*Original Article*

# Feasibility of using screw-acrylic bar technique for canine mandibular fracture fixation

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*Abstract*

Bone plates and screws (BPS) have been used for mandibular fracture repair for decades. Although bone healing can be achieved, complications such as damage of dental roots and the inferior alveolar nerve in the mandibular canal have been reported. A screw-acrylic bar technique (SAB) was developed in this study as an approach to minimize those complications. The objective of this study was to compare the percentage of dental root and mandibular canal damage induced by inappropriate screw insertion using the SAB technique with that using BPS fixation. Fifteen mesocephalic canine cadavers were used for this study. For each cadaver, bilateral transverse mandibular fractures were created between the 4th premolars and 1st molars. Pre-operative planning by CT scanning was performed to minimize the chance of inappropriate screw insertion. The fracture of the right mandible was stabilized using a conventional BPS method while the contralateral ramus was stabilized with the SAB technique using the same number of screws. Post-operative CT scanning was carried out for the evaluation damage to dental roots and mandibular canals. Statistical analyses by paired t-test revealed a significantly lower percentage of dental root and mandibular canal damage for the SAB stabilized mandibles when compared to those that underwent BPS fixation ($P<0.05$). In conclusion, this novel SAB technique is a feasible alternative for the stabilization of mid-body mandibular fractures, and involves a lower risk of dental root and mandibular canal damage.

**Keywords:** bone plate, dog, mandible, mandibular fracture, PMMA, screw

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## Introduction

Mandibular fracture fixation using bone plate and screw (BPS) configurations has been the standard stabilization technique used in humans and animals for decades (Dover et al., 1999). Although this technique has been effective, post-operative complications may arise, associated with inappropriate placement of screws, leading to dental root and inferior alveolar nerve damage and tooth death, loss of lower lip sensation, and implant failure (Boudrieau and Kudisch, 1996; Dover et al., 1999; Legendre, 2005; Boudrieau and Verstraete, 2012). It has been documented that 32.5% of canine cases that use BPS fixation may suffer from dental trauma (Verstraete and Ligthelm, 1992). Screw-dental root contact has also been reported as a crucial risk factor for implant failure, the risk of screw loosening increases when the distance between the screw and the tooth root is less than 1.0 mm (Asscherickx et al., 2008). Inappropriate screw insertion into the mandibular canal can compress the inferior alveolar nerve, leading to long-term loss of sensation, as has been frequently reported in human patients when using conventional BPS fixation (Bouwman et al., 1995).

The three-dimensional (3D) plates for the fixation of human mandibular fractures have recently been developed to increase the ability of BPS configurations to withstand bending, torsion and shear. The geometric configuration of these 3D plates resembles two parallel straight mini-plates with interconnections between the plates. This type of plate was designed for use with monocortical screws. The stability of the 3D plate configuration has been compared to conventional plate fixation of human mandibular fracture, and satisfactory bone healing can be achieved with both approaches. However, additional intermaxillary fixation may be required to improve the stability of conventional BPS fixation, but not for 3D plate stabilization (Barde et al., 2014). Although the 3D plate may offer better treatment outcomes in human mandibular fractures, its application in veterinary medicine is limited due to the high cost of the implant system. In the current study, it is hypothesized that a similar construct could be developed for dogs that would achieve the principles underlying the design of the 3D plate, without the associated costs of a human implant system.

To minimize the complications associated with the use of BPS, a screw-acrylic bar fracture fixation technique (SAB) was developed as an internal fixator for mandibular fracture stabilization in dogs. The SAB technique developed relied on a number of screws that were positioned in the mandible in such a way as to avoid the destruction of dental roots and the neurovascular bundle within the mandibular canal. Two rows of screws were placed on tension and compression regions of the mandible either side of the fracture. Using the concept of interconnection between the two rows of screws embodied in the design of the human 3D plate, an acrylic bar of polymethyl methacrylate (PMMA) was attached to the screw heads as a platform to interconnect and increase the holding strength of the screws by proving a more rigid stabilization construct. It was hypothesized that the SAB system would help neutralize the forces generated during mastication, and when used in-vivo, stabilize the bone fragments until healing has been accomplished. The aim of this cadavers based study was to determine the feasibility of using SAB technique for canine mandibular fracture stabilization. This study compared the rates of dental root and mandibular canal damage using a conventional BPS approach with the SAB technique in canine cadavers. CT scan images of the mandibles were used for pre-operative planning and post-operative assessment of dental root and mandibular canal damage.

