A DISSERTATION

FOR THE DEGREE OF MASTER

Development of Dental Hygiene Chew for Dogs Considering Their Anatomical Features of Dentition

개의 품종 별 치아 구조를 반영한 반려견용 구강 건강껌(dental hygiene chew)의 개발

by

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ABSTRACT

The purpose of this study was to develop effective dental hygiene chews for dogs considering the anatomical features of each small breed's dentition and the pattern of chewing motion.

Small breed dogs were volunteered for dental impressions with yellow stone and alginate under intravenous anesthesia with tiletamine-zolazepam, tramadol and, medetomidine. Twenty-five dogs (9 Maltese, 8 Miniature poodles, and 8 Shih-Tzus) were recruited. Twenty-two criteria were checked to compare dental impressions. For the chewing motion study, two beagle dogs' chewing motion was reviewed with an image analyzing program.

Statistically, Shih-Tzus had smaller teeth and shorter interdental spaces than those of Maltese and Miniature poodles ($P < 0.017$). Grossly, the horizontal gap between upper and lower teeth was wider in Shih-Tzus. Certain chewing patterns such as an oval shape were recognized in the chewing motion study. Dental hygiene chews were designed with a wider gaping space (4.5 mm) for Maltese and Miniature poodles, and shorter (3.5 mm) for Shih-Tzus, respectively. The width, height of teeth and interdental spaces of each teeth were considered primarily.

Dental hygiene chews customized for each breed considering the different anatomical features of their teeth might be effective for oral care.

Keywords: dental hygiene chew, dental care, dentition, dog, periodontal disease

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CONTENTS

Introduction

Periodontal disease is the most common oral disease in small animal medicine (Capik *et al.*, 2011). By 2 years of age, it is well known that 80% of dogs and 70% of cats have various forms of periodontal disease. Small and toy breeds are particularly predisposed to periodontal disease (Brook, 2013; Harvey *et al.*, 1994). There are several causes: decreased interdental space (crowding), decreased oral chewing, rotated teeth, prolonged life span, and larger proportion of teeth height to mandible compared to large breeds (Brook, 2013; Gioso *et al.*, 2001).

Although owners use many strategies to manage the dental health of their companion animals, such as brushing teeth, dental hygiene chew, and chewing toys, there are no absolute ways to improve their dental state (Capik *et al.*, 2011; Holmstrom *et al.*, 2005). However, oral health can be improved with a dental hygiene chew that has an increased chewing time as well as an increased number of chews (Beynen, 2011; Bjone *et al.*, 2005; Gorrel *et al.*, 1998; Gorrel and Bierer, 1999; Hennet, 2001; Hennet *et al.*, 2006; Jensen *et al.*, 1995).

Therefore, the development of more effective hygiene chews is needed. There are many kinds of dental hygiene chews. However, none of them have been developed based on scientific research. Although a few have been developed reflecting the difference of size, the only difference between each chew is the overall size. According to the previous study, the shape and size of teeth might affect the accumulation of plaque and calculus. Using the same equation for a mean mouth scoring system in all breeds was also not reasonable, as each breed had different teeth (Colin, 2002). This logic could be adjustable to small and toy breeds.

Therefore, it was hypothesized that the anatomical differences such as teeth size, interdental space, and size of bone around teeth among each small and toy breed, may affect the dental health and the efficacy of various tools for dental care. In other words, different sized and shaped chews for dental care might be required to enhance their efficacy. In addition, it is well known that horses have a specific chewing motion, 3 rotations: pitch, roll, and yaw (Bonin *et al.*, 2006). As horses are herbivores, they have a habit of grinding materials when they eat. As carnivores, dogs have a habit of biting and chewing when they eat. However, there has been no research on dogs' mouth movements while they chew materials, particularly regarding the movement of their teeth. As the motion of chewing might affect periodontal disease, it is worthwhile to study this scientifically using imaging tools.

The purpose of this study was to develop effective dental chews for dogs' oral health management, compared to existing dental chews. The chief consideration of development was the anatomical features of each small breed's dentition.

