IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 17, Issue 7 Ser. 2 (June. 2024), PP 15-24
www.iosrjournals.org

Evaluation Of Maxillary Fourth Premolar Teeth With Endodontic Treatment In 39 Dogs—A Retrospective Study

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Abstract

Background

In dogs, fractures more commonly occur in the maxillary fourth premolar teeth than in other teeth. If the pulp is damaged, the treatment options could be tooth extraction or root canal therapy.

Objective

The purpose of this study was to evaluate fractured maxillary fourth premolar teeth prognosis in dogs after endodontic treatment.

Animals and procedures

Thirty-nine maxillary fourth premolars were treated in 39 dogs over a 2-year period. All treatments were performed by the same operator with standard root canal therapy, the prognosis was evaluated using dental radiographs and visual inspection for an average of 6 months, and the success rate of root canal treatment was evaluated. The 39 dogs were evaluated for breed, size, age, sex, weight, and cause, degree, and location of fracture.

Results

After root canal treatment, 35 out of 39 dogs showed improved symptoms, while 4 dogs developed facial edema, periapical abscess, and periodontal inflammation that necessitated extraction. Additionally, the success rate of endodontic treatment was found to be reduced in dogs with periapical osteolysis on preoperative dental radiographs.

Conclusion and clinical relevance

Endodontic treatment is considered a valuable treatment option in the case of a fractured maxillary fourth premolar because of its ability to maintain the structure and masticatory movement.

Date of Submission: 14-07-2024 Date of Acceptance: 24-07-2024

I. Introduction

Fractures of the maxillary fourth premolar tooth in dogs are common (1). A recent study reported that tooth fracture occurs in 27% of domestic dogs, and, importantly, 10% of domestic dogs have one or more teeth with pulp exposure (2, 3). The maxillary fourth premolar tooth is one of the most commonly affected teeth (4, 5), accounting for 29.5% of total tooth fracture cases (6).

Frequent injury to the crown results in a fractured crown with pulp exposure, which leads to acute or chronic pulp inflammation, that can progress to endo-perio lesions (7). Injury to the pulp can lead to inflammation (pulpitis), swelling (pulpal edema), hemorrhages (pulpal hemorrhage) (8), and infection, potentially resulting in chronic pain, worsened bacteremia, or organ infection, culminating in tooth abscess formation (9).

Treatment options for a tooth fracture include root canal therapy, vital pulpotomy, and tooth extraction (10). A vital pulpotomy may be used when pulp vitality can be maintained and healing can be expected (11).

In cases of pulpal death, treatment should be administered by endodontic therapy, tooth extraction or vital pulpotomy (12). Extraction in dogs is typically performed to remove infected and/or painful teeth. Indications include severe periodontal disease, endodontic disease (e.g., fractured or intrinsically stained teeth), malpositioned teeth causing oral trauma, persistently or infected deciduous teeth, unerupted teeth, among others (13, 14). However, surgical interventions such as root canal therapy or endodontic treatment can effectively preserve many of these teeth and should be considered as options before extraction (15). When applied correctly, endodontic therapy proves to be an effective method for preserving teeth affected by endodontic disease while

maintaining periodontal health. The primary goal of periapical surgery is to eliminate diseased tissue, facilitating healing and tissue regeneration (16, 17).

The objective of this study was to evaluate the outcome of endodontic treatment in maxillary fourth premolar teeth in dogs, to compare the outcomes of patients who were treated with endodontic treatment, and to assess whether there were any significant differences.

II. Materials And Methods

A total of 39 dogs with a maxillary 4th premolar tooth fracture(s) with exposed pulp who underwent treatment at a local veterinary dental clinic over a 2-year period were included in the study.

Endodontic procedures are usually performed on the teeth compromised by infection or those at risk for potential infection. Therefore, the protocol used should include broad-spectrum antibiotics, achieve therapeutic blood concentration at the time of surgery, and provide medication for 7 to 10 days post-operatively. Cefazolin (Cephazolin Injection®; Chong kun dang Pharmaceutical Corp., Seoul, Korea) 20 mg/kg IV injection was given as a prophylactic antibiotic.

In the evaluation of the patient's general status, a blood test (complete blood cell count, chemistry, and electrolyte test), thoracic and abdominal radiographic examination, electrocardiography, and measurement of blood pressure were performed; no abnormalities were detected. General anesthesia was performed as follows: premedication with midazolam (Midacum Injection®; Myungmoon Pharm Co., Hwaseong, Korea) 0.1 mg/kg IV; butorphanol (Butopan Injection®; Myungmoon Pharm Co., Hwaseong, Korea) 0.1 mg/kg IV; and induction with propofol (Provide Injection® 1%; Myungmoon Pharm Co., Hwaseong, Korea) 6 mg/kg IV. After intubation, isoflurane 2%–3% was used to maintain anesthesia.

In all the teeth under the treatment plan, ultrasonic scaling was performed prior to root canal treatment and the tooth fracture type was classified as complicated crown fracture (CCF) or complicated crown-root fracture (CCRF) (Figure 1).

For a fracture of the maxillary 4th premolar tooth with pulp exposure, treatment was performed by standard root canal therapy (18). All root canal therapies were conducted by one practitioner. Before treatment, the teeth were examined with dental radiography to confirm suspicious periapical lesions. Treatment involved drilling a hole in the crown up to the level of the pulp cavity, measuring the working length of the root canal with an endodontic file, and removing the pulp from the cavity with a barbed broach. Next, the pulp cavity was cleaned, shaped with endodontic files, and flushed with 4% sodium hypochlorite; EDTA gel (RC Prep®; Premier Dental Product Co., Hannover, Germany) was used as a chelator and file lubricant as needed (Figure 2). Final obturation was achieved with gutta-percha cone and endodontic sealers, including lateral compaction and vertical compaction with thermoplastic gutta-percha. Access openings were closed with a glass-ionomer intermediate layer and restoration composite (Figure 3).

