The preliminary research of intercanine distance between humans and dogs by bite mark analysis

Lee Deng Yeong[1], Murnisari Dardjan[2], Sri Susilawati[3]
Fahmi Oscandar[1*], Zainul Ahmad Rajion[4]

[1*]Department of Dentomaxillofacial Radiology-Forensic Odontology, Faculty of Dentistry Universitas Padjadjaran, Indonesia
[2]Department of Oral Biology, Faculty of Dentistry Universitas Padjadjaran, Indonesia
[3]Department of Dental Public Health, Faculty of Dentistry Universitas Padjadjaran, Indonesia
[4]Oral Maxillofacial Surgery & Oral Diagnosis, Kulliyyah of Dentistry International Islamic University Malaysia

ABSTRACT

Introduction: Bite marks between humans and dogs have a similar appearance and it becomes a challenge study for the dentist and forensic odontologists to discern between them. Intercanine distance (ICD) is one of the parameters to identify the biter species in humans and animals. The aim of this study was to analyse the differences of the ICD between humans and dogs. **Methods:** The analytical study design was done by measuring the ICD of bite marks in 65 humans and 22 dogs selected by purposive non-random sampling method with the inclusion criteria for human samples, students of Faculty of Dentistry Universitas Padjadjaran between 18 to 28 years old, canine occlusal relationship class I, presence of both intact canine teeth in each jaw, normal overjet and no diastema at the anterior teeth; and for dog samples, mesaticephalic skull shaped, having four intact canine teeth, and located across animal centres in Bandung. The gender and dental arch shape in humans and dogs were excluded. Human bite registrations were taken using wax pieces, while dog anterior teeth impressions were taken which were then casted with dental stone. The ICD was then measured using a digital vernier caliper with 0.01 mm resolution. The inter- and intra-observer variability calibrations were done before the sample measurements. The Mann-Whitney U statistical analysis was done to determine the significance between ICD of humans and dogs ($p<0.05$). Ethical clearance (No.1225/UN6.KEP/EC/2018) was obtained for both groups prior research study. **Results:** The statistical analytic showed, ($p=0.0002$) between humans and small and large sized dogs; ($p=0.5093$) for medium sized dogs in the maxillary. In the mandibula, showed ($p=0.0002$) between humans and small and large sized dogs; ($p=0.0003$) for medium sized dogs. **Conclusion:** The ICD analysed in this study were concluded to be different between humans and dogs (all sizes) in mandibular, humans and dogs (small and large sized) in maxillary. Conversely, the ICD between humans and medium sized dogs in maxillary were similar.

Keywords: human bite mark; dog bite mark; intercanine distance

p-ISSN: 1979-0201; e-ISSN: 2549-6212; Available from: http://jurnal.unpad.ac.id/pjd/article/view/26584
DOI: 10.24198/pjd.vol33no2.26584
Submission: Mar 07, 2020; Accepted: May 18, 2021; Published online: Jul 31, 2021

**Corresponding author: Fahmi Oscandar, Department of Dentomaxillofacial Radiology, Faculty of Dentistry Universitas Padjadjaran, Indonesia. Jalan Sekeloa Selatan I, Bandung, West Java, 40132, Indonesia. Phone: +62 812-1434-3669; e-mail: fahmi.oscandar@fkg.unpad.ac.id*

INTRODUCTION

Man have interacted with and domesticated animals ever since prehistoric times and this relationship often results in injuries. Dogs with mesaticephalic skull shape such as that of German Shepherds and Rottweilers account for 76–94% of animal bite injuries in low- and medium-income countries, with children in mid-to-late childhood making up the largest percentage of their victims.[1,2,3,4,5,6]

Bite marks are defined as teeth contact resulting in physical alteration in any substance capable of being marked by these means. The central dogma of bite mark analysis is based on the uniqueness of each tooth and it is rendered during the biting process to enable identification along with sufficiency of their detail according to Pretty and Turnbull.[7,8,9]