## Materials and Methods

***Canine cadavers:*** Fifteen adult mesocephalic canine cadavers weighing between 11.5 and 30 kg were obtained from the Autopsy Unit, Department of Pathology, Faculty of Veterinary Medicine Kasetsart University. Canine breeds included Golden retriever, Labrador retriever, American pit bull, Siberian husky, Rottweiler and crossbred dogs. Each cadaver had an oral examination to confirm maturity with a complete dental formula, and the absence of periodontal disease and deciduous teeth.

***Pre-operative CT scan evaluation:*** Computed tomography images of the left and right mandibles from each cadaver were derived using a high-resolution protocol of 128 slices with thickness of 0.625 mm. per slice (Optima CT660, GE healthcare, USA). The CT scan images were used for pre-operative planning to identify the areas on the mandible into which the screws can be inserted safely and efficiently without causing damage to the tooth root and inferior mandibular canal.

***Mandibular fracture fixation:*** Fracture lines were created between the fourth premolar and the first molar teeth on both sides of each specimen using an oscillating saw. Two methods of fixation, conventional BPS and SAB stabilizations, were utilized for comparison in the study (Fig. 1). On the right mandible, two mini bone plates (2.0 mm system) containing 8 or 6 holes were attached on the tension and compression surfaces, respectively, by the method described by Boudrieau and Verstraete (2012). Briefly, one bone plate (8-hole plate) was attached on the tension surface under the alveolar crest and the other (6-hole plate) was attached to the compression surface above the ventral border. For each plate, four 2-mm mini screws were employed for stabilization of the fracture (2 screws for each fragment). The positions of the screw inserted into the plate holes were carefully selected based on CT images to best avoid damage to the dental roots and neurovascular structures in the mandibular canal. A bicortical screw technique that allowed a minimal distance of 1 mm between each screw and dental root or ventral border of the mandible was used to ensure stability of the screw (Poggio et al., 2006).

The SAB technique was applied to the left mandible. Four 2-mm mini screws were inserted into the mandibular ramus using the optimal position previously identified on CT images for both tension and compression surfaces. A set of four 2-mm screws was placed on the tension surface of the left mandible bicortically and another set of four 2-mm screws was inserted monocortically into the compression surface close to the ventral border of the left mandible. Each screw head and approximately 3 mm of the shaft protruded above the bony surface (Fig. 2 and 3). The PMMA (PALACOS® R, Heraeus Medical GmbH, Germany) was prepared aseptically. The PMMA was formed into a rectangular shape with the thickness of 4 mm, and attached to all the protruding heads of the screws as a connecting bar. An absorbable hemostatic gelatin sponge (SPONGOSTAN TM, Ferrosan Medical Devices, Denmark) was packed between the bony surface and PMMA bar to reduce thermal necrosis during PMMA polymerization. The components of SAB construct are schematically demonstrated in figure 4. During the polymerization process, bone alignment was adjusted to achieve normal dental occlusion.