Postoperative follow-up was performed from 1 month to 24 months (mean, 6 months). An evaluation fracture site recovery was observed through a gross exam and dental radiography.

The success of the treatment followed the quality guidelines of the European Society of Endodontology (16). The success or failure of cases were determined based on the expansion of the periapical radiolucency, improvement of masticatory movements, and the presence of oral lesions. Treatment was also considered successful if there was no pain, swelling, and other symptoms, no functional loss, and radiological evidence of normal periodontal ligament space around the periodontal root. Facial swelling, gingival inflammation were assessed via macrography, chewing movement and appetite were assessed when available (3, 19).

In this study, the 39 subjects were categorized based on age, gender, body size, body weight, breed, and fracture type(s).

III. Results

The study group comprised several breeds, as follows: Dachshund (six dogs), Mongrel (six dogs), Poodle (six dogs), Welsh Corgi (six dogs), Spitz (five dogs), Boston Terrier (two dogs), Miniature Pinscher (two dogs), Cocker Spaniel (one dog), Maltese (one dog), Pit Bull Terrier (one dog), Pomeranian (one dog), Schnauzer (one dog), and Yorkshire Terrier (one dog) (Table 1). The ages of the dogs ranged from 2 to 14 years (mean ± SD, 6.46 ± 3.00) (Table 2), and weights ranged from 4.3 to 24 kg (mean ± SD, 8.67 ± 3.90) (Table 3). Among the subjects, there were 18 female dogs (46.15%) and 21 male dogs (53.84%). (Table 4). Regarding breed size, there were 1 large-size (2.56%), 19 medium-size (48.71%), and 19 small-size (48.71%) breeds. (Table 5). The causes of tooth fracture were feeding in 34 dogs (87.91%), toy biting in 3 dogs (7.69%), and the reason was unknown for the remaining 2 dogs (5.21%) (Table 6). In 39 patients, a fracture of the right maxillary fourth premolar tooth (#108) was observed in 19 patients (48.71%), while a fracture of the left maxillary fourth premolar tooth (#208) was observed in 20 patients (51.28%) (Table 7). Regarding fracture type, CCF was observed in 11 dogs (28.20%), while CCRF was observed in 28 dogs (71.79%) (Table 8). In addition,

preoperative periapical lucency was present in 4 (10.26%) cases of CCF and 7 (17.95%) cases of CCRF (Table 9). Preoperative root resorption was detected in 1 (2.56%) of CCF and 1 (2.56%) of CCRF (Table 10).

The follow-up duration ranged from 1 month to 24 months (average, 6 months). According to the owners, their dogs reported no issues with mastication, appetite, or daily activities. Intraoral radiographs were obtained before surgery, immediately after surgery, and during follow-up examinations after surgery using the bisecting angle technique with a dental radiography unit and a radiographic film (periapical, size 2).

In this study, improvement was observed in 35 of the 39 dogs who underwent root canal therapy for the maxillary fourth premolar tooth, with a success rate of 89.74%. In these successful cases, there was no expansion of periapical radiopacity, improvement of masticatory movement, and the absence of oral lesions. In addition, there was no pain, oedema, and functional loss, and radiological evidence of normal periodontal ligament space around the periodontal root.

Among the remaining four cases, in which root canal treatment failed, the CCF fracture type was observed in two dogs, while CCRF was observed in two dogs; surgical extractions were conducted in all four of these dogs. At follow-up, additional complications were identified in some cases, including root resorption in one dog and various symptoms such as facial swelling, impaired masticatory movement, and an expansion of periapical lesions in three dogs (Table 11). These findings underscore the importance of continued monitoring and proactive management strategies to address potential complications and ensure optimal long-term outcomes for canine patients undergoing dental interventions (Figure 5).

IV. Discussion

Tooth fracture refers to damage to the hard tissue of a tooth caused by trauma, and can be divided into enamel crack, crown fracture, crown-root fracture, and tooth root fracture (20). Fractures of the crown and tooth roots were found in 49.6% of companion animals (20). Additionally, 10% of dogs have teeth that directly expose the pulp (20). Dental fractures have been reported to occur most commonly in functionally important teeth that play a role in grasping and chewing. Tooth fracture is the second most common dental disease in dogs after periodontitis (6).

Looking at the fracture rate by tooth, canine teeth were the most common at 38.8%, followed by Premolar (33.1%) and Incisor (25.9%). However, 67.7% of Canine and Incisor fractures occurred in the large breed, and premolar fractures (especially 108 and 208) occurred more frequently in the small and medium breeds (6). The most common cause of tooth fracture in humans is strong impact force caused by chewing hard objects or uncontrolled contact of teeth during occlusion. In dogs and cats, the main causes are reported to be trauma such as play, training, bite, traffic accident, or fall. The most common causes of fracture of incisor teeth were trauma (30.6%) and game (27.8%), and for canine teeth, training (24.1%), game (24.1%), and trauma (14.8%) were the most common causes. However, in the case of premolar and molar teeth, the main cause is chewing on treats and toys (21). These findings emphasize the multifactorial nature of dental fractures in dogs and underscore the significance of tailored preventive measures and patient-specific management strategies. By elucidating the underlying causes and risk factors contributing to dental trauma, veterinarians can implement targeted interventions aimed at promoting optimal oral health and well-being in canine companions.