Bite marks are found in human criminal assaults and dog attacks. Human bites range from bruising, abrasions, lacerations and to a much severe extent, tissue avulsion while dogs often produce laceration type damage.[6,10] Bite mark analysis requires documentation and interpretation of the evidences surrounding patterned injuries that may, or may not, be bite marks.[11,12] There have been instances where human bite marks have been misjudged as dogs', especially in the case for small children and infants. The opposite situation had also occur where the wrongly accused was held responsible for a dog attack.[11,13,14,15]

Human and dog bite marks although may seemed easily distinguishable by their morphology, the movements that happened during the bite along with many other factors like tissue resiliency and pressure applied can lead to lesions inflicted by one to resemble another. Bite mark assault cases thus may be misinterpreted wrongly of the source of biter if not cautious.[6,9,10,16]

The intercanine distance (ICD) measurement which is the measurement between the cusp tips of the cuspids transversely across an arch is important because anterior teeth' impression on the skin or other mediums is prominent. They are used in metric analysis part for quality control measure as they are stable in the bite mark.[17,18,19]

So far, there was scant research on the ICD between humans and dogs. Past studies failed to compare dogs according to size to humans statistically. The present study will present a novelty by analysing the ICD between dog groups to humans in a statistical manner. The aim of this study was to analyse the differences of the ICD between humans and dogs.

METHODS

Subjects

Bite registrations of 65 human samples collected from 185 student's population of Faculty of Dentistry Universitas Padjadjaran were selected by a purposive non-random sampling method with the use of Slovin's formula with an error margin, *e* (0.10). The inclusion criteria for human population**: students** of Faculty of Dentistry Universitas Padjadjaran between 18 to 28 years old, canine occlusion relationship class I, presence of both intact canine teeth in each jaw, normal overjet and no diastema at the anterior teeth**.** The gender and dental arch shape in humans were excluded.

Bite registration was collected by the author according to the procedural bite registration methods. Impression models of 22 dogs taken cross-sectionally from 30 dog populations from Animal Centres in Bandung were selected by a purposive non-random sampling method with the use of Slovin's formula with an error margin, *e* (0.10). The inclusion criteria for dogs: mesaticephalic skull shape, and having all four intact canine teeth.

Dog gender was excluded. All the dog impressions were taken post sedation prior scheduled surgeries; there was thus no unnecessary anaesthetic exposure. The procedure of anaesthesia administration was done by attending veterinarians. The human gender and dog size distribution are shown in table 1. Ethical approval for the current study was obtained from the Institutional Health Ethics Committee, Faculty of Medicine Universitas Padjadjaran (Ref. No: 1225/UN6.KEP/EC/2018).

The analytical research design was done for this study. The human bite registrations were made using type II medium baseplate wax pieces. Prior written consent was obtained. They were then instructed to bite on the softened folded wax pieces with a piece of cardboard sandwiched in between until the wax re-hardens, thus

forming the bite marks of both the maxillary and mandibular teeth on each side of the folded wax. The canine marks of each arches corresponding to the canine teeth were identified and the linear distance between the cusp tips were measured with a digital vernier caliper (Fig.1).

The measurements were repeated twice by both the observers to calculate the average. The observers included a forensic odontologists and a student of dentistry. The measurements recorded were shown in table 3.The dog subjects were classified by body weight into 3 groups where body weights of small, medium and large sized dogs were between 5 to <10 kg, 10 to 25 kg and >25 to 45 kg, respectively according to Hawthorne's Classification. (Tab. 1). [20,21]

Prior written consent was obtained from their caretakers. Impressions of the anterior teeth of both arches using alginate in modified partial trays (Fig. 2) were taken separately after the dogs were sedated. The impressions were casted with dental stone (Fig.3).

The ICD were measured on the model from cusp tips of one side to the contralateral side on both arches with a digital vernier caliper (Fig. 4). The measurements were repeated twice by both of the observers to calculate the average and recorded as shown in table 4.

Statistical Analysis (4)

Analytical statistics for the ICD measurements were done. Paired t-test was used to determine the statistical significance of inter-observer and intra-observer variability. A p-value of 0.05 or less was considered significant.