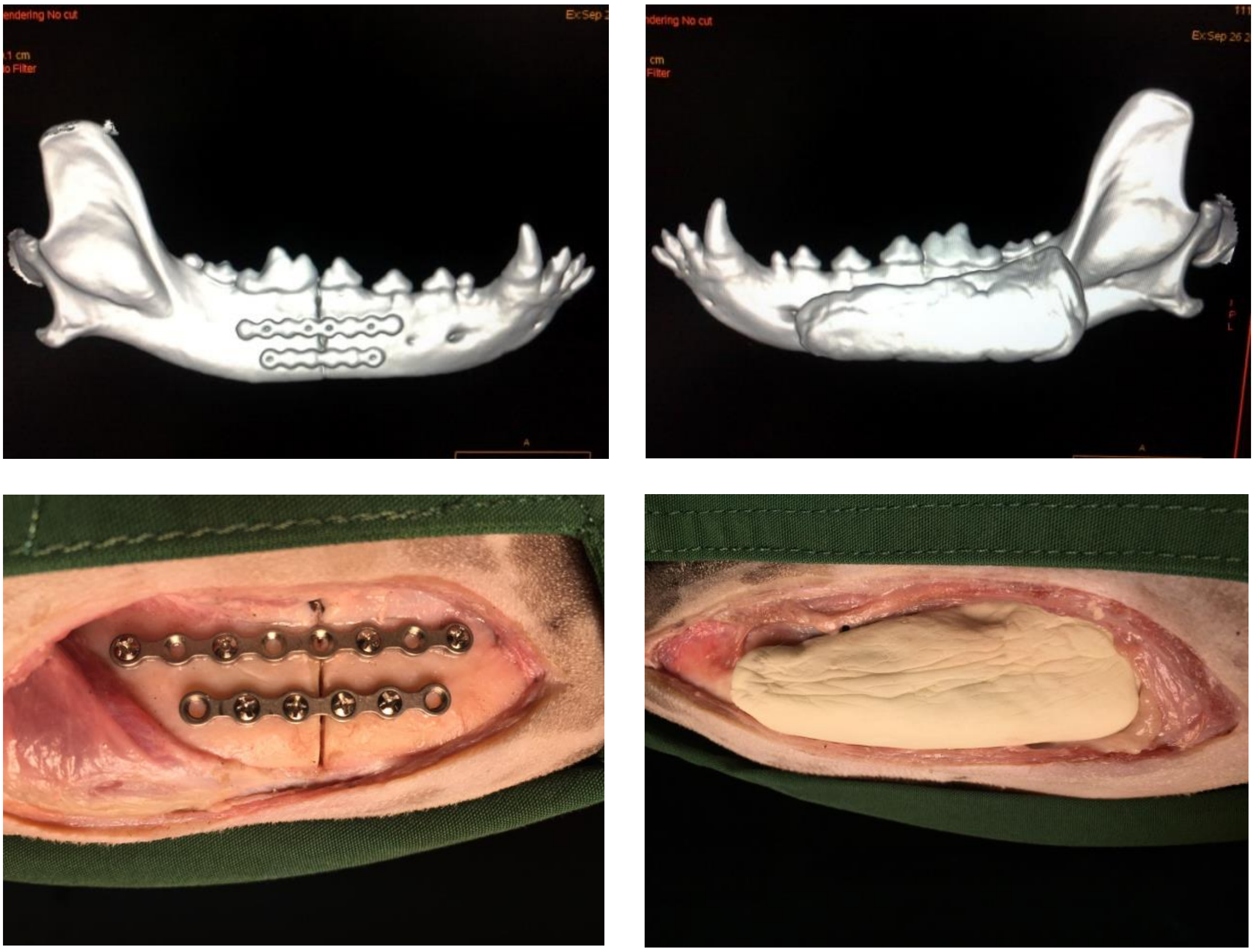

**Figure 1** Computed tomography images (upper left and right) compared to photographs (lower left and right) of the bone plates and screws and screw-acrylic bar fixation techniques on the mandibular rami of a cadaver.