Materials and Methods

1. Experimental animals

All dogs were recruited as volunteers and informed consent was obtained from all participants. Breeds were restricted to Shih-Tzus, Maltese, and Miniature poodles, which they were small to toy breeds that accounted for a large portion of companion dogs. To exclude the variance related to aging, age was also restricted to middle aged (Maltese: 4.22 ± 1.47 years old, Miniature poodles: 3.12 ± 1.84 years old, Shih-Tzus: 6.75 ± 1.85 years old). Twenty-five dogs (9 Maltese, 8 Miniature poodles, and 8 Shih-Tzus) with no teeth loss were included in this study. This study was approved by the Institutional Animal Care and Use Committee of Seoul National University (SNU-140328-6).

2. Anesthesia

Prior to anesthesia, blood analysis and radiological examination were performed to evaluate the dogs' physical health. There were no remarkable findings in all dogs. Tiletamine-zolazepam 1.5 mg/kg (Zoletil®, Virbac Laboratories, Carros, France), tramadol 0.96 mg/kg (Huons TRAMADOL HCl INJ, Huons Co., Ltd, Chung-buk, Republic of Korea), and medetomidine HCl 0.006 mg/kg (Domitor®, Orion Pharma, Espoo, Finland) combination was administered intravenously for measurements of oral cavity and dentition with dental impression.

3. Measurements

Dental impressions with yellow stone (Neo Plum Stone®, Mutsumi Chemical Industries Co., Ltd, Yokkaich, Japan) and alginate (Selection J Alginate Impression®, Youdent Co., Ltd, Chiba, Japan) were made under general anesthesia. Dental impressions made of yellow stone were measured with a digital caliper (NA500-200WPS, Blue Bird Inc., Seoul, Republic of Korea). The length, width, and height of premolar 3 (PM3), PM4, and molar 1 (M1) of the maxilla and PM4 and M1 of the mandible were measured. The interdental space between the apex of each tooth was also measured: PM3-PM4 and PM4-M1 in the maxilla PM4-M1 and M1-M2 in the mandible. The length between the distal ends of maxilla PM4 (a) and the length from the mid-point of A to the right behind the incisors (b) were measured to compare a/b ratio of each breed. Lastly, the widest distance from the maxilla to the mandible caudal to PM2 of maxilla (WDMM), was also recorded (Fig. 1).

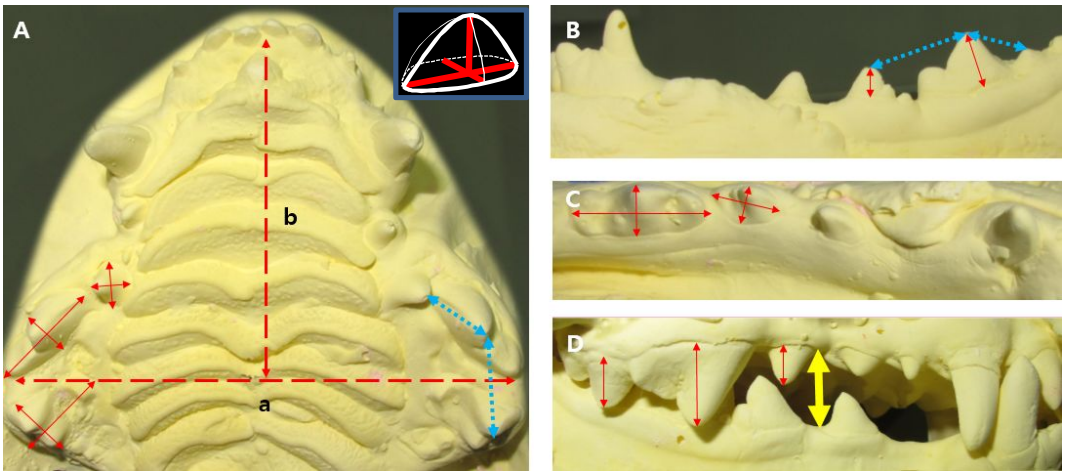

Fig. 1. The criteria of measurement with a digital caliper. (A) maxilla: the length between the distal ends of maxilla PM4 (a) and the length from the mid-point of A to the right behind the incisors (b) (red dash line), length and width of each tooth (red solid line on PM3, PM4, and M1), interdental space (blue dot line on PM3-PM4, PM4-M1), (B) mandible: height of each tooth (red solid line on PM4 and M1), interdental space (blue dot line on PM4-M1, M1-M2), (C) mandible: length and width of each tooth (red solid line on PM4 and M1), (D) maxilla: height of each tooth (red solid line on PM3, PM4, and M1), WDMM: the widest distance from the maxilla to the mandible, caudal to PM2 of maxilla (yellow bold line).