Mann Whitney U test was applied to compare the difference of the ICD between humans and different dog sizes pairwise.The level of significance was set at $p < 0.05$. Pearson's correlation test was done to verify the relation between the dogs' ICD and bodyweight. The statistical analysis was performed with Statistical Package for Social Science (SPSS) version 22.0 (SPSS Inc., Chicago, IL.).

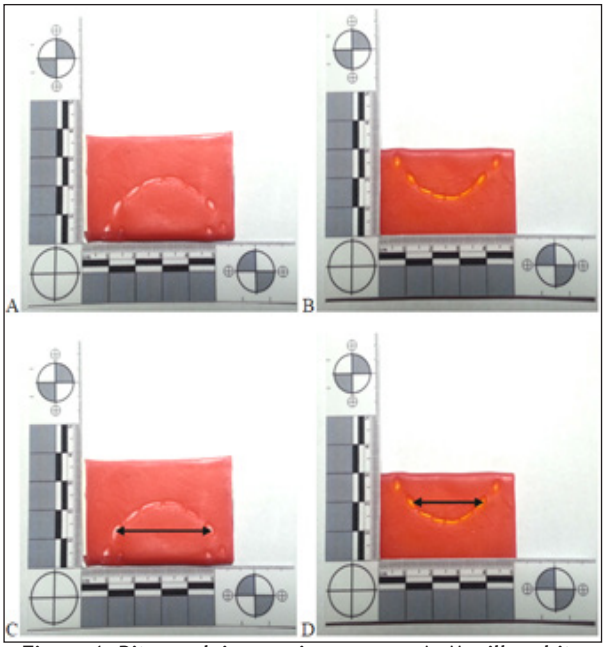

Figure 1. Bite mark impression on wax: A. Maxillary bite mark impression; B. Mandibular bite mark impression; C. Maxillary ICD measurement (black double arrows); D. Mandibular ICD measurement (black double arrows)