Tooth fractures can occur at any age. However, studies in humans have shown that most tooth fractures occur between the ages of 7 and 15 with underdeveloped teeth. Looking at the relationship between tooth fracture and age in dogs, the incidence rate of fracture was lower in dogs younger than 3 years of age, with the highest rate occurring in dogs aged 3 to 6 years, followed by those aged 7 to 10 years (20, 22-24). Fractures involving the tooth root are classified as crown root fractures according to the AVDC classification and are classified as either Complicated crown root fracture or Uncomplicated crown root fracture depending on whether or not the pulp is exposed. In the case of crown root fracture, the fracture extends to the cemento-enamel junction, creating a periodontal pocket (1). In addition, the length of the root trunk is shorter than that of humans, so the probability of furcation involvement is high (25). Crown root fractures account for 5% of permanent tooth damage in humans and 15% of all fractures in dogs. Complicated crown root fractures with exposed nerves account for 13.1% of all fractures (20, 26).

In the case of a complicated crown root fracture, the pulp is exposed and is extremely painful. Slab fractures can also occur, which is when a slab of the crown separates from the side of the tooth, exposing the pulp cavity (20). If left untreated, it can lead to pulp necrosis and periapical inflammation due to saliva containing bacteria, so treatment is necessary. Treatment for complicated crown root fracture can be divided into root canal treatment and tooth extraction. Extraction is often the treatment of choice for teeth with severe crown root fractures when tooth-preserving techniques cannot be applied due to the severity of the fracture and lack of operator skill. In humans, vertical crown root fractures generally require tooth extraction, and tooth extraction is also recommended when the fractured fragment constitutes more than one-third of the root and the fracture is along the long axis of the tooth (26). In dogs, tooth extraction is necessary if the fracture direction is vertical to

the root or if root fracture is severe (1). Another treatment option is hemisection extraction, which removes only the root involved in the fracture if the fractured tooth is multi-rooted and one or more roots are intact (1).

Root canal treatment is a treatment that can maintain the appearance and function of teeth (4). Root canal treatment refers to removing the infected pulp within the root canal, cleaning and shaping the pulp cavity, and filling the root canal with treatment material to seal the exposed portion (6). The success rate of Root canal treatment is reported to be over 90% in humans and 69% to 95% in dogs. Periapical lesions and external inflammatory root resorption have been reported as factors affecting the failure rate of endodontic treatment, and prognosis was mainly evaluated between 3 and 6 months (27).

The maxillary fourth premolar stands out as one of the teeth most vulnerable to fracture, with complicated crown root fractures occurring with notable frequency (4). Given its functional significance in canine dentition, preserving the integrity of the maxillary fourth premolar is paramount, as emphasized by both dental professionals and pet owners alike. Unlike in human dentistry, where established standards guide endodontic interventions for complicated crown root fractures, the landscape in veterinary medicine presents a notable gap in definitive guidelines. While case reports documenting root canal treatments in veterinary patients exist, there remains a lack of comprehensive research elucidating clear standards for such procedures. This study endeavors to address this gap by systematically investigating the impact of key factors, such as the depth of the periodontal pocket created by the fracture and the extent of furcation involvement, on the success rate of treatment. By focusing specifically on root canal treatment for the maxillary fourth premolar with a complicated crown root fracture in dogs, this research aims to establish evidence-based standards that can guide clinical practice and improve patient outcomes. Central to this study's objective is understanding how variations in the anatomical and pathological characteristics of the affected tooth influence treatment outcomes. Factors such as the depth of the periodontal pocket and the extent of furcation involvement are hypothesized to play crucial roles in determining the efficacy of root canal therapy. By meticulously assessing these variables and correlating them with treatment outcomes, this research seeks to identify predictive indicators of success and delineate guidelines for optimizing the management of complicated crown root fractures in canine patients. Ultimately, the findings of this study hold the potential to revolutionize veterinary dental practice by providing practitioners with evidence-based protocols for treating complicated crown root fractures in dogs. By establishing standardized criteria for assessing treatment success and failure, as well as delineating best practices for root canal therapy, this research aims to enhance the quality of care delivered to canine patients while promoting the preservation of their dental health and overall well-being.

The maxillary fourth premolar is one of the most functionally important teeth in dogs. Since the tooth is involved in the bite action and in feeding, it is vulnerable to fracture (7). A wound in the crown fracture exposes the pulp, which results in pulp and periapical inflammation. In this study, we analyzed 39 dogs who underwent maxillary fourth premolar tooth treatment over a 2-year period. The 39 subjects comprised a total of 13 breeds. The average weight of the dogs was 8.67 kg; a total of 27 dogs weighed 4.6-10 kg (69.23%) and 9 dogs weighed 10-15 kg (23.09%). The majority of the patients were small- and medium-size breeds; more specifically, 19 patients (48.71%) were small-size breeds, but had an average weight of 6.24 kg, which is considered slightly heavy for small breeds.

