Journal of Veterinary Science & Technology

Chongphaibulpatana and Kalpravidh, J Vet Sci Technol 2016, 7:6
DOI: 10.4172/2157-7579.1000398

Research Article Open Access

# The 3rd Generation of Dental Acrylic Intraoral Splint for Immobilization of Mandibular Fracture

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## Abstract

This study was divided into 3 phases. The 1st phase was the experiment in seven cadaver skulls to compare force from 2 techniques of weight load; interdental wiring and interdental wiring together with dental acrylic, with 1, 2 and 3 kilogram bar for 10 minutes. The evaluation was done by measuring the gap of the fracture line in a lateral radiograph. The force was calculated from the gap according to momentum and force balance law. Force after the interdental wiring technique and force after intraoral acrylic splint together with interdental wiring were compared by paired t-test. The results found significant difference ($P<0.05$) (-22.76 and -3.58). The 2nd phase's objective was to test tissue inflammation when use dental acrylic in the oral cavity. Upper canine teeth of 3 experiment dogs were banded with dental acrylic for 14 days. Then the gum was checked for inflammation. There was very mild to no inflammation. The last phase was done in mandibular body fractures of 2 dogs using the intraoral splint together with dental acrylic and which was followed up until mandibular bone was healed. Both of them had progressive bone healing at 2 months and clinical bone union at 4 months after surgery.

**Keywords:** Dental acrylic; Mandibular fracture; Intraoral splint

## Introduction

Oromaxillofacial fractures could be classified by area of fractures, including mandibular body, mandibular symphysis separation, mandibular ramus and maxillary (zygomatic, palatine, frontal, nasal, maxillary bones). The major causes of oromaxillofacial fractures are automobile traumas, high fall and fighting [1,2]. Those causes usually make concurrent injuries such as neurologic damage, internal bleed and internal organ's injuries and respiratory disturbance [3]. Therefore, patients must be stabilized before surgical operation.

Pathological fractures are seen in severe periodontitis, oral tumors or metabolic diseases that affect bone [3]. Pathological fractures could slow the healing rate. Pathological mandibular fractures usually occur at canine teeth and the 1st molar teeth. In contrast, traumatic fractures are usually at the middle 3rd of mandible [4-6].

Access to the intraoral area for operation is limited. Therefore, surgeons should have experience. For sterilization, the intraoral area cannot be completely sterilized. However, sterilization must be done. Furthermore, the most important thing to consider is the maintenance of proper occlusion of the teeth. Mandibular fractures could cause more problem than maxillary fractures because of its great mobility which could cause dropped jaw and malocclusion [4-6].

Understanding the biomechanics of the mandibula could increase success rate of mandibular fractures treatment. Most mandibular muscles had insert at the ramus of mandibular. When mandibular body fracture, the frontal part of the fractures does not have muscle to received force. When the bending force (from chewing or biting) pushes frontal part of fracture, mandibular bone will be separated [7].

Normally, temporal, masseter and medial pterygoid muscles could help mouth close and induce bending force on mandibular. If line of mandibular fracture is caudodorsal, the 3 muscles will make the fracture line closely. But if the line of fracture is caudoventral, 3 muscles will pull rear part of the fracture to dorsal and the diagastric muscle will pull the frontal part of the fracture to ventral and caudal then 2 parts of the fracture will widely separated [3].

Treatment of mandibular fractures that could be done by several techniques including tape muzzle, intraoral composite splint, intraosseous wiring, external fixation extra oral acrylic splint and plate and screw fixation. Each technique is suitable for certain area of fractures, stable or unstable fractures, deciduous or permanent teeth and mixed or edentulous dentition. The stabilization methods of mandibular body fracture are shown in Table 1. Sometimes are used more than 1 technique [4,8-10].

Management of mandibular body fractures in young children usually uses acrylic splint because of cost- effectiveness, easy application and removal, less operation time, minimal trauma, high stability and comfort [11]. Treatment of incisive bone fractures in a horse also uses an acrylic splint because it is very simple, inexpensive and non-invasive [12].