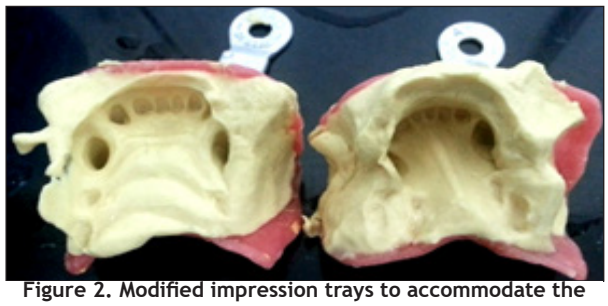

Figure 2. Modified impression trays to accommodate the long canines of dogs

Figure 3. Casts produced from impression of dog's anterior dentition

Table 1. Classification of dogs by bodyweight

Size	Weight (kg)
Small	5.0 - <10.0
Medium	10.0 - 25.0
Large	>25.0 - 45.0

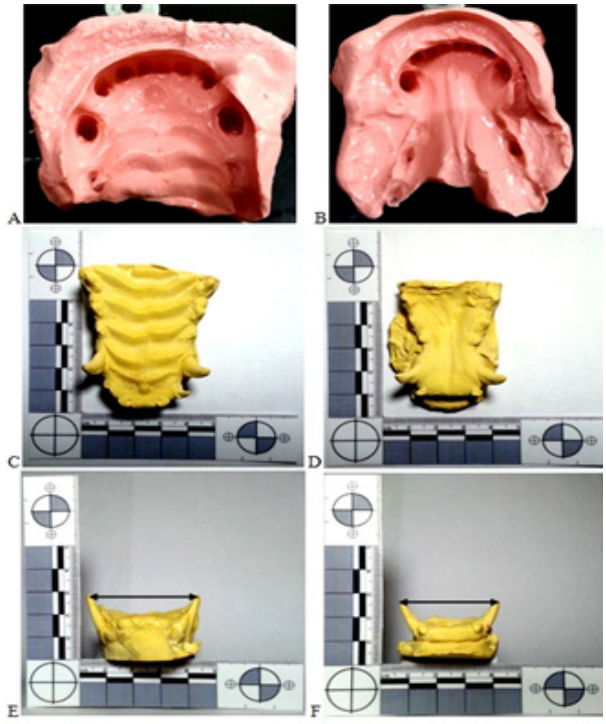

Figure 4. Dog sample collection and measurement: A. Maxillary arch impression of anterior teeth; B. Mandibular arch impression of anterior teeth; C. Maxillary cast model of anterior teeth; D. Mandibular cast model of anterior teeth; E. Maxillary ICD measurement from anterior view (black double arrows); F. Mandibular ICD measurement from anterior view (black double arrows)

RESULTS

Table 2. Distribution of subjects

Subjecrs	N	%
Humans	65	100
Dogs		
Small sized dogs	5	22.7
Medium sized dogs	12	54.6
Large sized dogs	5	22.7
Total	**22**	**100**

Table 3. Human maxillary and mandibular ICD

Intercanine distance (ICD)	Min (mm)	Max (mm)	Range	$\bar{x}$	SD
Maxillary	29.73	38.53	8.80	34.81	2.00
Mandibular	23.93	32.57	8.64	27.63	1.99

Table 4. Dog maxillary and mandibular ICD

Intercanine distance (ICD)	Min (mm)	Max (mm)	Range	$\bar{x}$	SD
Maxillary					
Small sized dogs	22.60	24.37	1.77	23.20	0.71
Medium sized dogs	29.43	42.27	12.84	35.56	3.70
Large sized dogs	43.53	55.33	11.8	47.77	6.57
Mandibular					
Small sized dogs	16.00	21.77	5.77	19.89	2.33
Medium sized dogs	27.30	36.00	8.70	32.08	2.72
Large sized dogs	36.37	44.63	8.26	40.43	4.13

Descriptive statistics of the distribution of subjects and the human and dog ICD are shown in table 2, 3 and 4. The author did not consider the gender of the human and dog subjects. Dog samples were divided according to size.

The author found no significant differences for intra-observer (p = 0.552) and inter-observer (p = 0.107) in all the maxillary ICD variances; intra-observer (p = 0.133) and inter-observer (p = 0.120) in all the mandibular ICD variances, and separately

Table 5. Paired t-test for inter- and intra-observer variability

Intercanine distance (ICD)	Intra-observer variability		Inter-observer variability,	
	p-value	t-value	p-value	t-value
Maxillary				
Overall	0.552	-0.596	0.107	-1.628
Humans	0.262	-1.131	0.078	-1.791
Dogs				
Small sized dogs	0.674	0.322	0.160	1.723
Medium sized dogs	0.709	-0.383	0.186	-1.141
Large sized dogs	0.260	-1.31	0.114	-2.012
Mandibular				
Overall	0.133	1.516	0.120	1.569
Humans	0.079	1.922	0.120	1.574
Dogs				
Small sized dogs	0.468	-0.802	0.178	-1.633
Medium sized dogs	0.838	-0.209	0.269	-1.163
Large sized dogs	0.690	-0.428	0.141	-1.831

Table 6. Mann-Whitney U test between the ICD of humans and dogs according to size

ICD	Mann-Whitney U	Z	p-value	Conclusion
Maxillary				
Human – Small sized dog	162.5	3.6943	0.0002	Significant
Human – Medium sized dog	390.0	-0.6600	0.5093	Not significant
Human – Large sized dog	162.5	-3.6943	0.0002	Significant
Mandibular				
Human – Small sized dog	162.5	3.69432	0.0002	Significant
Human – Medium sized dog	357.5	-4.1116	0.0003	Significant
Human – Large sized dog	162.5	-3.6943	0.0002	Significant

for each of the sample groups (p values range from 0.260 to 0.709 for intra-observer variances, and from 0.078 to 0.186 for inter-observer variances in maxillary; p values range from 0.079 to 0.838 for intra-observer variances, and from 0.120 to 0.269 for inter-observer variances mandibular) (Table.5).The Mann Whitney U test showed that, except for the difference of maxillary ICD between humans and medium sized dogs (p = 0.5093), the difference between humans and both small and large sized dogs (p = 0.0002) was statistically significant. The test also showed that the difference between the mandibular ICD of humans and dogs was statistically significant (p = 0.0002 for small, and large sized dogs, and p = 0.0003 for medium sized dogs) (Tab. 6).