Other reports have suggested that 52% of maxillary fourth premolar tooth fractures occur in large breeds (7). The differences between these previously obtained results and those of the present study may be due to the fact that Koreans raise more small breeds than large breeds, as confirmed by data from the Rural Development Administration in 2018 showing that the average weight of dogs in Korea was 7.1 kg. These cases highlight the fact that small dogs weighing 5-10-kg have a higher risk of tooth fracture. Other studies have reported that fractures of the maxillary fourth premolar tooth in dogs occurred from chewing on very hard treats and toys, including large, prepared or unprepared animal bones, cow hooves, ice cubes, and objects made of hard nylon (1). The shearing forces generated by biting these materials can cause the fourth premolar tooth to break away from the buccal portion of the maxilla, resulting in a fracture (28). Eating meals is considered the largest cause of tooth fracture. In our study, in 34 dogs (87.17%), tooth fracture occurred during the partaking of solid foods, such as bone segments or dog gums, while, in 3 dogs (7.69%), tooth fracture occurred during the biting of a frisbee or toy. In 87.17% of cases in our study, tooth fractures occurred at less than 10 years of age, and sex was not a significant influencing factor. Regarding fracture type, CCRF accounted for 71.79% of total cases, which was higher than the rate of 28.20% of CCF.

In the majority of cases, the crown fracture was located at either the left or right maxilla, and we conducted root canal treatment on 39 teeth in 39 patients. Interestingly, upon reviewing existing literature, we found a striking absence of case reports detailing bilateral maxillary fractures. This underscores the uniqueness of our findings and the potential significance of further exploration into this phenomenon.

Adding to this intrigue, a study cited in the literature revealed compelling insights into the lateral distribution of dental fractures in canines. According to their findings, 43% of fracture cases occurred on the right side, while 46% manifested on the left side. Remarkably, only 11% of cases exhibited fractures on both

sides simultaneously. This notable disparity prompts a deeper investigation into the underlying factors driving this lateral preference in dental trauma.

An insightful explanation for this observed pattern lies in the inherent behavior of dogs during feeding and object manipulation. It is widely acknowledged that dogs tend to exhibit a preferred side of the maxilla when engaging in activities such as biting or chewing various objects. This habitual preference can lead to increased wear and stress on the corresponding dental structures, thereby predisposing them to fractures. By elucidating these behavioral tendencies, we gain valuable insights into the etiology of dental injuries in canine populations. Furthermore, understanding the biomechanical forces at play during canine activities can inform preventive strategies aimed at mitigating the risk of dental trauma.

These authors observed that most dogs with tooth fractures were highly energetic and that some of them were aggressive; however, this observation was not directly related to the study's objective and there were insufficient supporting data. Nevertheless, a meaningful relationship between tooth fractures and dog characteristics may exist. Further research exploring the potential correlation between specific traits such as energy levels and aggression tendencies in dogs with tooth fractures could provide valuable insights into understanding the underlying causes and risk factors associated with dental injuries in canine populations. Additionally, conducting thorough behavioral assessments alongside comprehensive dental examinations may help elucidate any potential links between temperament and dental health, ultimately contributing to more targeted preventive measures and treatment strategies for promoting overall canine well-being.

Of the 39 dogs who underwent treatment in our study, 35 showed no side effects. We performed extraction in four dogs with side effects and achieved a success rate of 89.74%, which is higher than the rate of 50% reported in a previous study on the maxillary fourth premolar tooth (4). The factors that contributed to the higher success rate of our study include the breeding environment, treatment methods, and treatment environment. At follow-up, we conducted oral radiography and a macrography and evaluation of masticatory movement in all dogs; under macrography, face swelling, gingival inflammation, decreased appetite, and pain were evaluated. The owners of the 35 dogs without side effects reported satisfaction with the treatment results, normal masticatory movements, and active daily activities of their dogs.

Many owners wish to preserve their pet's dentition after damage due to trauma (4). Endodontic therapy maintains the shape and function of a tooth and is the preferred alternative to dental extraction when feasible (29). Appropriate endodontic therapies can salvage and maintain the affected teeth (4). A study revealed that endodontic treatment was less invasive than tooth extraction, showed no development of post-operative pains, maintained the facial structure, and achieved a higher success rate than treatment with extraction; moreover, the treatment did not impact masticatory movements and preserved the quality of life of dogs, and the owners expressed a high level of satisfaction with these results (30).

In human patients, the significant factors associated with the outcome of root canal treatment included evidence of pre-operative periapical lucency (31-34) and pulp necrosis (35-37). Another study indicated that root canal treatment was significantly less likely to be successful in roots with pre-operative periapical lucency than in those without any preexisting periapical lucency (31, 37).

The maxillary fourth premolars play an important role in the equilibrated crossways bite action of teeth and in feeding; based on these findings, clinicians should attempt to preserve these teeth (7). Endodontic treatment maintains the shape and function of the tooth (4) but increases its brittleness (7, 38), which can increase its susceptibility to further deterioration. Based on these findings, we replaced the crown with a metallic crown in 20 cases.

The limitation of this study was the small sample size of 39 dogs. The small sample size may have resulted in insufficient statistical significance. Another limitation was the relatively low success rate. Previous studies have reported a success rate of 95%, but the success rate in this study was 89.74%, which is relatively low. The authors believe that this is due to the relatively low weight of the dogs in the study, which may have caused some technical difficulties. Lastly, the cases included in this study were a mixture of CCF and CCRF. Although they both require root canal treatment, they have different treatment modalities and different success rates. Therefore, the authors believe that further research is needed in this area.

In conclusion, the maxillary fourth premolar tooth is one of the most important teeth in terms of functionality and has the highest susceptibility to fracture. Root canal therapy for fractures in these teeth was less invasive, achieved tooth preservation, and thereby improved both the quality of life for dogs and owner satisfaction.

Root canal treatment showed potential as an effective approach to maintaining function and recovering fractured maxillary fourth premolar teeth in a variety of canine patients.