4. Statistical analyses

Statistical analysis was performed using SPSS Statistics 21.0 software (IBM SPSS Statistics®, IBM Co., Ltd, Armonk, New York, USA). To compare the difference among three breeds, Kruskal-Wallis test and Mann-Whitney U test were used. A *P* value of less than 0.017 was considered statistically significant, according to Bonferroni method.

5. Chewing motion analyses

To analyze the chewing motion, a digital camera was used to record chewing motion of beagle dogs, the general experimental dog. Before recording the images, operation staples were used to expose teeth better in two beagle dogs by allowing the eversion of skin covering the teeth under short time anesthesia. After recovery from anesthesia, recording was performed in 2 different directions: lateral and frontal views. Recorded images were reviewed with an image analyzing program (Adobe After Effect®, Adobe Systems Inc., San Jose, California, USA). A certain appropriate point that could be recognized with an image tool was fixed as a reference point. With a fixed reference, certain points that represented the chewing motion were tracked as linear curves.

6. Modeling of dental hygiene chews

Dental hygiene chew considering the anatomical features of teeth was designed for each breed. Three dimensional modeling tool (3DS MAX® Autodesk Inc., San Rafael, California, USA) was used for image modeling.

Results

1. Anatomical differences of teeth among three breeds

Twenty-two criteria for featuring the anatomical differences of teeth were measured with a digital caliper. Comparative analysis between the Maltese and Miniature poodles showed that there were only 1 statistically different value: the interdental space between PM3 and PM4 in the ($P < 0.017$; Table 1, Fig. 2). However, Shih-Tzus had many values that were statistically different from Miniature poodles and Maltese. Between Shih-Tzus and poodles, all values except for the width of PM3 and M1 in the maxilla PM4 in the mandible, the interdental space PM4-M1 in the maxilla, PM4-M1 in the mandible, and the WDMM were statistically different ($P < 0.017$; Table 1, Fig. 2). Similarly, only the length of PM4 and M1 in the maxilla, the width of M1 in the maxilla and M1 in the mandible, the interdental space PM4-M1 in the maxilla and PM4-M1 in the mandible, and WDMM were not statistically different for Shih-Tzus and Maltese ($P \geq 0.017$). Ratio of a/b was also significantly different. In Maltese and Miniature poodles, they were 0.94 and 0.84, respectively. However, it was 1.47 in Shih-Tzus ($P < 0.017$; Table 1, Fig. 2).

Table 1. Measurement of each tooth impression of Maltese, Miniature poodles, and Shih-Tzus using a digital caliper (mm)

Criteria \ Breed		Maltese	Miniature Poodles	Shih-Tzus
Maxilla PM3	length	6.06 ± 0.41 [a]	5.36 ± 0.60 [a]	7.09 ± 0.22 [b]
	width	2.87 ± 0.33 [a]	3.16 ± 0.27 [a, b]	3.21 ± 0.17 [b]
	height	3.20 ± 0.38 [a]	3.22 ± 0.46 [a]	4.02 ± 0.13 [b]
Maxilla PM4	length	11.99 ± 0.55 [a. b]	12.91 ± 0.69 [a]	11.37 ± 0.72 [b]
	width	5.27 ± 0.36 [a]	5.60 ± 0.17 [a]	4.39 ± 0.18 [b]
	height	6.41 ± 0.45 [a]	6.69 ± 0.15 [a]	4.77 ± 0.60 [b]
Maxilla M1	length	8.27 ± 0.45 [a,b]	8.89 ± 0.27 [a]	7.82 ± 0.42 [b]
	width	9.04 ± 0.68 [a]	9.59 ± 0.48 [a]	8.53 ± 0.68 [a]
	height	4.16 ± 0.37 [a]	4.26 ± 0.33 [a]	3.60 ± 0.42 [b]
Mandible PM4	length	6.53 ± 0.23 [a]	6.66 ± 0.45 [a]	5.79 ± 0.42 [b]
	width	3.74 ± 0.22 [a]	3.86 ± 0.23 [a, b]	3.40 ± 0.30 [b]
	height	4.52 ± 0.33 [a]	4.80 ± 0.39 [a]	3.61 ± 0.40 [b]
Mandible M1	length	13.77 ± 0.67 [a]	14.33 ± 0.63 [a]	12.18 ± 1.03 [b]
	width	5.46 ± 0.38 [a, b]	5.86 ± 0.23 [a]	5.14 ± 0.42 [b]
	height	7.22 ± 0.58 [a]	7.64 ± 0.48 [a]	5.91 ± 0.64 [b]
a		39.11 ± 1.91 [a]	38.89 ± 1.99 [a]	47.63 ± 2.27 [b]
b		41.53 ± 2.66 [a]	46.25 ± 4.20 [a]	32.50 ± 2.62 [b]