This study chose the intraoral acrylic splint because of its good occlusive alignment and reasonable stability. Moreover, it could neutralize forces on the fracture line. Minimal or no soft tissue disruption preserves teeth and tooth roots. Furthermore, this technique could be removed following fracture healing without disturbing the soft tissue or bone. However, intraoral acrylic splint could cause halitosis and gingivitis. But these problems could be clear by cleaning the oral cavity every day after meal. The use of the acrylic splint is simple, inexpensive and noninvasive, and has short operation time. Moreover, the intraoral acrylic splint has high stability when combined with the interdental wiring [13-15].

Post operation care is very simple. Liquid food would be given to the patients during wearing equipment and the operative area is cleaned with warm sterile water after meal. After removal of all of the

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**Received** October 24, 2016; **Accepted** November 02, 2016; **Published** November 07, 2016

**Citation:** Chongphaibulpatana P, Kalpravidh C (2016) The 3rd Generation of Dental Acrylic Intraoral Splint for Immobilization of Mandibular Fracture. J Vet Sci Technol 7: 398. doi: 10.4172/2157-7579.1000398

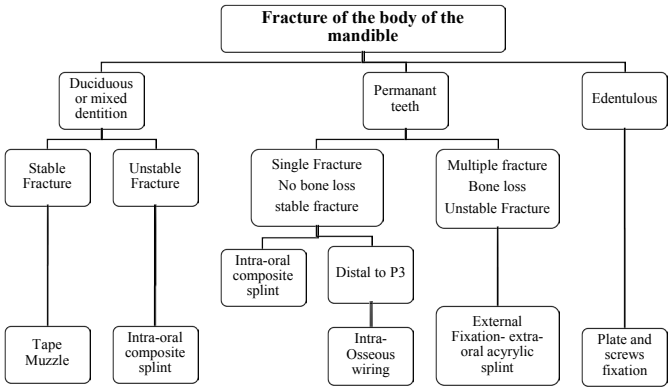


**Table 1:** Methods of mandibular body fracture stabilization [4].

equipment, dental scaling and polishing have to be done for removing the dirty plaques [15].

Nowadays, the dental acrylic had 3 generations, heat-cured acrylic, light-cured acrylic and cold-cured or self-cured acrylic. Heat-cured acrylic and light-cured acrylic would cause high heat and have long setting time. So, they could burn surrounded tissue. Cold-cured or self-cured acrylic could be completely processed at room temperature. Furthermore, cold-cured or self-cured acrylic chosen in this study has key benefits such as high fracture resistance, easy and fast handling, smooth surface and ability to be worn for long term (more than 6-12 months) [16,17].

Protemp™4 (Figure 1), the product used in this study, is commonly used for temporization material for crown and bridge restorative in human. It has high fracture resistance and strength, easy handling, fast procedure (about 5-10 minutes). It has smooth surface and can be used for long term temporization (more than 6-12 months).

The expected outcomes of this study were the result could be applied in actual practice. The technique is very simple, less equipment, and non-invasive. In addition, the dental acrylic is safe because of less heat in the oral cavity. Animals could have a better life during the treatment.

## Materials and Methods

This study was divided into 3 phases. The 1st phase was the experiment in seven cadaver skulls to compare the force from weight loading of the 2 techniques; interdental wiring and interdental wiring together with dental acrylic, with 1, 2 and 3 kilogram bar for 10 minutes. 7 fresh canine cadavers (1 Poodle, 1 Pug, 1 American Pit Bull, 1 English Cocker Spaniel, 1 Thai Ridgeback and 2 Mixed breed) were used. Cadavers did not have fracture of skull and mandible or any lesions on head and was kept in the refrigerator for no longer than 7 days. Then, appearance of the skulls was recorded and dental scaling was done to remove dental tartar. A scalpel blade was used for incising to approach the mandible. After that, thin saw was used to cut the mandible at cranial of the 1st Molar. Then weight loaded with 1, 2 and 3 kilogram bars for 10 minutes. The evaluation was done by measuring the gap of the fracture line in the lateral radiograph. The force was calculated from the gap according to momentum and force balance law with the formula $S=[(W+W_j)T]/d$ (W - the bar weight, $W_j$ - the cut jaw weight, T - the thickness of the mandible, d - the length of the fracture gap). Force after the interdental wiring technique (S1) and force after intraoral acrylic splint together with interdental wiring (S2) were compared by paired t-test.

