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Development of Novel Dental Chews for Dogs Considering Breed Variations in Anatomical Features of Dentition

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Abstract : The purpose of this study was to find anatomical variation of each small breed dog's dentition for designing more effective dental chews. Small breed dogs were volunteered for dental impressions with dental stone and alginate under tiletamine-zolazepam, tramadol, and medetomidine intravenous anesthesia. Twenty-two criteria were measured to compare dental impressions. Twenty-five dogs (9 Malteses, 8 Miniature Poodles, and 8 Shih-Tzus) were recruited. Statistically, Shih-Tzus had smaller teeth and shorter interdental spaces than those of Maltese and Miniature Poodles. Grossly, the distance between upper teeth and lower teeth was wider in Shih-Tzus. Shih-Tzu had different dental anatomy in comparative to Miniature Poodle and Maltese. It was recommended to design the dental chew considering these differences.

Key words **:** canine dentition, dental chew, dental hygiene, dog, periodontal disease.

Introduction

Periodontal disease is the most common oral disorders in small animal clinics (6). It is well known that 80% of dogs and 70% of cats have various forms of periodontal diseases after two years old (4). Especially, small and toy breeds are predisposed to periodontal diseases (4,13). There are several causes: crowded interdental space, rotated teeth, prolonged life span, and increased ratio of tooth height to mandible height compared to large breeds (4,9).

Owners have tried many methods such as brushing teeth, dental chews, and chewing toys for managing the dental health of their companion animals. However, there are no the best ways to improve companion animals' dental state (6,16). However, dental chews offer the potential promise of being easy to use and effective. Dental chews are defined as dental care items that both abrasively clean the tooth surface and contain additives for oral health (5). Additionally, oral health can be improved with a dental chew that has an increased chewing time as well as an increased number of chews (1,2,10,11,14,15,17). Dental chews that increased the number of chews or the duration of chewing would theoretically have more increased contact time with tooth surfaces for abrasive removal of calculus and plaque. There have been many kinds of dental chews and many researches about their efficacy (1,11,14,15,17). However, none have been developed based on scientific research. Although a few have been developed based on overall size of dog, the only difference between each chew is the overall size. According to one study, the shape and size of teeth may affect the accumulation of plaque and calculus (12). Using the same equation for a mean mouth scoring system that shows the state of teeth numerically is not reasonable, as there are breed-related differences in dental anatomy such as size of teeth, interdental spacing, and width of jaw (12). It was hypothesized that the anatomical differences such as rotated teeth, teeth size, and the extent of crowding between 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 enhance their efficacy.

The purpose of this study was to describe the anatomical features of the dentition of different small-breed dogs and to make more effective dental chews for each breed individually.

Materials and Methods

All dogs were recruited as volunteers. Twenty-five dogs including 9 Malteses, 8 Miniature Poodles, and 8 Shih-Tzus participated in this study. Informed consent was obtained from all participants. Breeds recruited were restricted to Shih-Tzus, Malteses, and Miniature Poodles. They were small to toy breeds that accounted for a large portion of companion dogs in Korea. The study population was restricted to middle-aged dogs (4-10 years old). All of them had normal full mouth dentition. This study was approved by the Institutional Animal Care and Use Committee of Seoul National University (SNU -140328-6).

Prior to anesthesia, blood analysis and thoracic radiographs were obtained to check the dogs' physical health. There were no significant findings in all dogs. Intravenous tiletamine-zolazepam (50 mg/mL; Zoletil 50®, Virbac Co., Ltd, Carros, France), tramadol (40 mg/mL; Huons TRAMADOL HCl INJ., Huons Co., Ltd, Chung-buk, Republic of Korea), and medetomidine (0.2 mg/mL; Domitor®, Orion Corporation,