[abc] Different superscripts within a line mean significantly different ($P < 0.017$).

a = The length between the distal ends of maxilla PM4; b = The length from the mid-point of A to the right behind the incisors.

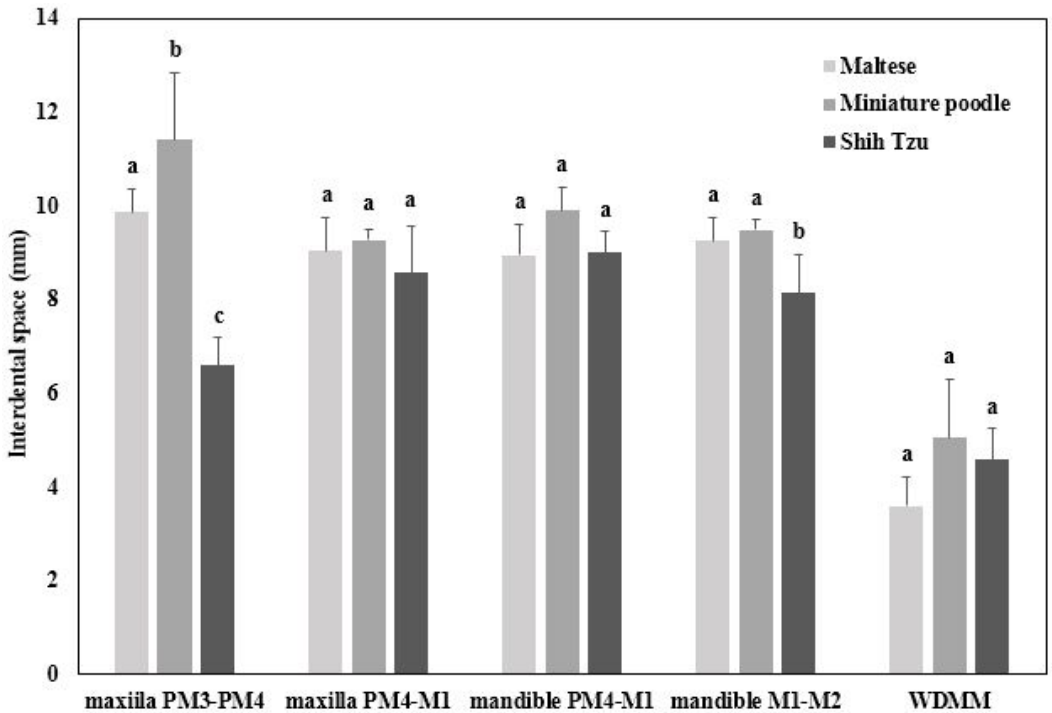

Fig. 2. Interdental space between each tooth of each breed based on the measurement using a digital caliper (mm).

[abc] Different superscripts within an each bar group mean significantly different ($P < 0.017$); PM = premolar, M = molar, WDMM = Widest distance from the maxilla to the mandible, caudal to PM2 of maxilla.

2. Gross examination of dental impressions among three breeds

In a gross examination of dental impressions, distinct differences among each breed could be easily distinguished (Fig. 3). The horizontal gap between the teeth of the maxilla and the mandible was much wider in Shih-Tzus than those of Miniature poodles and Maltese.