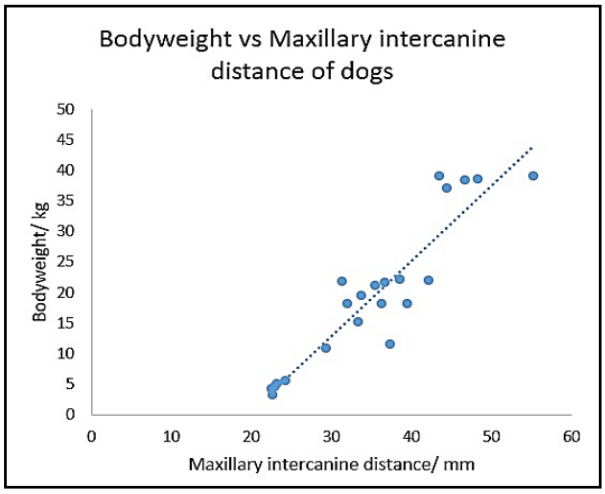

Figure 5. Correlation between body weight of dog and their maxillary ICD

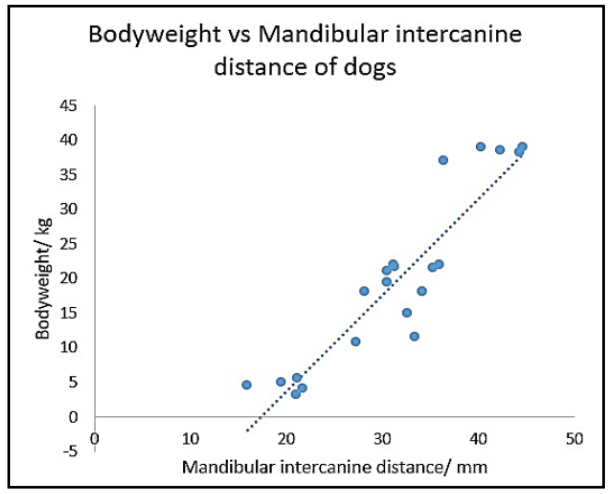

Figure 6. Correlation between body weight of dog and their mandibular ICD

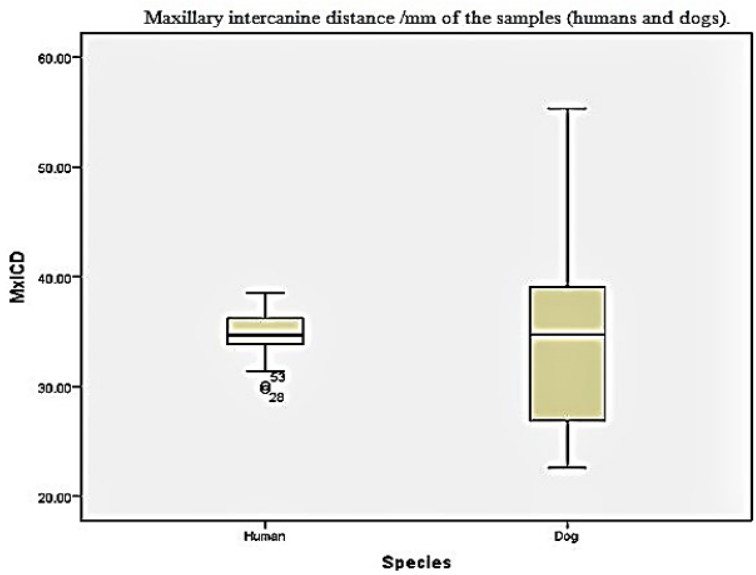

Figure 7. Maxillary ICD /mm of the samples (humans and dogs)