The second phase was done in 3 healthy mix-breed laboratory dogs to study the effect of the dental acrylic to the surrounding tissue in the oral cavity. The dogs had no gingivitis, periodontitis and dental tartar. The experiment was done under general anesthesia. Upper canine teeth of all dogs were banded with the dental acrylic for 14 days. Then, the gum was checked for inflammation at days 1, 2, 3, 7 and 14. After that, acrylic was removed and the inflammation score was classified into 8 levels following Table 2. The data was collected and analyzed.

The last phase was done in the animal patients that were presented at dentistry unit of Chulalongkorn small animal hospital. Mandibular body fractures of 2 dogs were treated with the intraoral splint together with the dental acrylic. Both dogs had stable mandibular body fracture with one side fracture, no bone loss and strong teeth. Complete blood profile was done before general anesthesia, to ensure no other systemic signs and ability to undergo anesthesia and surgery. After general anesthesia, dental scaling and polishing were done for cleaning the oral cavity. Soft tissue repair and reduction of fracture were done before interdental wiring with modified stout loop technique. After wiring, an acrylic splint was placed over the interdental wire. Tape muzzles were applied on all dogs for 1-2 months. Antibiotic and mouth washing solution were prescribed. Dogs were followed up and radiographed to check for bone union and device alignment at 4, 8, 12, 16 weeks after surgery. Dog A was brought to the hospital at 14 July 2012. After fight with other dog and had gum tear and an open transverse fracture of left mandibular body at caudal P4 (P4-M1). So, an intraoral acrylic splint was applied. Dog B was brought to the hospital at 17 August 2013. After it was bit at its mouth and had a fracture of the left mandibular body. Then an intraoral acrylic splint was applied.

## Results

### The 1st phase

Mean of the head weight was 1.44 kilogram and mean of the cut mandible weight was 0.15 kilogram. Mean of the distance of fracture line to the end of the mandible was 0.0513 meter and mean of the average of mandible thickness was 0.0156 meter. The data of each sample was shown in Tables 3 and 4. The fracture gap of the interdental wiring and the interdental wiring with intraoral splint groups were shown in Table 5. S1 and S2 forces of each sample were shown in Table 6. Mean S1 was 57.42 N ± 10.46 N. and mean S2 was 70.59 N ± 12.73 (N is newton, 1 N=9.81 kg). Results from this study showed significant difference ($P<0.05$). The intraoral acrylic splint with interdental wiring


**Figure 1:** The Protemp™4 completely assembled and ready to use.

| Score | Signs |
|---|---|
| **0** | No heat, swelling, redness / No pain / Can use mouth / No depressed /No fever |
| **1** | One of heat, swelling, redness / No pain / Can use mouth / No depressed /No fever |
| **2** | Two of heat, swelling, redness / No pain / Can use mouth / No depressed /No fever |
| **3** | Heat, swelling, redness / Pain but can palpate at mouth / Can use mouth / No depressed /No fever |
| **4** | Heat, swelling, redness / Pain and cannot palpate at mouth / Can use mouth / No depressed /No fever |
| **5** | Heat, swelling, redness / Pain and cannot palpate at mouth / Cannot use mouth / No depressed /No fever |
| **6** | Heat, swelling, redness / Pain and cannot palpate at mouth / Cannot use mouth / Depressed /No fever |
| **7** | Heat, swelling, redness / Pain and cannot palpate at mouth / Cannot use mouth / Depressed / Fever |

**Table 2:** Inflammation scores.

| Number of sample | Weight of head (kg) | Weight of cut mandible (kg) |
|---|---|---|
| 1 | 1.15 | 0.08 |
| 2 | 1.1 | 0.11 |
| 3 | 0.85 | 0.07 |
| 4 | 2 | 0.13 |
| 5 | 2.65 | 0.43 |
| 6 | 0.85 | 0.07 |
| 7 | 1.5 | 0.16 |
| Mean (SD) | 1.44 (0.67) | 0.15 (0.13) |