References

[1] Reiter Am And Lewis Jr. Dental Bulge Restoration And Gingival Collar Expansion After Endodontic Treatment Of A Complicated Maxillary Fourth Premolar Crown-Root Fracture In A Dog. Journal Of Veterinary Dentistry 2008;25 (1).
[2] Matelski J, Rendahl A, And Goldschmidt S. Effect Of Alternative Palatal Root Access Technique On Fracture Resistance Of Root Canal Treated Maxillary Fourth Premolar Teeth In Dogs. Frontiers In Veterinary Science 2020;7: 600145.
[3] Niemiec B, Gawor J, Nemec A, Et Al. World Small Animal Veterinary Association Global Dental Guidelines. Journal Of Small Animal Practice 2020;61 (7): E36-E161.
[4] Brine Ej And Marretta Sm. Endodontic Treatment And Metal Crown Restoration Of A Fractured Maxillary Right Fourth Premolar Tooth: A Case Report. Journal Of Veterinary Dentistry 1999;16 (4): 159-163.
[5] Wagnild Gw And Mueller Ki. Restoration Of The Endodontically Treated Tooth. Pathways Of The Pulp 2002;9.
[6] Capik I, Ledecký V, And Ševčík A. Tooth Fracture Evaluation And Endodontic Treatment In Dogs. Acta Veterinaria Brno 2000;69 (2): 115-122.
[7] Pavlica Z, Erjavec V, And Petelin M. Treatment Of The Injuried Upper Fourth Premolar In The Dog. 2001.
[8] Goldstein G And Anthony J. Basic Veterinary Endodontics. Compendium On Continuing Education For The Practicing Veterinarian 1990;12 (2): 207-217.
[9] Clarke De. Endodontics Of Dogs And Cats: An Alternative To Extraction. Australian Veterinary Journal 1995;72 (10): 383-389.
[10] Clarke De. Vital Pulp Therapy For Complicated Crown Fracture Of Permanent Canine Teeth In Dogs: A Three-Year Retrospective Study. Journal Of Veterinary Dentistry 2001;18 (3): 117-121.
[11] Wiggs R And Lobprise H. Advanced Endodontic Therapies. Veterinary Dentistry: Principles And Practice 1997: 325-350.
[12] Luotonen N, Kuntsi-Vaattovaara H, Sarkiala-Kessel E, Junnila Jj, Laitinen-Vapaavuori O, And Verstraete Fj. Vital Pulp Therapy In Dogs: 190 Cases (2001–2011). Journal Of The American Veterinary Medical Association 2014;244 (4): 449-459.
[13] Smith Mm. Exodontics. Veterinary Clinics Of North America: Small Animal Practice 1998;28 (5): 1297-1319.
[14] Wiggs R And Lobprise H. Oral Surgery. Veterinary Dentistry: Principles & Practice 1997: 232-258.
[15] Niemiec Ba. Extraction Techniques. Topics In Companion Animal Medicine 2008;23 (2): 97-105.
[16] Endodontology. Eso. Int Endod J. Int Endod J 2006;39: 921-930.
[17] Kim S And Kratchman S. Modern Endodontic Surgery Concepts And Practice: A Review. J Endod 2006;32: 601-623.
[18] Boyd Rc. Basic Endodontic Therapy. Wiggs's Veterinary Dentistry: Principles And Practice 2019: 311-334.
[19] Johnson Ac, Miller Hc, And Wynne Cd. How Dog Behavior Influences Pet Owner's Perceptions Of Dog Preference For Dental Chews. Animals 2023;13 (12): 1964.
[20] Soukup Jw, Hetzel S, And Paul A. Classification And Epidemiology Of Traumatic Dentoalveolar Injuries In Dogs And Cats: 959 Injuries In 660 Patient Visits (2004–2012). Journal Of Veterinary Dentistry 2015;32 (1): 6-14.
[21] Soltero-Rivera M, Elliott Mi, Hast Mw, Et Al. Fracture Limits Of Maxillary Fourth Premolar Teeth In Domestic Dogs Under Applied Forces. Frontiers In Veterinary Science 2019;5: 339.
[22] Burke F. Tooth Fracture In Vivo And In Vitro. Journal Of Dentistry 1992;20 (3): 131-139.
[23] Ellis Sg, Macfarlane T, And Mccord J. Influence Of Patient Age On The Nature Of Tooth Fracture. The Journal Of Prosthetic Dentistry 1999;82 (2): 226-230.
[24] Cardoso M And De Carvalho Rocha Mj. Association Of Crown Discoloration And Pulp Status In Traumatized Primary Teeth. Dental Traumatology 2010;26 (5): 413-416.
[25] Zacher A And Marretta Sm. Diagnosis And Management Of Furcation Lesions In Dogs–A Review. Journal Of Veterinary Dentistry 2022;39 (2): 151-172.
[26] Niemiec Ba. Management Of A Complicated Maxillary Fourth Premolar Crown-Root Fracture In A Dog. Journal Of Veterinary Dentistry 2000;17 (3): 128-133.
[27] Lee Db, Arzi B, Kass Ph, And Verstraete Fj. Radiographic Outcome Of Root Canal Treatment In Dogs: 281 Teeth In 204 Dogs (2001–2018). Journal Of The American Veterinary Medical Association 2022;260 (5): 535-542.
[28] Cohn L And Côté E. Cote's Clinical Veterinary Advisor: Dogs And Cats: Mosby International Ltd, 2019.
[29] Harvey C. Periodontal Disease. Small Animal Dentistry 1993: 89-144.
[30] Holmstrom Se, Fitch Pf, And Eisner Er. Veterinary Dental Techniques For The Small Animal Practitioner-E-Book: Elsevier Health Sciences, 2004.
[31] Kuntsi-Vaattovaara H, Verstraete Fj, And Kass Ph. Results Of Root Canal Treatment In Dogs: 127 Cases (1995–2000). Journal Of The American Veterinary Medical Association 2002;220 (6): 775-780.
[32] Jokinen M, Kotilainen R, Poikkeus P, Poikkeus R, And Sarkki L. Clinical And Radiographic Study Of Pulpectomy And Root Canal Therapy. European Journal Of Oral Sciences 1978;86 (5): 366-373.
[33] Kerekes K. Radiographic Assessment Of An Endodontic Treatment Method. Journal Of Endodontics 1978;4 (7): 210-213.
[34] Selden Hs. Pulpoperiapical Disease: Diagnosis And Healing: A Clinical Endodontic Study. Oral Surgery, Oral Medicine, Oral Pathology 1974;37 (2): 271-283.
[35] Pekruhn Rb. The Incidence Of Failure Following Single-Visit Endodontic Therapy. Journal Of Endodontics 1986;12 (2): 68-72.
[36] Storms J. Factors That Influence The Success Of Endodontic Treatment. Journal Of The Canadian Dental Association 1969;35 (2): 83-97.
[37] Strøm Pc, Arzi B, Lommer Mj, Et Al. Radiographic Outcome Of Root Canal Treatment Of Canine Teeth In Cats: 32 Cases (1998–2016). Journal Of The American Veterinary Medical Association 2018;252 (5): 572-580.
[38] Gammon R. Crown Restorations. Veterinary Focus 1990;2 (1): 13-16.