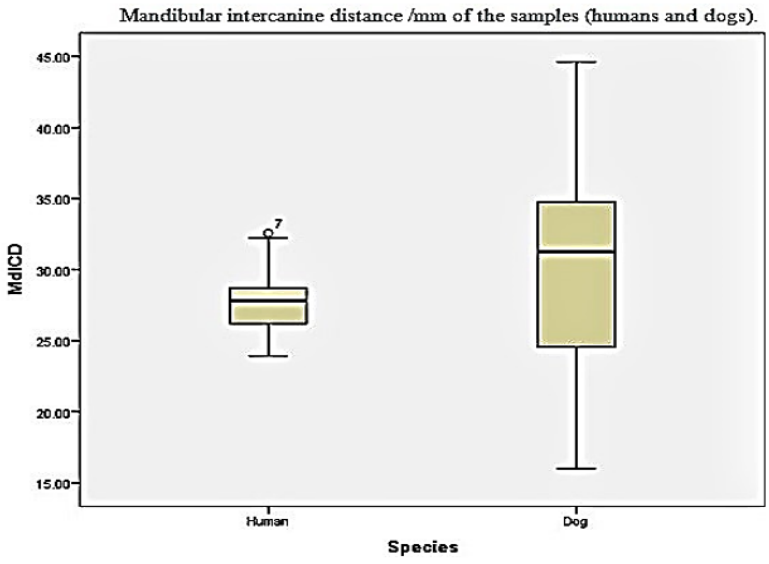

Figure 8. Mandibular ICD /mm of the samples (humans and dogs)

According to figure 5 and 6, a strong positive correlation (*Pearson*) was observed between the dogs' bodyweight and both the maxillary (r=0.924) and mandibular (r=0.914) ICD.The values for the maxillary and mandibular ICD respectively of the whole sample (humans and dogs). The values are concentrated between 28 mm to 37 mm for humans (Fig. 7 and 8).

DISCUSSION

In the present study, the intra- and inter-observer calibrations were done to verify the variability of the measurements. Significant relationship was shown with variability of intra-observer (p = 0.552) and inter-observer (p = 0.107) in all maxillary, and intra-observer (p = 0.133) and inter-observer (p = 0.120) in all mandibular ICD variances. The result of the observer variability measurements was similar to the previous study by Tedeschi-Oliveira *et al*[10] that mentioned only intra-observer calibration was done as only one examiner performed the calculation of the measurements. Inter-observer calibration was not done in the previous study by Tedeschi-Oliveira *et al*[10] The results from the present study possessed a higher validity from this comparison. In contrast, another study by Kashyap *et al*[16] mentioned that neither intra- nor inter-observer calibration was done as the measurements were calculated using Diagora software version 2.7.103.437 on x-rays of the bite marks. As far as the author is aware, though software is utilised, examining inter- and intra-observer variability calibration is recommended to increase the study validity.

In the present study, the Mann Whitney U test showed that the difference in ICD between humans and the three dog groups was statistically significant except for the maxillary ICD between humans and medium sized dogs (p = 0.5093). The present study partially agrees to the previous study by Tedeschi-Oliveira *et al*[10] which mentioned descriptive differences of the mean values of ICD between humans and medium sized dogs were minute despite not statistically analysed.

Another study by Johnson *et al*[22] studied dog sizes of only medium to large with descriptive statistics.[22] The present study was contrary to the study by Kashyap *et al*[16] has assessed ICD between humans and different dog breeds and shown significant statistical comparisons between all the mean values. So far, the study by Kashyap *et al*[16] could not be compared.

The present study, though a preliminary one, conducted statistical analysis to investigate the significance between the variances and it is one of the advantages of this study. As far as the author is aware, the insignificant difference between maxillary ICD of humans and dogs relates to the similarities in the measurements between the groups and no further explanation can be given. Similar research was scant, and this poses a limitation to the present study.