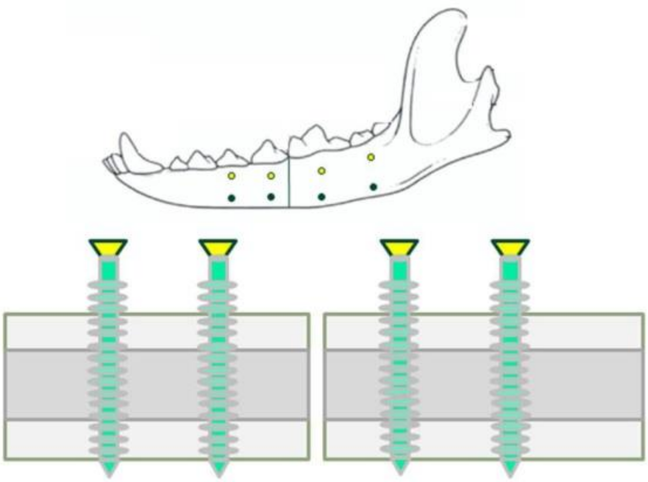

**Figure 2** Bicortical screw insertion into the tension surface of the mandible.

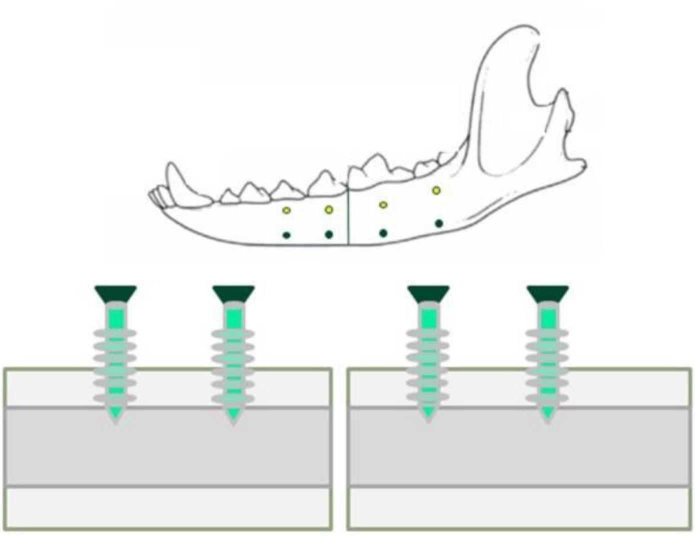

**Figure 3** Monocortical screw insertion into the compression surface of mandible.

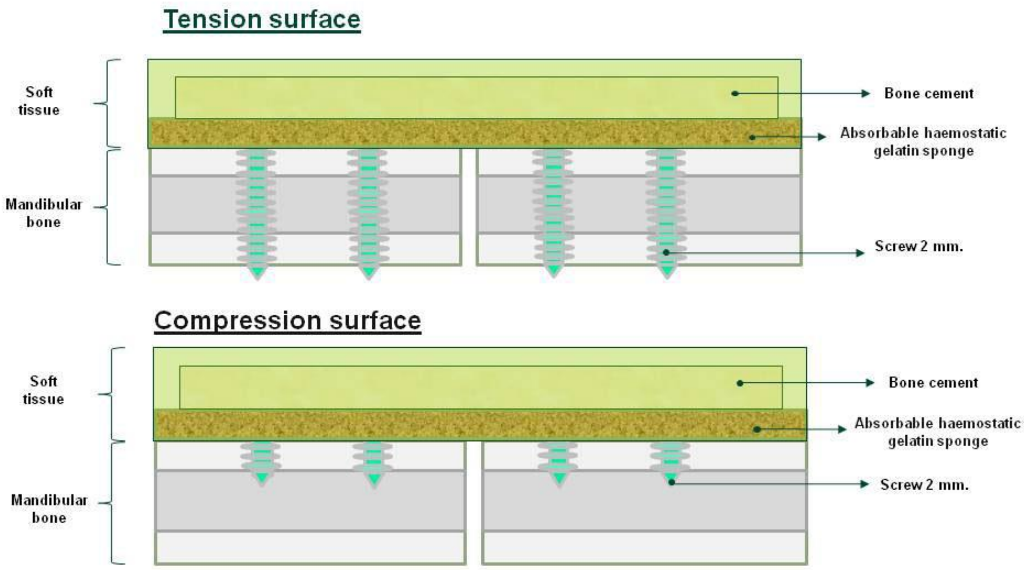


**Figure 4** Cross section view of the components of screw-acrylic bar (SAB).

***Post-operative assessment:*** The mandibles from all cadavers underwent a post-operative CT scan for assessment. The outcome measures evaluated were divided into 2 categories; 1) tooth root damage as observed on images in vertical, horizontal, and axial planes; and 2) mandibular canal damage as observed on images in axial plane. The invasion of a screw into the mandibular canal across more than 25% of the width of the mandibular canal in axial plane was defined as mandibular canal damage.

***Statistical analyses:*** The number of screws that caused damage to either dental roots or the mandibular canal was recorded for each mandible, and the values from the conventional BPS and SAB stabilization techniques were compared using paired t-tests. The significant level was set at p-value < 0.05.