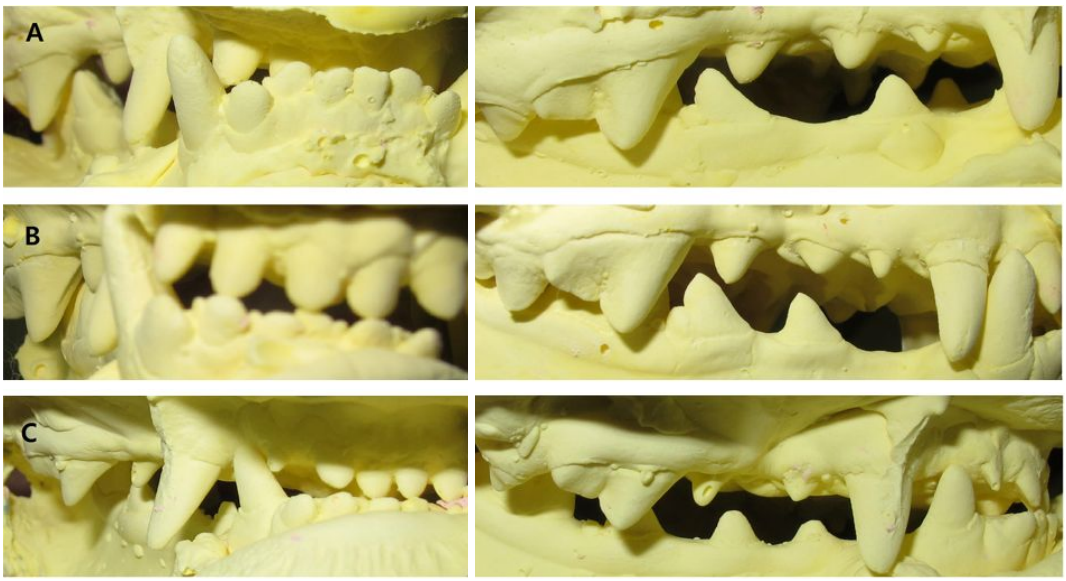

Fig. 3. Representative images of frontal and lateral views from a dental impression in dogs: (A) Maltese, (B) Miniature poodle, (C) Shih-Tzu. The horizontal gap between the teeth of the maxilla and the teeth of the mandible was much wider in Shih-Tzus than in Miniature poodles and Maltese.

3. Chewing motion analysis of dogs

With analyzing the dogs' chewing motion, it was recognized that each tooth had a specific motion pattern for chewing in beagle dogs. Canine and PM4 teeth in the maxilla and the mandible were tracked for pattern analysis. Both sides showed an oval shape tracking pattern. However, the range of backward and forward movement was shorter in the mandible (Fig. 4).

4. Modeling of dental hygiene chews

Two different chews were designed as Maltese & Miniature poodle model and Shih-Tzu model. Their overall shape was similar, but the detailed size was different. The cut end was the shape of a toothed wheel. The cleft width was set as 3.5 mm in the Shih-Tzu model and 4.5 mm in the Maltese & Miniature poodle model. The depth of each cleft on the dental hygiene chew was set reflecting the height of the teeth. It was 6 mm in the Shih-Tzu model, and 8 mm in the Maltese and Miniature poodle models. The diameter was set as 16 mm in the Shih-Tzu model and, 20 mm in the Maltese and Miniature poodle models, reflecting WDMM, approximately 4 mm, and the height of the teeth. The length was set as 60 mm. The surface of the chew was covered with irregular shapes such as wavy shapes (Fig. 5)