In the present study, a positive correlation between the dogs' ICD and bodyweight (Fig. 5 and 6) was shown. This result is in line to previous study by Tedeschi-Oliveira *et al*[10] mentioned that there are significant correlation between the ICD and bodyweight. Another study by Geiger *et al*[20] mentioned that the dogs' skull dimensions increases along with bodyweight, hence the dentition and jaw dimensions increase along with the growth of the canine skull form, but the study was an ontogenetic study with dependent variables.[23,24,25,26]

The previous study is contrary to the present study which was studied with independent variables. The present study is in line with the previous study by Kashyap *et al*[16] that mentioned the high variability in results among the dogs was due to the different size and skull form attributed to the different breeds, and author suggested that this phenomenon greatly relates to the biological variation of the growth and development of dogs.

Bite assault cases, be it from humans or dogs should be analysed with scrutiny and then the source of biter be distinguished. It is important to note that differences exist in the dental anatomy in morphology and numbers between humans and dogs.

However, not all beings possess an intact dentition since tooth structure may be lost due to periodontal disease or fractures. Tissue movements during the biting process are complex and marks left behind may be distorted or incomplete which may result in difficulties in analysis.

In the present study, the differences between ICD of humans and dogs were analysed due to its importance in bite mark analysis. Similarly, another study by Bernitz *et al*[19]

mentioned the measurement of ICD as part of bite mark analysis is useful in identifying the biter species by comparing the ICD on wound to the ICD of a suspected biter as it is stable in the bite mark. Based on the same study, deeper bites would require the use of mesial bone height as an alternative parameter. In the present study, bite registrations for human samples were taken with dental grade wax due to its stability when stored properly, and teeth impressions for dog samples were taken using alginate with modified impression trays (Fig. 2) to reproduce to anterior dentitions.

This method partially agrees with previous studies by Fonseca *et al*[19] and Bernitz *et al*[27] where alginate impressions were sufficient to reproduce the dogs' dentition. As far author is aware, alginate is one of the most commonly used materials to reproduce the replica of dentition in dentistry, due to its ease of use and availability, thus author chose this material for the dog sample collection. In the present study, before taking the impressions, the author fabricated custom trays to accommodate the dentition of dogs of different sizes.

This process presents an important step towards the progress of the study and it presents an advantage for this study because the author is required to take impressions of animal dentitions (under the supervision of their caretakers) instead of humans. In the present study, samples of various dog breeds with different sizes (small: miniature poodles; medium: mixed breed dogs and golden retrievers; large: German Shepherd, Alaskan Malamute and Rottweilers) were included. ICD of small and large (maxillary and mandibular) and medium (mandibular) sized dogs were significantly different compared to humans.

This presents a difficulty for the study because the measurement of ICD in humans is impossible to be categorised according to type of human jaw. The present study was partially in line with the study by Kashyap *et al*[16], where different dog breeds (Poomarian Cani, German Shepherd, Doberman and Indian Cani) showed statistically significant differences between human and dog ICD. Another study by Bernitz *et al*[27], mentioned that ICD is important to eliminate dogs of different sizes. The variety of the breeds presents a challenge for future studies because growth and development of each breed is greatly influenced by the local geography. In the present study, ICD is useful in bite mark analysis as shown in table 6, but was not suitable when bite marks of suspects involved humans and medium sized dogs. Previous study by Kashyap *et al*.[16] Mentioned the reliability of ICD in bite mark analysis, however, this study needed to increase accuracy with other further investigatory parameters.[16]

This finding is in contrast to another study by Tavardi *et al*.[28] which mentioned ICD is unreliable to be used as a metric method. Due to the similarities between the maxillary ICD of humans and medium sized dogs, thus, solitary use of the parameter for analysis in bite marks would be insufficient with respect of defining the biter.

The present study showed that human ICD between the range of 23.93 mm ± 1.99 to 38.53 mm ± 2.00 (table 3 and 4) overlapped with the overall ICD of dogs, hence values outside of this range can be excluded as human bite marks. Human bite marks have ICD that varies minimally and range mentioned should be considered as a reference only.