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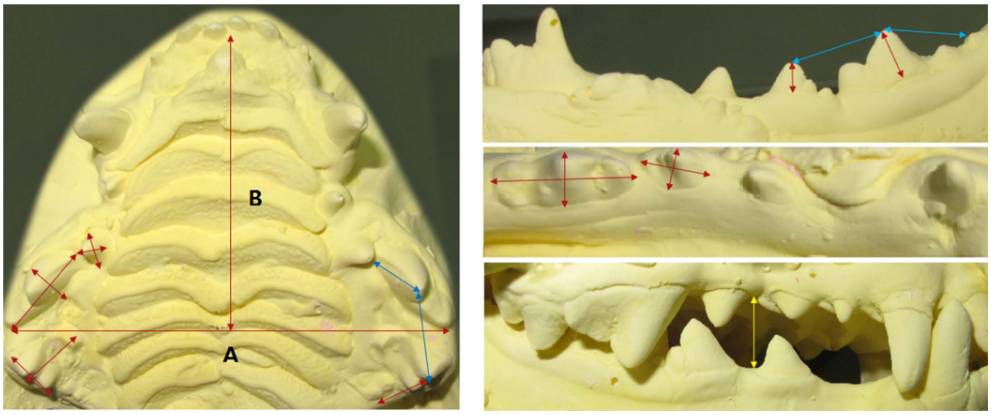

Fig 1. The criteria of measurement with a digital caliper. (Left) Maxilla. A and B, length, width, and height of each tooth of PM3, PM4, and M1, interdental space between the apex of each tooth of PM3 and PM4, PM4 and M1; (Right top and middle) mandible. Length, width, and height of each tooth of PM4 and M1, interdental space between the apex of each tooth of PM4 and M1, M1 and M2; (Right bottom) WDMM. The widest distance from the maxilla to the mandible.

Espoo, Finland) combination anesthesia was used for dental impressions with dental stone (Neo Plum Stone®; Mutsumi Chemical Industries Co., Ltd, Yokkaichi, Japan) and alginate (Selection J Alginate Impression®; Youdent Co., Ltd, Chiba, Japan). Dental impressions made of dental stone were measured with a digital caliper (NA500-200WPS; Blue Bird Inc., Seoul, Republic of Korea). PM3, PM4, and M1 of the maxilla and PM4 and M1 of the mandible were measured according to the following criteria. The length, width, and height of each tooth were measured. The length of teeth was measured from the proximal point of teeth to the distal point of teeth. Width was measured from the most labial point of teeth to the most palatal point of teeth. Height was measured from the top of the crown to the gingival margin. The interdental space between the apexes of each tooth was also measured: PM3-PM4, PM4-M1, and M1-M2 in the maxilla, PM4-M1 and M1-M2 in the mandible. The length between the distal aspect of each maxilla PM4 (Fig 1A) and the length from the mid-point of A to the distal aspect of the incisors (Fig 1B) were measured to compare A/B ratio of each breed. The widest distance from the maxilla to the mandible (WDMM) was also measured. The Mann-Whitney U test was used for statistical analyses (IBM SPSS Statistics®; IBM Co., Ltd, Armonk, New York, USA). A P value of less than 0.05 was considered statistically significant.

Based on the difference between breeds, more effective dental chews were designed using 3D computer graphics software (Autodesk 3ds Max; Autodesk Inc., Montreal, Quebec, Canada).

Table 1. Measurement of each tooth impression of Malteses, 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[b]	7.09 ± 0.22[c]
	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]	12.91 ± 0.69[b]	11.37 ± 0.72[a]
	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]	8.89 ± 0.27[b]	7.82 ± 0.42[a]
	width	9.04 ± 0.68[a]	9.59 ± 0.48[a,b]	8.53 ± 0.68[b]
	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]	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]	5.86 ± 0.23[a,b]	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[b]	32.50 ± 2.62[c]

[a,b,c], Different superscripts within a line mean significantly different ($P < 0.05$).
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.

Results

Twenty-five dogs (9 Malteses, 8 Miniature Poodles, and 8 Shih-Tzus) with no previous dental extractions were included in this study. Twenty-two criteria for classifying the anatomical differences of teeth were measured with a digital caliper. Comparative analysis between the Malteses and Miniature Poodles showed that there were only 7 statistically different values: the length of maxilla PM3, PM4, and M1, the interdental space between PM3 and PM4 in the maxilla and PM4 and M1 in the mandible, WDMM and B ($P < 0.05$). However, Shih-Tzus had 19 values different from Miniature Poodles, and 16 values different from Maltese, statistically. Between Shih-Tzus and Miniature Poodles, all values except for the width of PM3 in the maxilla, the interdental space between PM4 and M1 in the maxilla, and the WDMM were statistically different. Similarly, only the length of PM4 and M1 in the maxilla, the width of M1 in the maxilla and M1 in