## *Results*

The CT scan images revealed that the most appropriate locations for screw placement included the intra-radicular areas of the PM4, M1 and M2 teeth, and inter-radicular areas between PM2-PM3, M1-M2 and M2-M3 teeth (Fig. 5). There were 60 screws placed on the tension or compression surfaces for each of the fixation techniques on 15 cadavers. Thirty percent of the screws (18 of 60 screws) inserted into the tension surface of the mandible caused tooth root damage when using BSP fixation. In contrast, when using the SAB technique, significantly fewer screws (3.3%; 2 of 60 screws) caused tooth root damage when placed on the tension surface of the mandible (P<0.05). Ninety percent of the screws (54 of 60 screws) inserted into the compression surface of the mandible led to mandibular canal damage when using the BSP technique, whereas significantly fewer screws (15%; 9 of 60 screws) caused mandibular canal damage when using the SAB technique (P<0.05).

## *Discussion*

The most common maxillofacial fracture in canine is a mandibular body fracture caused by a motor vehicle accident, fighting or pathological changes including neoplasia, periodontitis, and metabolic disease (Bubenik, 2005; Kitshoff et al., 2013). Inappropriate treatment may result in oral pain and dysfunction. In some cases, mandibulectomy may eventually become the only treatment option available, but this diminishes the quality of life in these patients. The goals of mandibular fracture repair are to restore normal occlusion, to maintain stable fixation, to preserve fracture biology, to avoid iatrogenic dental root and mandibular canal damage, and to restore normal mastication (Glyde and Lidbetter, 2013).

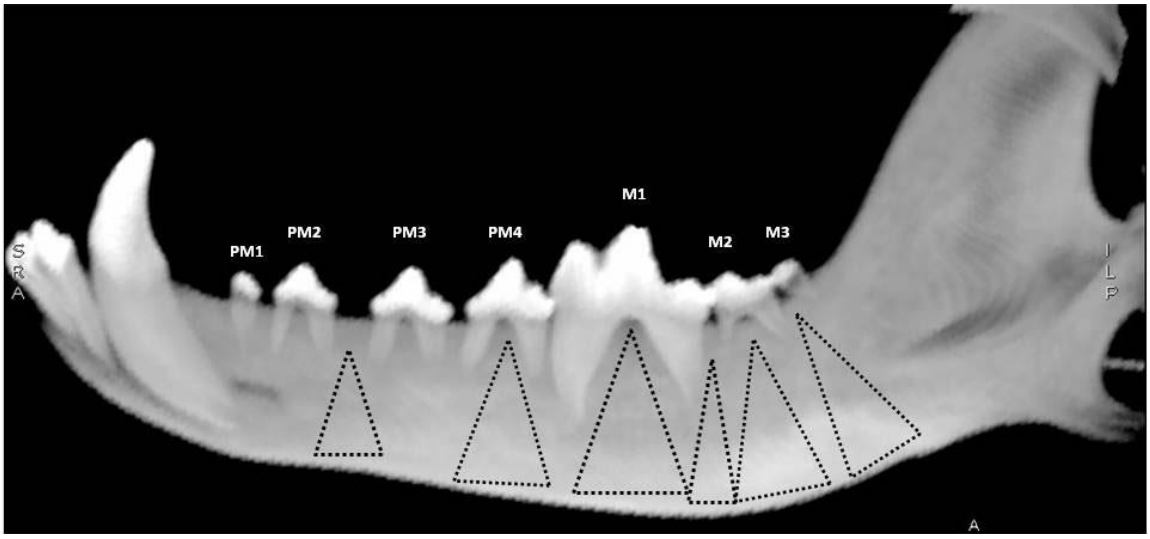


**Figure 5** Schematic illustration of appropriate areas for placing screw including the intra-radicular of PM4, M1 and M2, and inter-radicular of PM2-PM3, M1-M2 and M2-M3

The current study was prompted by concerns over inappropriate implant insertion techniques that may result in complications including dental root and neurovascular structure damage, tooth infection, chronic pain and tooth death. Without careful pre-planning, iatrogenic destruction to dental root and neurovascular structure during operation are likely to occur because of the variations in size of the mandible and configuration of the teeth among individual dogs. Moreover, the dental root and mandibular canal occupy 45-70% of mandibular area (Boudrieau and Verstraete, 2012). Such anatomical variations may increase the possibility of dental root and mandibular canal damage. Therefore, the identification of appropriate positions for screw insertion using an advanced imaging modality such as CT is recommended prior to surgery.