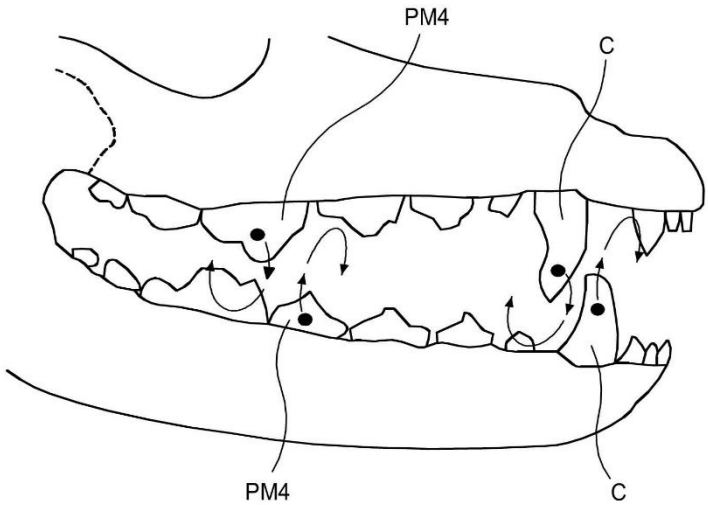

Fig. 4. Motion of teeth diagram tracked using an image analyzing program. The direction of movement of the teeth on the maxilla and the teeth on the mandible differed.

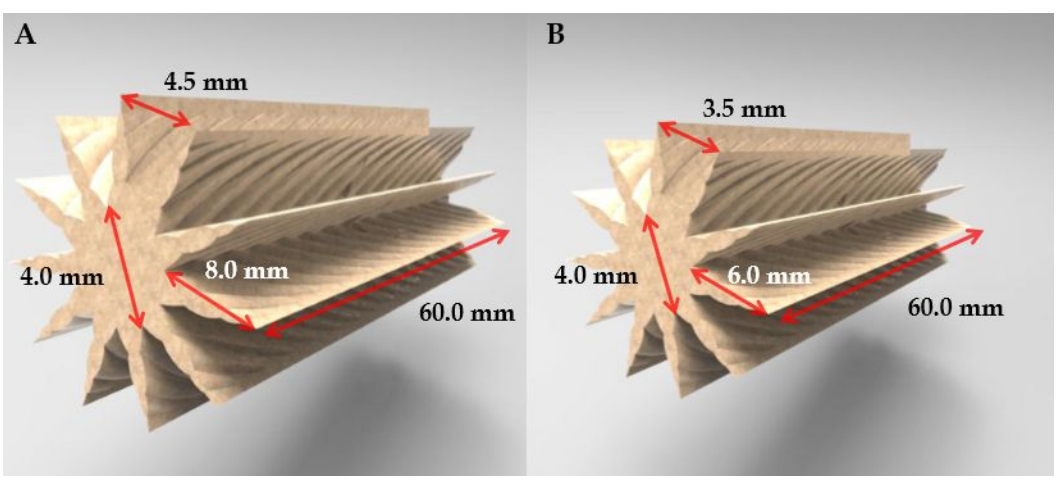

Fig. 5. Modeling of the dental hygiene chews according to the results of this study: (A)

Maltese & Miniature poodle model, (B) Shih-Tzu model.

Discussion

The importance of dogs' health is increasingly being emphasized, as their lifespans are being prolonged with advancements in veterinary medicine (Colmery, 2005). As dogs are now living longer, it is natural for owners to take care of their dogs' health. In terms of health care, oral care for dogs is quite different from that of human beings. It is related to the difficulty of management. According to a previous study, there are no fully effective methods for oral care in dogs (Capik *et al.*, 2011). However, many reports have been published demonstrating the positive effects of dental hygiene chew for oral care (Bjone *et al.*, 2005; Bonin *et al.*, 2006; Colmery, 2005; Gorrel *et al.*, 1998; Gorrel *et al.*, 1999; Hennet, 2001).

To determine the criteria of anatomical features of teeth, the results of previous study were considered (Colin, 2002; Hennet *et al.*, 2006). Not only in the previous study but also clinically, were the following teeth shown to be critical components in evaluating the state of overall teeth: premolar 3 (PM3), PM4 and molar 1 (M1) in the maxilla, and PM4 and M1 in the mandible. Therefore, these were focused in this study.