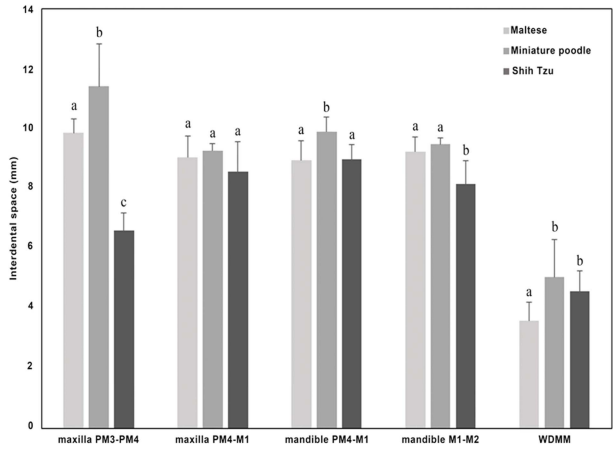

Fig 2. Interdental space (mm) between each tooth of each breed based on the measurement using an electrical caliper (^{a,b,c}, Different superscripts within an each bar group mean significantly different ($P < 0.05$); WDMM, Widest distance from the maxilla to the mandible.

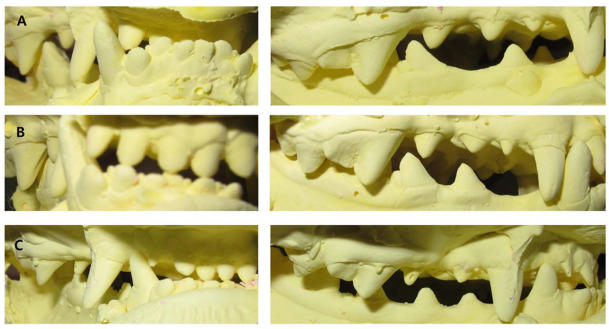

Fig 3. Representative images of oblique and lateral views from a dental impression in dogs. (A) Maltese; (B) Miniature Poodle; (C) Shih-Tzu. The distance between the teeth of the maxilla and the teeth of the mandible was much wider in Shih-Tzu than in Miniature Poodle and Maltese.

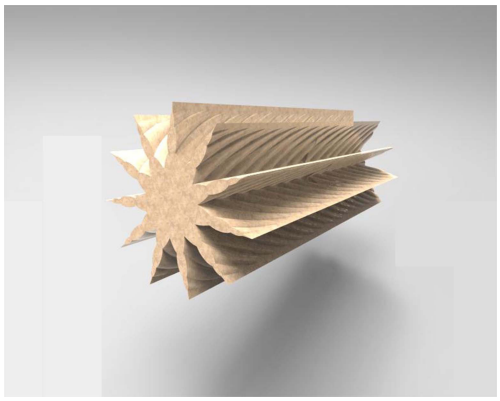

Fig 4. Overall modeling of the dental chew according to the results of this study.

the mandible, the interdental space between PM4 and M1 in the maxilla and PM4 and M1 in the mandible were not statistically different for Shih-Tzus and Maltese ($P < 0.05$, Table 1 and Fig 2).The A/B ratios were also significantly different. In Malteses and Miniature Poodles, they were 0.94 and 0.84, respectively. However, it was 1.47 in Shih-Tzus ($P < 0.05$).

Gross difference in dental impression examination could be easily distinguished among each breed (Fig 3). The distance between the teeth of the maxilla and the mandible was much wider in Shih-Tzus than those of miniature poodles and Maltese.

With 3D computer graphics software, two different models of dental chews based on the difference of each breed's dentition were designed as Fig 4. The cleft width on the dental chews was set as 3.5 mm in the Shih-Tzu model and 4.5 mm in the Maltese and Miniature Poodle model. The depth of each cleft was set as 6 mm in the Shih-Tzu model, and 8 mm in the Maltese and Miniature Poodle models. The length of the dental chew was designed in two types, 60 mm and 120 mm.