**Table 3:** Weight of head and cut mandible.

| Number of sample | Distance of fracture line to the end of mandible (m) | Average of thickness of mandible (m) |
|---|---|---|
| 1 | 0.069 | 0.0158 |
| 2 | 0.0458 | 0.0126 |
| 3 | 0.0536 | 0.0146 |
| 4 | 0.0493 | 0.0132 |
| 5 | 0.0588 | 0.0265 |
| 6 | 0.0354 | 0.0111 |
| 7 | 0.0471 | 0.0155 |
| Mean(SD) | 0.0513(0.0106) | 0.0156(0.0051) |

**Table 4:** Distance of fracture line to the end of mandible and average of thickness of mandible.

| Number of sample | Weight of bar (kg) | Fracture gap (m) of the interdental wiring group | Fracture gap (m) of the interdental wiring with intraoral splint group |
|---|---|---|---|
| 1 | 0 | 0.0003 | 0.0022 |
| | 1 | 0.0067 | 0.0032 |
| | 2 | 0.0078 | 0.0047 |
| | 3 | 0.0101 | 0.0069 |
| 2 | 0 | 0.0019 | 0.0028 |
| | 1 | 0.0057 | 0.0034 |
| | 2 | 0.0063 | 0.0032 |
| | 3 | 0.0069 | 0.0044 |
| 3 | 0 | 0.0026 | 0.0019 |
| | 1 | 0.0074 | 0.0034 |
| | 2 | - | 0.0042 |
| | 3 | - | 0.0055 |
| 4 | 0 | 0.0013 | 0.0012 |
| | 1 | 0.0014 | 0.0014 |
| | 2 | 0.0018 | 0.0014 |
| | 3 | 0.0028 | 0.0017 |
| 5 | 0 | 0.00215 | 0.00135 |
| | 1 | 0.0033 | 0.0033 |
| | 2 | 0.00385 | 0.0037 |
| | 3 | 0.0047 | 0.0046 |
| 6 | 0 | 0.0014 | 0.0023 |
| | 1 | 0.0063 | 0.0043 |
| | 2 | 0.0089 | 0.0075 |
| | 3 | 0.0103 | 0.0098 |

| | | | |
|---|---|---|---|
| 7 | 0 | 0.0017 | 0.00225 |
| | 1 | 0.0054 | 0.0054 |
| | 2 | 0.0061 | 0.0058 |
| | 3 | 0.0071 | 0.0074 |

**Table 5:** Fracture gap (m) of the interdental wiring and interdental wiring with intraoral splint groups (Sample number 3, fracture gap of the interdental wiring group at 2 and 3 kilograms' bars were absent because of wire was torn at 2 kilograms' bar).

| Number of sample | Weight of bar (kg) | $S_1$ (N) | $S_2$ (N) |
|---|---|---|---|
| 1 | 0 | 41.33 | 5.64 |
| | 1 | 24.98 | 52.31 |
| | 2 | 41.33 | 68.59 |
| | 3 | 47.27 | 69.19 |
| 2 | 0 | 7.21 | 4.89 |
| | 1 | 24.26 | 40.67 |
| | 2 | 41.73 | 82.15 |
| | 3 | 56.15 | 88.06 |
| 3 | 0 | 3.86 | 5.28 |
| | 1 | 20.71 | 45.07 |
| | 2 | - | 70.59 |
| | 3 | - | 79.95 |
| 4 | 0 | 12.95 | 14.03 |
| | 1 | 104.52 | 104.52 |
| | 2 | 153.23 | 197.01 |
| | 3 | 144.75 | 238.42 |
| 5 | 0 | 51.99 | 82.80 |
| | 1 | 112.65 | 112.65 |
| | 2 | 164.08 | 170.73 |
| | 3 | 189.72 | 193.84 |
| 6 | 0 | 5.44 | 3.31 |
| | 1 | 18.49 | 27.10 |
| | 2 | 25.33 | 30.05 |
| | 3 | 32.46 | 34.11 |
| 7 | 0 | 14.31 | 10.81 |
| | 1 | 32.66 | 32.66 |
| | 2 | 53.84 | 56.63 |
| | 3 | 67.68 | 64.93 |

**Table 6:** S1 and S2 force.

technique could sustain weight loading significantly more than the interdental wiring technique alone.