The dental hygiene chew for dogs was designed considering the anatomical features of dentition. Our findings indicated that there was no substantial statistical difference in the teeth of Miniature poodles and Maltese. However, Shih-Tzus were distinguishable from the former two breeds. Shih-Tzus generally had smaller teeth than those of Miniature poodles and Maltese. Interdental spaces also showed the same tendency. Generally, it is believed that friction with the surface of teeth is an important mechanism for removing

calculus and plaque in dental hygiene chew (Beynen, 2011). Therefore, it could be presumed that the cleft or gaping spaces designed in dental hygiene chew for Shih-Tzus should be smaller to ensure more efficient removal of calculus and plaque by rubbing. Additionally, Shih-Tzus were the only brachycephalic breed with mandibular prognathism used in this study, as presented by higher a/b ratio of Shih-Tzu in compared to lower a/b ratio of Maltese and Miniature poodle. This anatomical difference might also have contributed to these results.

Although a specific pattern was recognized when each tooth was tracked while dogs chewed materials, this pattern was estimated as insignificantly affecting the elimination of dental calculus by dental hygiene chew. As this pattern was not consistent, it was not a critical condition for designing the dental hygiene chew.

The overall size of chews was determined based on measurements with a digital caliper. For overall size, 3 values were considered. The first one was the longest distance between maxilla and mandible, which ranged from approximately 3.5 mm to 4.5 mm. There are some dental hygiene chews on the market with a thickness of less than 3.5 mm. They might be too thin to remove calculus and plaque effectively, as thin dental hygiene chews cannot rub the entire surface of the teeth during chewing. To rub the entire surface of the teeth, chews' thickness or diameter should be greater than the distance from the free gingival margin of the maxilla teeth to the free gingival margin of the mandible teeth. The second and third values to consider were the length between the distal ends of maxilla PM4 (a) and the length from the mid-point of A to the right behind the incisors (b). If the chew was shorter than a and b, it could be eaten and swallowed easily at a time. Subsequently, the chewing time might naturally decrease. In other words, this may not be sufficient chewing time to remove calculus and plaque. Therefore, dental hygiene chews

should be longer than 45 mm, theoretically.

Two different chews were designed considering the findings of this study and the simplification of manufacturing. The fundamental function of dental hygiene chew was the abrasion of the tooth surface to the extent possible. Therefore, the number of abrasive surfaces should increase by increasing the number of cleft spaces or gaping spaces. The cleft width might be adjustable if slightly narrower than the tooth width. Therefore, it was set as 3.5 mm in the Shih-Tzu model, shorter than 4.5 mm in the Maltese & Miniature poodle model. The depth of each cleft on the dental hygiene chew reflected the height of the teeth shorter in the Shih-Tzu model (6 mm) than that of Maltese & Miniature poodle model (8 mm). The diameter reflected WDMM, approximately 4 mm, and the height of the teeth. The length was 60 mm considering the value a and b. Irregular shapes such as wavy shapes covering the surface of the chew was for reinforcing the function of scraping out calculus and plaque (Fig. 5).

There were three limitations in this study. The first was the small sample size. With an increased sample size, more accurate statistical significance might be achieved. The second was the variance in each breed. Same breed dogs can vary in size. To minimize this limitation, dogs with a similar body weight were chosen as much as possible. Furthermore, the efficacy of these dental hygiene chew models should be investigated clinically for each breed.

Conclusions

The present result suggests that Shih-Tzus have smaller teeth and shorter interdental spaces than those of Maltese and Miniature poodles. Dental hygiene chews structurally customized for each small breed dog were designed and developed, considering the anatomical features of each small breed's teeth. These breed-customized dental hygiene chews might be beneficial for owners in oral hygiene care of their dogs by removing calculus and plaque, more effectively than existing dental hygiene chews.

References

Beynen AC, 2011. Incorporation of cellulose into a chew treat for dogs increases elasticity and chewing time. American Journal of Animal and Veterinary Sciences 6, 117-120.

Bjone S, Brown W, Billingham J, Harris A, McGenity P, 2005. Influence of chewing on dental health in dogs. In: Proceedings of the Australian Veterinary Association Annual Conference, Gold Coast, Australia. Annual Australian Veterinary Association Conference, Gold Coast, QLD, Australia.

Bonin SJ, Clayton HM, Lanovaz JL, Johnson TJ, 2006. Kinematics of the equine temporomandibular joint. American Journal of Veterinary Research 67, 423-428.

Brook AN, 2013. Periodontitis. In: Veterinary Periodontology. Iowa, Blackwell Publishing, 51.