Discussion

The importance of dogs' health is increasingly being emphasized, as their lifespan are being prolonged with advancements in veterinary medicine (7). As dogs are now living longer, the period requiring dental management generally increases. 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 (6). However, many reports have been published demonstrating the positive effects of dental chews for oral care (2,7,10,11,14,15).

In this study, anatomical features of the dentition of different small-breed dogs was studied for designing a better dental chew. Our findings indicated that there was no substantial statistical difference in the teeth of Miniature Poodle and Maltese. However, Shih-Tzus were distinguishable from the former two breeds. Shih-Tzus generally had smaller size teeth than those of Miniature Poodles and Malteses. Interdental spaces of Shih-Tzus were also shorter than those of Miniature Poodles and Malteses. Generally, friction with the surface of teeth is an important mechanism for removing calculus and plaque in dental chews (1). Therefore, the cleft designed in dental chews for Shih-Tzus should be smaller to ensure more efficient removal of calculus and plaque by rubbing, considering shorter interdental space.

Additionally, Shih-Tzus were the only brachycephalic breed with mandibular prognathism used in this study. This anatomical difference may also have contributed to these results. Generally, large to giant breeds with long muzzles have large interdental intervals (8). The size of skull also affected to anatomical feature of dentition. The A/B ratio of Malteses and Miniature Poodles was lower than 1. It meant they were much closer to long muzzle breed than Shih-Tzus. Further studies about correlation between skull size and anatomical feature of dentition are therefore needed.

Clinically, it is known that calculus and plaque tend to deposit more around maxilla PM3 and PM4. Generally, it is related to the opening of the salivary gland (3). Crowding which means short interdental space between each tooth, is also one of the reasons for more deposition of calculus and

plaque around maxilla PM3 and PM4. As shown in Fig 2, interdental space between maxilla PM3 and PM4 of Shih-Tzus was much shorter than those of Malteses and Miniature Poodles. It meant that Shih-Tzus might have more calculus and plaque around maxilla PM3 and PM4 in comparative to Malteses and Miniature Poodles. Therefore, it could be recommended clinically that the owner of Shih-Tzus need to pay more attention to their dogs' oral health, especially to maxilla premolar teeth.

Based on the result in this study, a dental chew should be designed considering statistically significant criteria as followed. The first one was the space between the teeth of the maxilla and of the mandible, which ranged from approximately 3.5 mm to 4.5 mm. There are some dental 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 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 distal aspect of the incisors (B). If the chew was shorter than A or B, it could be chewed and swallowed easily at a time. Therefore, the chewing time would subsequently decrease. In other words, this may not be sufficient chewing time to remove calculus and plaque. Therefore, dental chews should be longer than 45 mm, theoretically. The last one was the width of teeth. There are some dental chews on the market with various size of cleft on the surface of dental chews. However, if the cleft on the surface of dental chews was much wider than the width of teeth, it could not rub the surface of teeth effectively, as manufacturers expected. Therefore, the cleft on the surface of dental chews should be shorter than the width of teeth, as lower than 3-4 mm.

Two different chews were designed considering the findings of this study and the simplification of manufacturing. Their overall shape was similar, but the detailed size was different. The fundamental function of dental chews 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 cut end was the shape of a toothed wheel. 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 and 4.5 mm in the Maltese and miniature poodle model. The depth of each cleft on the dental chews 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 20 mm, reflecting the distance from the teeth of the maxilla to the teeth of the mandible, and the height of the teeth. The length was set as 60 mm due to the value A and B. Another chew that was 120 mm in size was also designed for dogs that often hold chew with both front legs. To reinforce the function of scraping out calculus and plaque, the surface of the chew was covered with irregular shapes such as wavy shapes (Fig 4).

There were two 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 chew models should be investigated clinically for each breed.

Conclusion

Teeth of Shih-Tzus was generally smaller than those of Miniature Poodles and Malteses. Interdental spaces of Shih-Tzus were also shorter than those of Miniature Poodles and Malteses. Between Miniature Poodles and Malteses, there was no substantial difference of dental anatomy. Additionally, it would be better to design a dental chew based on the anatomical features of canine dentition.

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