Figure Legends

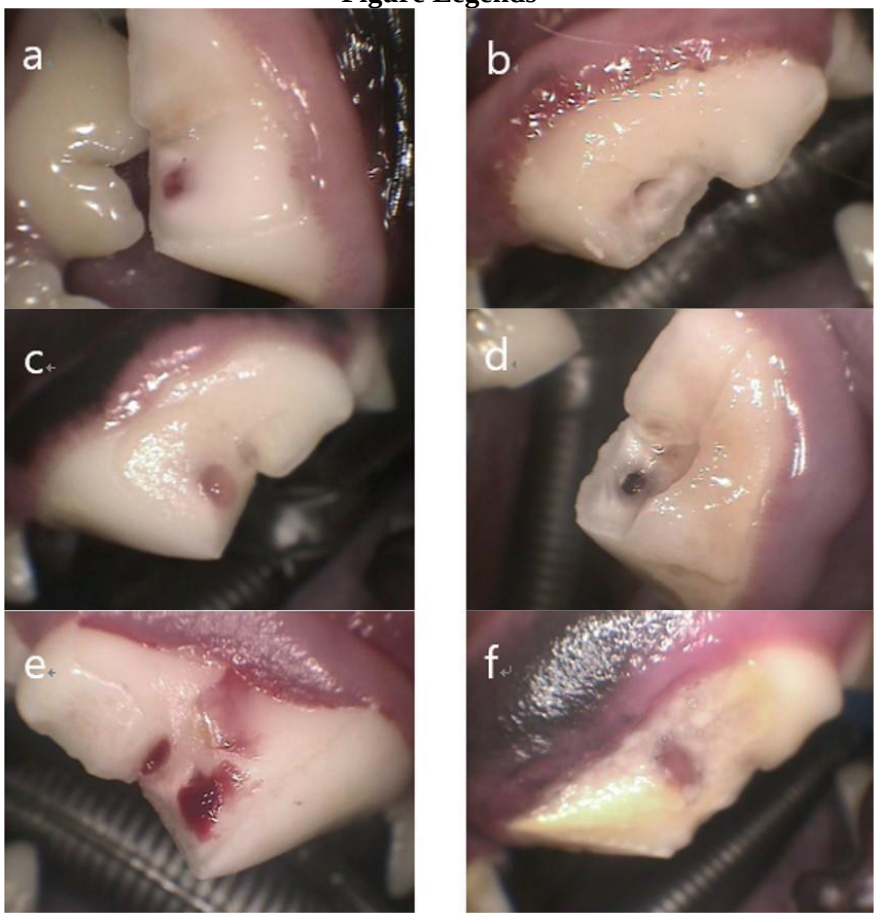

Figure 1. Classification of the maxillary 4th premolar tooth fracture. (a, b, c) Complicated crown fracture. (d, e, f) Complicated crown-root fracture.