### The 2nd phase

Before wearing the acrylic splint, 3 dogs had mild dental tartar and slight gingivitis. After wearing the acrylic, dog 1 had no signs of inflammation during wearing the acrylic (Figure 2). Dog 2 had score 1 of the inflammation score only on days 2 and 3 (Figure 3); dog 3 had score 1 after wearing acrylic instantly but disappeared on the next day. The inflammation score of each dog during the experiment was shown in Table 7.

### The 3rd phase

Dog A and sample B had better use of their mouths within 1 week after surgery; they just only used a simple muzzle for protecting them from biting and chewing hard objects. One month after surgery, they had normal occlusion and normal use of their mouths. Radiographic findings showed normal alignment of the orthopedic instrument and progressive bone healing. At 2 months, the muzzles were taken out, and the radiographies showed normal alignment of the orthopedic instrument, decrease of fracture gap and progressive bone healing. At 3 months, radiographies showed clinical bone union, no evidence of osteomyelitis, and no gingivitis. One month after operation one month, plaque was found on the acrylic site (Figures 4-12).

## Discussion

In the 1st phase, there were only 2 samples of brachycephalic breed, Pug and American Pit Bull. Shape and size of the skull could affect the capability to weight loading shown in Table 8. Biting force in the small brachycephalic breed was less than the mesocephalic and dolichocephalic breeds. However, biting force in medium and large brachycephalic breeds were more than the mesocephalic and dolichocephalic breeds [18,19]. This is the reason why American Pit Bull's skull was more capable to weight loading when compared to the others. Pug's weight loading capability should be low, but its capability was the highest in this study. Pug's weight is 6-8 kilograms. This Pug's structure is bigger than normal and made skull larger than the small breeds. So, dog's skull should be classified by skull shape and size for accurate analysis. In addition, this pug had abnormal alignment of teeth making the fracture gap closer than normal. Therefore, S force was greater than other specimen.

In 2008, Kovan [20] studied the impact of loading in sheep, the molar region had ventral impact loading greater than angle of the mandible, canine and incisors, and premolars regions, respectively.

| Days | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|
| 0 | 0 | - | 1 |
| 1 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 |
| 3 | 0 | 1 | 0 |
| 7 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 |

**Table 7:** Inflammation scores of each sample during day 0-day 14.

| Skull Shape | Skull size | | |
|---|---|---|---|
| | Small | Medium | Large |
| **Brachycephalic** | 25.1 | 527 | 946 |
| **Mesocephalic** | 89.8 | 454 | 755 |
| **Dolichocephalic** | 40.9 | 377 | 661 |

**Table 8:** Evaluation of the biting force (N) by comparing shape and size of the skull [19].


**Figure 2:** The 2nd phase; Dog 1, no inflammation occurred while wearing acrylic for 28 consecutive days.

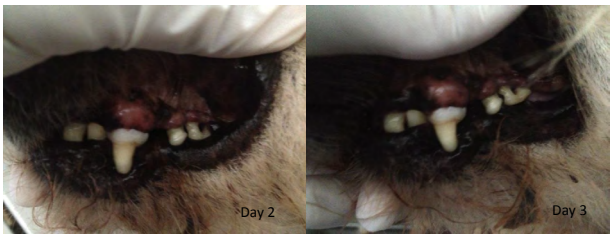


**Figure 3:** The 2nd phase; Dog 2, mild gingivitis at day 2 and 3.

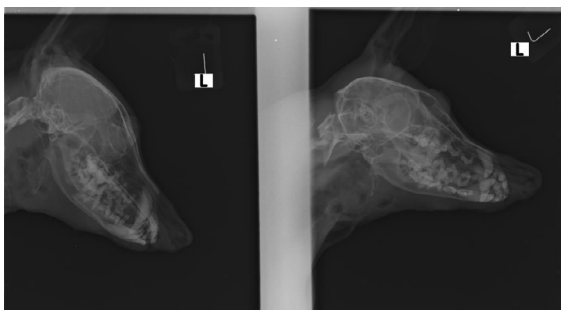

**Figure 4:** The 3rd phase; Dog A, the radiography image at the 1st day at hospital revealed open transverse fracture of the left mandibular body at caudal P4 (P4-M1).