Computer tomographic is ranked as a superior imaging technique for maxillofacial trauma compared to conventional radiographs not only because of the ability to identify the variety of anatomic components, but also the capability of detecting bone injuries (Bar-Am et al., 2008). In addition, a higher sensitivity for detecting bone union and nonunion compared to plain radiography has been reported (Morshed, 2014). In the current study, appropriate areas for screw placement were determined based on CT images at the intra-radicular space of PM4, M1 and M2, and the inter-radicular space between PM2-PM3, M1-M2 and M2-M3 teeth, and appeared to be particularly helpful in reducing iatrogenic injury associated with the implantation of the SAB constructs. The appropriate area for screw placement reported in the study is consistent with a previous study by Bar-Am et al. (2008).

Although experimental factors including surgeons, mandibular anatomy and the number of screws were controlled in this study, the conventional BPS technique yielded a higher complication rate (Verstraete and Ligthelm, 1992). Dental root damage may be associated with the fixed position of screw holes on the rigid plate used for BPS. For this reason, the flexibility of screw placement is reduced, and it is, therefore, difficult to avoid this complication. In contrast, the SAB technique is more flexible because screws can be inserted in appropriate areas previously identified by CT without restriction. An additional benefit of the SAB technique is the opportunity afforded by the approach to adjust dental occlusion during polymerization (hardening process) of the PMMA bar.

The mandibular canal occupies one-third or more of the ventral mandible. Therefore, bicortical screw insertion above the ventral border (compression surface) may cause damage to the inferior alveolar nerve and vessel. This may affect bone healing and cause loss of sensation (Dover et al., 1999). Monocortical screw insertion has been effectively used for the fixation of maxillofacial fractures in humans (Ikemura et al., 1984). For this technique, screws are inserted and attached only along the buccal cortical bone cortex, therefore avoiding damage to the neurovascular structures (Dover et al., 1999). However, this technique needs further investigation to prove its clinical advantages compared with the conventional bicortical screw insertion in the treatment of mandibular fracture of small animal patients. The current study has demonstrated that the monocortical screw insertion used in the SAB technique causes minimal deterioration of the neurovascular canal.

Since the anatomical configuration of the mandible resembles a lever arm without any support from other structures, the fixation methods applied to the mandible should be able to stabilize both tension and compression surfaces (Boudrieau and Verstraete, 2012). While the tension surface requires bicortical screw implantation near the alveolar crest to increase stability to withstand tensile forces, the compression forces can be counteracted by most commonly used fixation devices. For these reasons, monocortical screw insertion into the compression side of the mandible is likely to be sufficient to stabilize this area (Dover et al., 1999; Boudrieau and Verstraete, 2012).

The novel screw acrylic bar technique proposed in the current study was designed to reduce previously reported complications of BPS-based repairs. The PMMA possesses biocompatibility and is comparable to stainless steel and titanium bar in terms of stiffness, yield force, and ultimate force (Amsellem et al., 2010). The stiffness of a PMMA-based implant directly correlates with its dimensions. However, the polymerization process for PMMA can generate heat, therefore, the use of absorbable hemostatic sponge (as described in the current study) is recommended to reduce the risk of thermal necrosis of bone.

Bicortical screw insertion into the tension surface and monocortical screw insertion into the compression surface were utilized with the SAB technique to minimize dental root and mandibular canal damage. The acrylic bar made from PMMA created an interconnection among the screws on both compression and tension surfaces. The function of acrylic bar was similar to that of the human 3D plates used for facial reconstruction. The SAB technique developed in the current study may offer an alternative and economical method of mandibular fracture fixation in companion animal patients.

The results of the current study provide evidence to support the feasibility of this novel technique as a fixation method for mid-body mandibular fractures. In this proof of concept study, the screw and acrylic bar technique, in association with the CT-based pre-operative planning, reduced the rate of dental root and mandibular canal damage in cadavers. However, there is a need for further studies to test the biomechanical strength of SAB in mandibular fracture stabilization, and to determine optimal number of screws for each bone fragment. Possible clinical benefits as well as possible complications of the SAB technique should also be explored in the canine patient population.