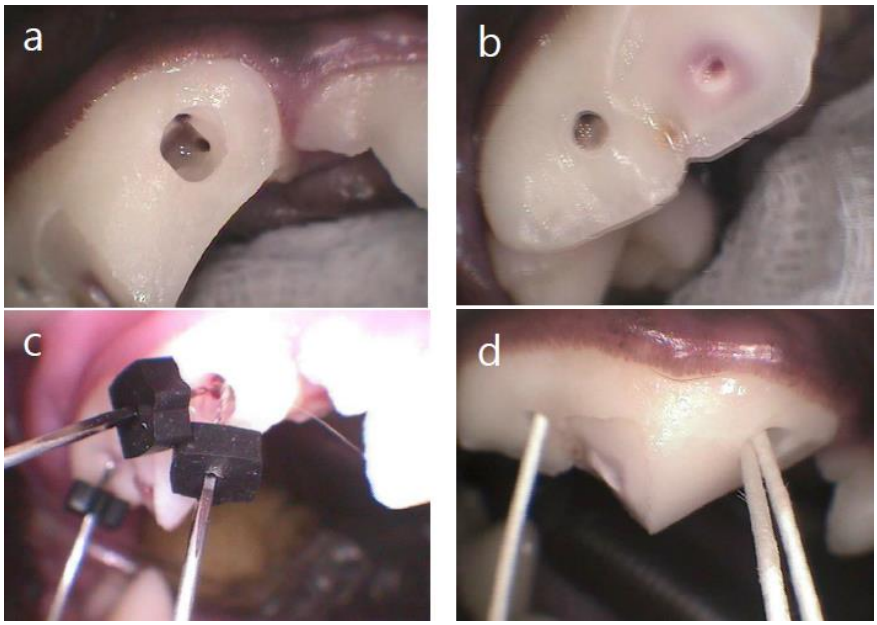

Figure 2. Endodontic treatment procedure of the maxillary 4th premolar tooth. (a) Approach of the mesial and palatal root canal. (b) Approach of the distal root canal. (c) Measurement of the working lengths of the roots using k-files. (d) Drying of the root canal with paper points after cleaning and shaping with k-files.

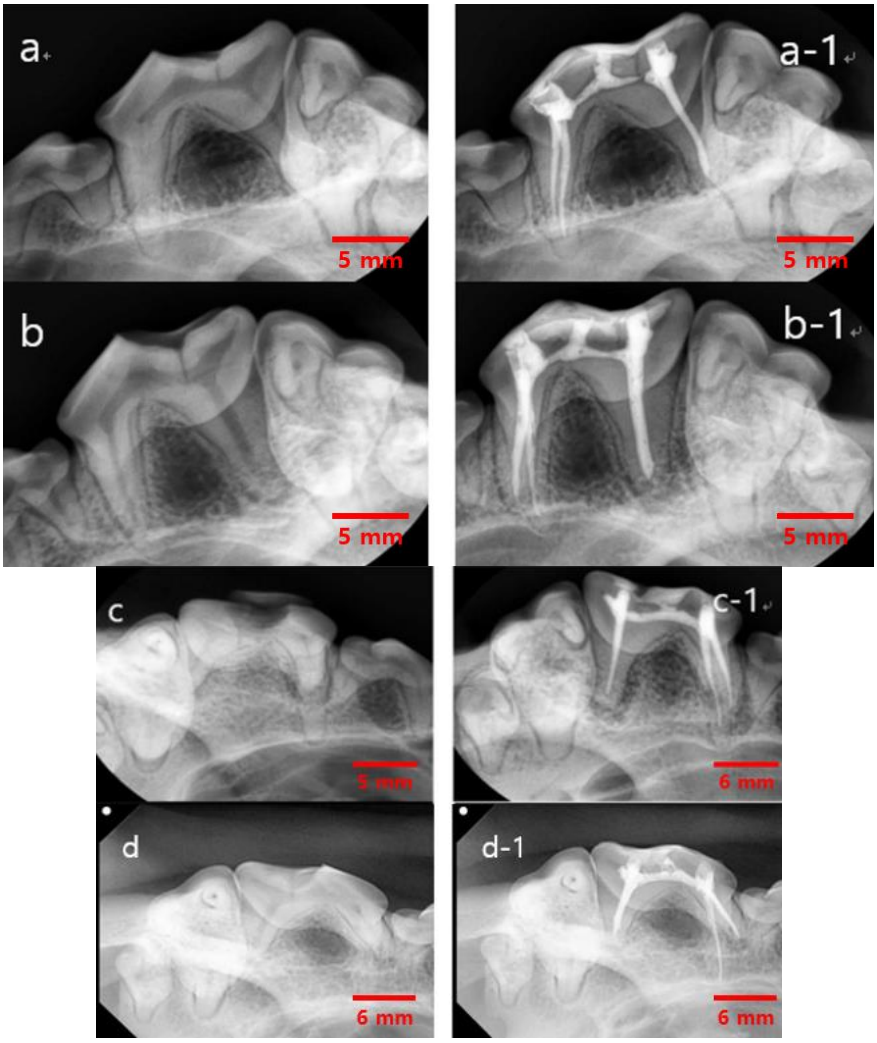

Figure 3. Dental radiographs pre- and post-endodontic treatment of the maxillary 4th premolar tooth. (a, b, c, d) Dental radiographs at pre-endodontic treatment. (a-1, b-1, c-1, d-1) Dental radiographs of the maxillary 4th premolar tooth restored with resin and glass-ionomer cement after obturation with gutta-percha cone.

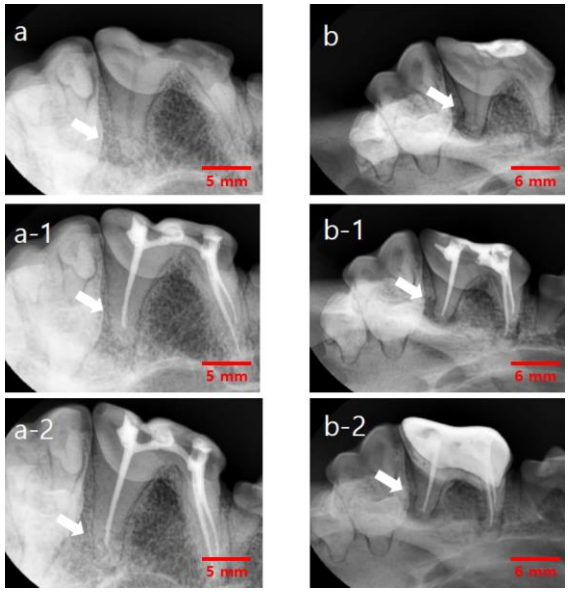

Figure 4. (a, b) Pre-operative dental radiographs. A decreased level of periapical lucency (arrows) was observed. (a-1, b-1) Post-operative dental radiographs after 1 month. (a-2, b-2) Post-operative dental radiographs after 2 months.