Capik I, 2011. Periodontal health vs. various preventive means in toy dog breeds. Journal Acta Veterinaria Brno 79, 637-645.

Colin EH, 2002. Shape and size of teeth of dogs and cats-Relevance to studies of plaque and calculus accumulation. Journal of Veterinary Dentistry 19, 186-195.

Colmery B III, 2005. The gold standard of veterinary oral health care. Veterinary Clinics of North America: Small Animal Practice 35, 781–787.

Gioso MA, Shofer F, Barros PS, Harvey CE, 2001. Mandible and mandibular first molar tooth measurements in dogs: Relationship of radiographic height to body weight. Journal of Veterinary Dentistry 18, 65-68.

Gorrel C, Bierer TL, 1999. Long-term effects of a dental hygiene chew on the periodontal

health of dogs. Journal of Veterinary Dentistry 16, 109-113.

Gorrel C, Inskeep G, Inskeep T, 1998. Benefits of a “dental hygiene chew” in maintaining periodontal health in cats. Journal of Veterinary Dentistry 15, 135-138.

Harvey CE, Shofer FS, Laster L, 1994. Association of age and body weight with periodontal disease in North American dogs. Journal of Veterinary Dentistry 11, 94-105.

Hennet P, 2001. Effectiveness of an enzymatic rawhide dental chew to reduce plaque in beagle dogs. Journal of Veterinary Dentistry 18, 61-64.

Hennet P, Servet E, Venet C, 2006. Effectiveness of an oral hygiene chew to reduce dental deposits in small breed dogs. Journal of Veterinary Dentistry 23, 6-12.

Holmstrom SE, Bellows J, Colmery B, Conway ML, Knutson K, Vitoux J, 2005. AAHA dental care guidelines for dogs and cats. Journal of American Animal Hospital Association 4, 277-283.

Jensen L, Logan E, Finney O, Lowry S, Smith M, Hefferren J, Simone A, Richardson D, 1995. Reduction in accumulation of plaque, stain and calculus in dogs by dietary means. Journal of Veterinary Dentistry 12, 161-163.

국 문 초 록

개의 품종 별 치아 구조를 반영한 반려견용 구강 건강껌(dental hygiene chew)의 개발

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본 연구에서는 소형견의 품종별 치아의 특징과 저작운동의 형태를 반영하여 효과적인 반려견용 구강 건강껌 (dental hygiene chew)을 개발하고자 하였다.

소형견의 품종별 치과인상 (dental impression)을 제작하기 위해, 모든 개체는 자발적 지원을 받았으며, 총 25마리 개 (말티즈 9마리, 미니어쳐 푸들 8 마리, 시츄 8마리)가 본 연구에 포함되었다. 치과인상의 제작은 전신 마취하에 진행되었다. 저작운동의 형태를 확인하기 위해서는 두 마리의 비글견이

사용되었다. 총 22가지의 측정 기준에 대해 각 품종의 치아를 비교하였다.

시츄는 말티즈나 미니어쳐 푸들에 비해 더 작은 치아와 더 좁은 치아 사이의 간격을 갖고 있는 것으로 확인되었다. 이는 통계적으로 매우 유의적이었다 ($P < 0.017$). 또한 상악과 하악의 치아 간의 수평 공간의 경우에는 시츄가 다른 두 품종에 비해 상대적으로 더 넓은 것으로 확인되었다. 저작운동 형태 분석에서는 타원 형태의 선형 곡선을 확인하였다. 반려견용 구강 건강껌은 크게 시츄를 위한 모델과, 말티즈, 미니어쳐 푸들을 위한 모델 두 가지로 개발되었다. 이 때 치아의 폭과 높이, 치아 사이의 공간이 중요하게 고려 되었으며, 구강 건강껌의 돌기 사이 간격은 시츄 모델의 경우 4.5 mm, 말티즈, 미니어쳐 푸들 모델의 경우 3.5 mm 로 각각 설정되었다.

추후 실질적인 상품화를 통해, 본 연구를 바탕으로한 품종 맞춤형 구강 건강껌이 개의 구강 건강에 효과적으로 사용될 것으로 생각된다.

주요어: 구강 건강껌, 구강 관리, 치아, 개, 치주질환

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