**Figure 5:** The 3rd phase; Dog A, after interdental wiring and intraoral acrylic splint.

**Figure 6:** The 3rd phase; Dog A, interdental wiring and intraoral acrylic splint.

**Figure 7:** The 3rd phase; Dog A, radiography image immediately after surgery.

This study cut mandible between premolar 4 and molar 1 so that the S force was lower than normal.

Concerning the method of cutting the mandible, thin saw, oscillating saw or pulsed ultrasound saw is good for cutting the mandible. The recommended method is three-point bending technique, this technique could cut the mandible in close fracture by blunt guillotine [21,22]. If this study had used this technique, the results would have been more reliable. The thin saw technique used in this study could damage soft tissue and affected S force.

**Figure 8:** The 3rd phase; Dog A, radiography image 28 days after surgery.

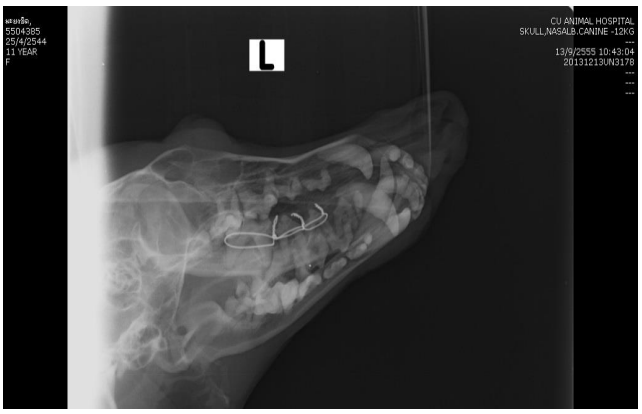

**Figure 9:** The 3rd phase; Dog A, radiography image 2 months after surgery.

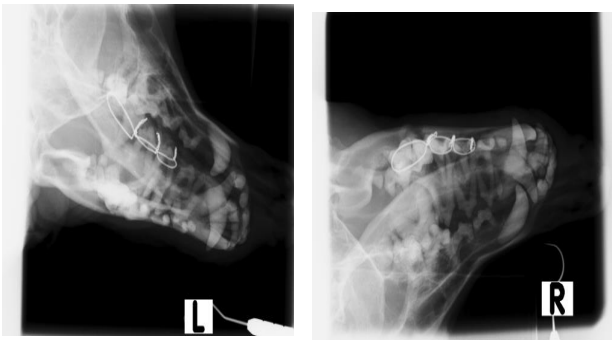

**Figure 10:** The 3rd phase; Dog A, radiography image 3 months after surgery.

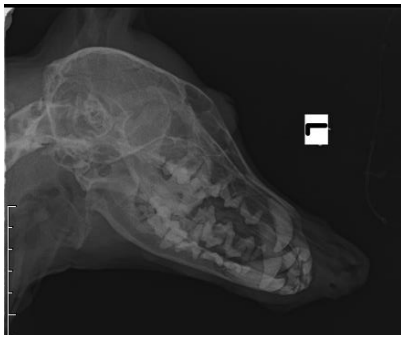

**Figure 11:** The 3rd phase; Dog A, radiography image 4 months after surgery (After removal of the interdental wiring and intraoral acrylic splint).

**Figure 12:** The 3rd phase; Dog A, radiography image 6 months after surgery.

In the 2nd phase, 14 days were enough for allergy or biocompatibility test. However, for clinical use, the longer test time would be better. The healing rate of mandible was approximately 3-4 months. Therefore, for further study, one should take more time for collecting data and collect gum tissue from 2 sides, wearing and not wearing acrylic sides for histopathology. The histopathological study is gold standard for examining inflammation response.

In the 3rd phase, 1 month after the operation, dogs could use mouth normally and had no complications besides plaque occurring on the acrylic and halitosis. A rough shape of acrylic make the food remain at the acrylic causing gingivitis and halitosis. The owner cleans the mouth with warm sterile water in the gauze, would prevent plaque formation. 2 months after the operation, even though the tape muzzle was taken off, fracture line was still in alignment, this can prove that the acrylic is strong for chewing in less than 10 kilogram body weight dog. In addition, the intraoral splint together with the dental acrylic did not cause osteomyelitis because the technique was non-invasive.

## Acknowledgements

This study was supported by 3M Thailand Company. The authors would like to thank Clinicians, graduated students and staffs of the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University for supporting in data collection.