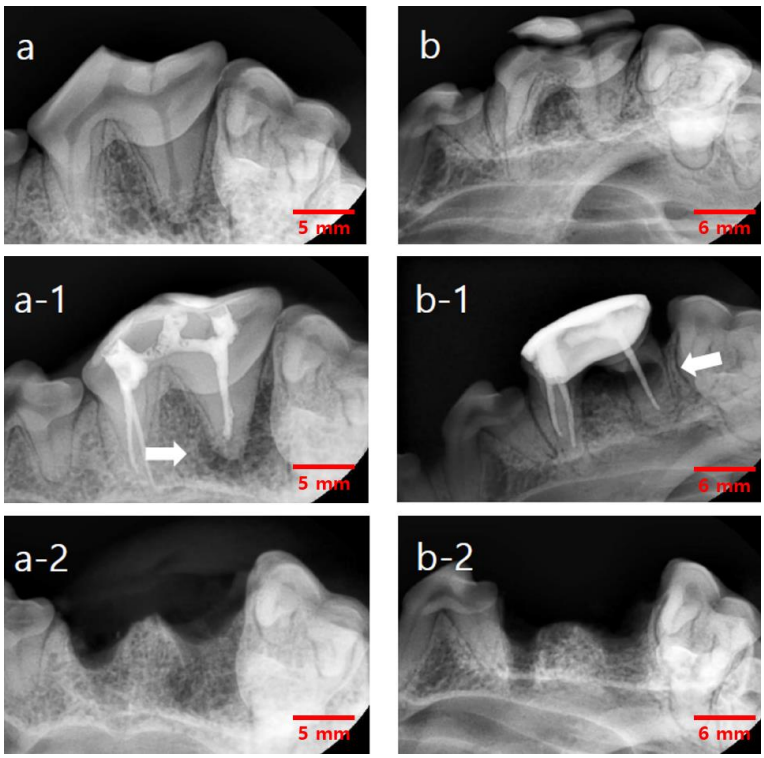

Figure 5. Cases of endodontic treatment failure. (a) Pre-operative dental radiograph of CCF. (b) Pre-operative dental radiograph of CCRF. (a-1)

Tables

Table 1. Prevalence of maxillary 4th premolar tooth fracture by dog breed.

Species	Number of fractures	%
Dachshund	6	15.38
Mongrel	6	15.38
Poodle	6	15.38
Welsh Corgi	6	15.38
Spitz	5	12.82
Boston Terrier	2	5.12
Miniature Pinscher	2	5.12
Cocker Spaniel	1	2.56
Maltese	1	2.56
Pit Bull Terrier	1	2.56
Pomeranian	1	2.56
Schnauzer	1	2.56
Yorkshire Terrier	1	2.56

Table 2. Relationship between maxillary 4th premolar tooth fracture and dog age.

Age	Number of fractures	%
0-3	7	17.95
4-6	11	28.21
7-10	16	41.03
11-15	5	12.82

Table 3. Prevalence of maxillary 4th premolar tooth fractures in relation to dog body weight.

Body weight	Number of fractures	%
0-4.5	2	5.12
4.6-10.0	27	69.23
10.1-15.0	9	23.09
15.1-20.0	0	
>20	1	2.56

Table 4. Prevalence of maxillary 4th premolar tooth fracture according to dog sex.

Sex	Number of fractures	%
Male	2	5.12
Castrated male	19	48.71

Female	3	7.69
Spayed female	15	38.46

Table 5. Prevalence of maxillary 4th premolar tooth fracture according to dog size.

Size of dog	Number of fractures	%
Large	1	2.56
Medium	19	48.71
Small	19	48.71

Table 6. Contributing factors to maxillary 4th premolar tooth fracture.

Cause	Number of fractures	%
Toy biting	3	7.69
Feeding	34	87.17
Unknown	2	5.12

Table 7. Prevalence of maxillary 4th premolar tooth fracture according to tooth location.

Tooth number	Number of fractures	%
108	19	48.71
208	20	51.28

Table 8. Prevalence of maxillary 4th premolar tooth fractures by fracture type.

Fracture type	Number of fractures	%
CCF[1]	11	28.20
CCRF[2]	28	71.79

[1] CCF: complicated crown fracture, [2] CCRF: complicated crown-root fracture.

Table 9. Prevalence of preoperative periapical lucency.

Periapical lucency	Number of teeth	%
CCF[1]	4	10.26
CCRF[2]	7	17.95

[1] CCF: complicated crown fracture, [2] CCRF: complicated crown-root fracture.

Table 10. Prevalence of preoperative root resorption.

Root resorption	Number of teeth	%
CCF[1]	1	2.56
CCRF[2]	1	2.56

[1] CCF: complicated crown fracture, [2] CCRF: complicated crown-root fracture.

Table 11. Reasons for tooth extraction after endodontic treatment.

Reason	Number of teeth	%
Periapical lesion	1	2.56
Root resorption	1	2.56
Facial swelling	1	2.56
Masticatory movement	1	2.56

[1] CCF: complicated crown fracture, [2] CCRF: complicated crown-root fracture.