## *Acknowledgements*

The authors express their sincere thanks to Professor Christopher B Riley, Institute of Veterinary, Animal and Biomedical Sciences, Massey University, New Zealand for his guidance and revision of this manuscript. Our special thanks are also given to the Department of Companion Animal Clinical Sciences, the Department of Pathology, and the Diagnostic Imaging Center of the Kasetsart University Veterinary Teaching Hospital. This research was financially supported by the Graduate Study Development Fund of the Faculty of Veterinary Medicine Kasetsart University.

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# บทคัดย่อ

## การศึกษาความเป็นไปได้ในการใช้เทคนิคหมุดยึดและแกนอะคริลิค ในการซ่อมแซมภาวะขากรรไกรล่างหักในสุนัข

***ภาคภูมิ สหพิบูลย์ชัย[1] มนชนก วิจารสรณ์[1*] นฤดี เกษมสันต์[2] วิจิตร ธรานนท์[3]***

แผ่นดามกระดูกและหมุดยึดถูกใช้ในการซ่อมแซมภาวะขากรรไกรล่างหักเป็นเวลาหลายทศวรรษ แม้ว่าการรักษาด้วยวิธีดังกล่าวจะทำให้เกิดการเชื่อมประสานของกระดูกกรามล่าง ยังคงพบรายงานภาวะแทรกซ้อน ได้แก่ ความเสียหายต่อรากฟันและคลองรากฟัน เทคนิคหมุดยึดและแกนอะคริลิคจึงได้รับการพัฒนาขึ้นเพื่อลดโอกาสการเกิดภาวะแทรกซ้อนดังกล่าว วัตถุประสงค์ของงานวิจัยนี้เป็นไปเพื่อเปรียบเทียบเปอร์เซนต์ของความเสียหายต่อรากฟันและคลองรากฟันอันเนื่องมาจากการฝังหมุดยึดในตำแหน่งที่ไม่เหมาะสมเมื่อซ่อมแซมกรามด้วยหมุดยึดและแกนอะคริลิคเปรียบเทียบกับแผ่นดามกระดูกและหมุดยึด งานวิจัยนี้ศึกษากระดูกกรามล่างจากซากสุนัขจำนวน 15 ตัว โดยทำการสร้างรอยหักที่ตำแหน่งฟันกรามน้อยที่ 4 และฟันกรามที่ 1 บนกรามล่างทั้ง 2 ซีก ใช้แผ่นดามกระดูกขนาดเล็กและหมุดยึดในการยึดตรึงรอยหักที่กรามล่างขวา และใช้หมุดยึดและแกนอะคริลิคในการยึดตรึงรอยหักที่กรามล่างซ้าย ทำการถ่ายภาพรังสีส่วนตัดโดยอาศัยคอมพิวเตอร์เพื่อวางแผนการฝังหมุดยึดของทั้ง 2 เทคนิค และทำการประเมินความเสียหายต่อรากฟันและคลองรากฟันอันเนื่องมาจากการฝังหมุดยึดของทั้ง 2 วิธีก่อนและหลังการยึดตรึงรอยหัก ตามลำดับ จากการวิเคราะห์ทางสถิติด้วยการทดสอบความแตกต่างของค่ากลางของ 2 ประชากรไม่อิสระ (paired *t*-test) พบว่า เทคนิคการซ่อมแซมกรามด้วยหมุดยึดและแกนอะคริลิคมีสัดส่วนของหมุดยึดที่ก่อให้เกิดความเสียหายต่อรากฟันและคลองรากฟันน้อยกว่าการใช้แผ่นดามกระดูกและหมุดยึดอย่างมีนัยสำคัญทางสถิติ ($P<0.05$) จากการศึกษาครั้งนี้ สรุปได้ว่าหมุดยึดและแกนอะคริลิคเป็นเทคนิคใหม่ที่อาจเป็นทางเลือกในการซ่อมแซมรอยหักของขากรรไกรล่างส่วนกลางซึ่งจะช่วยลดการทำลายรากฟันและคลองรากฟันอันเนื่องมาจากการฝังหมุดยึด

**คำสำคัญ:** แผ่นดามกระดูก สุนัข กราม กรามหัก อะคริลิค หมุดยึด

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