## References

1. Umphlet RC, Johnson AL (1988) Mandibular Fractures in the Cat. A Retrospective Study. Vet Surg 17: 333-337.
2. Umphlet RC, Johnson AL (1990) Mandibular Fractures in the Dog. A Retrospective Study of 157 Cases. Vet Surg 19: 272-275.
3. Taney KG, Smith MM (2010) Small Animal Dental, Oral and Maxillofacial Disease. In: Small Animal Dental, Oral and Maxillofacial Disease. Niemiec BA (ed). Manson Publishing, London, UK, pp: 207-213.
4. Verstraete FJM (2003) Textbook of Small Animal Surgery. Slatter DH (ed.), 3rd edn. Philadelphia: Saunders Elsevier, pp: 2196-2202.
5. Lobprise HB (2007) Maxillary and Mandibular fractures. In: Blackwell's Five-Minute Veterinary Consult Clinical Companion: Small Animal Dentistry. Chapter 43. Blackwell Publishers, Oxford, pp: 289-297.
6. Bellows J (2004) Oral surgical equipment, materials, and techniques. Small Animal Dental Equipment, Materials and Techniques. A Primer. pp: 297-361.
7. Boudrieau RJ (2012) Mandibular and Maxillofacial Fractures. In: Veterinary Surgery: Small Animal. Chapter 67. Tobias KM, Johnston SA (eds.). St. Louis: Elsevier/Saunders, pp: 1054-1077.
8. Lewis DD, Oakes MG, Kerwin SC, Hedlund CS (1991) Maxillary-mandibular wiring for the management of caudal mandibular fractures in two cats. J Small Anim Pract 32: 253-257.
9. Bennett JW, Kapatkin AS, Marretta SM (1994) Dental composite for the fixation of mandibular fractures and luxations in 11 cats and 6 dogs. Vet Surg 23: 190-194.

10. Hoffer M, Manfra Marretta S, Kurath P, Johnson A, Griffon D, et al. (2011) Evaluation of composite resin materials for maxillomandibular fixation in cats for treatment of jaw fractures and temporomandibular joint luxations. Vet Surg 40: 357-368.

11. Aizenbud D, Hazan-Molina H, Emodi O, Rachmiel A (2009) The management of mandibular body fractures in young children. Dent Traumatol 25 565-570.

12. Iacopetti I, De Benedictis GM, Faughnan M, Perazzi A, Busetto R (2009) Treatment of incisive bone fracture in a horse using an acrylic splint. Equine Vet Educ 21: 346-351.

13. Niemiec BA (2003) Intraoral acrylic splint application. J Vet Dent 20: 123-126.

14. Hall BP, Wiggs RB (2005) Acrylic splint and circumferential mandibular wire for mandibular fracture repair in a dog. J Vet Dent 22: 170-175.

15. Reiter AM, Rewis JR, Harvey CE (2012) Dentistry for the Surgeon. In: Veterinary Surgery: Small Animal. Tobias KM, Johnston SA (eds.). Chapter 66. St. Louis: Elsevier/Saunders, pp: 1037-1053.

16. Chokchaivorakul W (2007) The fatigue life of heat-activated acrylic resin denture base materials repaired with various methods. Chulalongkorn University.

17. Sastri VR (2010) Plastics in medical devices: properties, requirements and applications. 2nd edn. Elsevier, USA.

18. Lindner DL, Marretta SM, Pijanowski GJ, Johnson AL, Smith CW (1995) Measurement of bite force in dogs: a pilot study. J Vet Dent 12: 49-52.

19. Ellis JL, Thomason J, Kebreab E, Zubair K, France J (2009) Cranial dimensions and forces of biting in the domestic dog. J Anat 214: 362-373.

20. Kovan V (2008) An assessment of impact strength of the mandible. J Biomech 41: 3488-3491.

21. Frink M, Andruszkow H, Zeckey C, Krettek C, Hildebrand F (2011) Experimental trauma models: an update. Biomed Res Int 2011: 1-15.

22. Reifenrath J, Angrisani N, Lalk M, Besdo S (2014) Replacement, refinement, and reduction: necessity of standardization and computational models for long bone fracture repair in animals. J Biomed Mater Res A 102: 2884-2900.