, the muscles on the mandibular body will contract and pull the lower jaw up, whereas food or other hard materials will push the tip of the mandible down and produce a bending force. The bending force is the combination of two forces: tension (on the dorsal part of the mandibular body) and compression (on the ventral part). In some accidents, excessive force at the tip of the mandible can cause separation of the bone when the force exceeds the flexibility of the bone. Therefore, fixing and supporting the broken bone to be able to accommodate these forces must be the main target of surgical treatment (Boudrieau, 2012).

In the past decade, many methods have been developed to avoid as much as possible complications affecting the normal structure (Chongphaibulpatana, 2016; Sahapibonchai, 2018; Tomlinson, 2005). Nowadays, interdental wiring or interfragmentary wiring are the most common methods adopted to evade complications from using the bone plate and screw technique.

Interfragmentary wiring involves suture wires placed perpendicular to the fracture line. This method is easy and low-cost compared to other methods and resists rotational and bending forces (Bilgili and Kurum, 2003). However, it cannot be applied in cases involving a comminuted fracture or fragile bone. For example, an aged dog with limited bone strength can have recurrent fractures after surgery and consequently, such dogs need treatment using a plate and screw. With interfragmentary wiring, it is important to select the appropriate surgical wire. In general, monofilament wires are used, with the diameter depending on animal size (Sahapibonchai, 2018; Tomlinson, 2005). The wire suture tension is also important as if the tension is too low, then the mandible may be unstable and harmful to surrounding tissue, inducing inflammation, if the tension is too high, this may cause bone resorption, infection, and wire breakage which can influence the stability of the broken bone and healing process. After suturing the wire, the surgeon needs to bend the tip to protect tissue against irritation.

Generally, veterinarians use the paraosseous clamp-cerclage stabilization technique to treat long bone fractures instead of using bone plate fixation as it requires less surgical material, is not complicated, and inexpensive. Another study (Aumarm, 2012) experimented with paraosseous clamp-cerclage stabilization for long bone fracture treatment and reported that the important factors included pin size, wire size, and the distortion force used for material ligation significantly impacted the fixation strength resisting the bending load and the rotational load. The strength of the paraosseous clamp-cerclage stabilization technique is increased by using a double cerclage. However, using a pin larger than 2 mm in diameter makes it more difficult to distort and ligate materials resulting in reduced strength of the fixation.

This study compared the fixation strength of three techniques: interfragmentary wiring, paraosseous clamp-cerclage stabilization, and a combination technique based on the maximum sustainable load tested using a Hounsfield H50KS testing machine. The combination technique was better than the others as the acrylic plate was more stable than in the interfragmentary wiring method and the added strength from another lateral paraosseous Kirschner wire made the fixation method stronger. This method can be used to increase stabilization during fixation of a mandibular fracture when using the interfragmentary wiring method.

CONCLUSIONS

The combination technique of interfragmentary wiring and paraosseous clamp-cerclage stabilization was the best method investigated because this technique can tolerate the force that loaded on the rostral part of the acrylic plate better than other methods. This technique was useful for facilitating the stabilization of a mandible at a lower cost compared with the bone plate and screw method.

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AUTHOR CONTRIBUTIONS

CT provided the concept, designed the study, performed statistical analysis, and wrote the manuscript.
KW wrote the manuscript.
NS, PrP, PhP, and PS collected samples and performed the experiment.
TJ designed the study, data calculation, and contributed to manuscript editing.
All authors contributed to the drafting and revision of the manuscript. All authors have read and approved the final manuscript.

REFERENCES

Aumarm, W., Maneepong, G., Khothawornwong, N., Traywarunyoo, P., Chareonlap, W., 2012. Comparative study of paracortical fixation, intramedullary pin and bone plate fixaiton for treating the femoral fracture in dogs. J. Thai Vet. Pract. 24, 15-22.

Bilgili, H., Kurum, B., 2003. Treatment of fractures of the mandible and maxilla by mini titanium plate fixation systems in dogs and cats. Aust. Vet. J. 81, 671-673.

Boudrieau, R.J., and Verstraete, F.J.M., 2012. Maxillofacial trauma repair, In: Verstraete, F. J.M., and Lommer, M.J. (Ed.) Oral and maxillofacial surgery in dogs and cats. Elsevier, London, pp. 233-341.

Boudrieau, R.J., Kudisch, M., 1996. Miniplate fixation for repair of mandibular and maxillary fractures in 15 dogs and 3 cats. Vet. Surg. 25, 277-291.

Chongphaibulpatana, P., Kalpravidh, C., 2016. The 3rd generation of dental acrylic intraoral splint for immobilization of mandibular fracture. J. Vet. Sci. Tech. 7, 398.

Dover, M.S., Gerlach, K.L. and Erle, A. , 1999. Oral implantology and surgical management of mandibular fractures, In: Schendel, S.A., and Hausamer, J.E. (Ed.) Maxillofacial surgery PW Booth, Churchill Livingstone, London, pp. 57-1579.

Kim, S.E., Arzi, B., Garcia, T.C., Verstraete, J.M., 2018. Bite forces and their measurement in dogs and cat. Front Vet. Sci. 5(76), 1-6.

Kitshoff, A.M., de Rooster, H., Ferreira, S.M., Steenkamp, G., 2013. A retrospective study of 109 dogs with mandibular fractures. Vet. Comp. Orthop. Traumatol. 26, 1-5.

Linder, D.L., Marretta, S.M., Pijanowski G.J., Johnson, A.L., Smith, C.W., 1995. Measurment of bite force in dogs: A pilot study. J. Vet. Dent. 12(2), 49-52.

Manchi, G., Brunnberg, M.M., Shahid, M., Aiyan, A.A., Chow, E., Brunnberg, L., Stein, S., 2017. Radial and ulnar fracture treatment with paraosseous clamp-cerclage stabilisation technique in 17 toy breed dogs. Vet. Record Open. 4, e000194.

Sahapibonchai, P., Vijarnsorn, M., Kashemsant, N., Tharanon, W., 2018. Feasibility of using screw-acrylic bar technique for canine mandibular fracture fixation. Thai J. Vet. Med. 48, 179-185.

Schnerer, E., Hetzel, S., Snyder, C.J., 2019. Assessment of the role of the first mandibular molar in mandible fracture patterns in 29 dogs. J. Vet. Dent. 36, 32-39.

Tomlinson, J., 2005. Use of acrylic for fracture repair. In: The North American Veterinary Conference, Orlando, Florida, United State, pp. 796-798.

Umphlet, R.C., Johnson, A.L., 1990. Mandibular fractures in the dog. A retrospective study of 157 cases. Vet. Surg. 19, 272-275.

Wanivenhaus, G., 2001. Paraosseous clamp-cerclage stabilization: A biological osteosynthesis technique. Wien. Tierarztl. Monatsschr. 88, 123-128.

Wong, W.T., 1984. A survey of fractures in the dog and cat in Malaysia. Vet. Rec. 115, 273-274.

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