The bite marks analysis especially ICD is a valuable parameter, but should be used in adjunct with other distinguishable properties in the bite mark and dentition (bite depth, diastemas, tooth mark morphology and arch form). The present study is a preliminary research that has few limitations, which were small sample size, neglecting variation in dog breeds and human jaw types and not considering age and gender variables. Related studies were scant and in further studies, they need to be done with the other variables to develop alternative bite mark identification techniques in forensic odontology.

CONCLUSION

The ICD analysed in this study were concluded to be different between humans and dogs (all sizes) in mandibular, humans and dogs (small and large sized) in maxillary. Conversely, the ICD between humans and medium sized dogs in maxillary were similar.

REFERENCES

1. Touré G, Angoulangouli G, Méningaud JP. Epidemiology and classification of dog bite

injuries to the face: A prospective study of 108 patients. J Plast Reconstr Aesthetic Surg. 2015;68(5):654–8. DOI: 10.1016/j.bjps.2015.01.001
2. Georgevsky D, Carrasco JJ, Valenzuela M, McGreevy PD. Domestic dog skull diversity across breeds, breed groupings, and genetic clusters. J Vet Behav. 2013;9(5):228–34. DOI: 10.1016/j.jveb.2014.04.007
3. Esmaeilzadeh F, Rajabi A, Vahedi S, Shamsadiny M, Ghojogh MG, Hatam N. Epidemiology of animal bites and factors associated with delays in initiating post-exposure prophylaxis for rabies prevention among animal bite cases: A population-based study. J Prev Med Public Heal. 2017;50(3):210–6. DOI: 10.3961/jpmph.17.027
4. Sharma S, Agarwal A, Khan A, Ingle G. Prevalence of dog bites in rural and urban slums of Delhi: A community-based study. Ann Med Health Sci Res. 2016;6(2):115–9. DOI: 10.4103/2141-9248.181836
5. Andrew J, Christley R, Westgarth C. Contexts and consequences of dog bite incidents. J Vet Behav Clin Appl Res. 2018;23(1):33–9. DOI: 10.1016/j.jveb.2017.10.005
6. Leite A, Porto E, Ferreira B, Leite C, Fábia A, Cavalcanti C. Facial dog bite injuries in children : A case report. Int J Surg Case Rep. 2017;41:57–60. DOI: 10.1016/j.ijscr.2017.10.008
7. Gorea RK, Jasuja OP, Abuderman AA, Gorea A. Bite marks on skin and clay: A comparative analysis. Egypt J Forensic Sci. 2014;4(4):124–8. DOI: 10.1016/j.ejfs.2014.09.002
8. Pazhani MJ, Ambiga D. Accuracy of bite mark analysis from food substances: A comparative study. J Forensic Dent Sci. 2015;7(3):222–6. DOI: 10.4103/0975-1475.172442
9. Manas B, Nilesh P, Manika A, Betina C. Bite Marks - Revisited. J Forensic Sci Criminol. 2016; 4(5): 16. DOI: 10.1002/9781118864418.ch8
10. Tedeschi-Oliveira S V., Trigueiro M, Oliveira RN, Melani RFH. Intercanine distance in the analysis of bite marks: A comparison of human and domestic dog dental arches. J Forensic Odontostomatol. 2011;29(1):30–6.
11. Souviron R, Haller L. Bite mark evidence: bite mark analysis is not the same as bite mark comparison or matching or identification. J Law Biosci. 2017;4(3):617–22. DOI: 10.1093/jlb/lsx026
12. Malinda Y, Zakiawati D. Acquintance of bite mark identification procedures in forensic odontology. Padjadjaran J Dent. 2015;27(6):166–77. DOI: 10.24198/pjd.vol27no3.13557
13. Souviron RR. Animal Bites. In: Dorion RBJ, editor. Bitemark Evidence - A Colour Atlas and Text. 2nd ed. Florida: CRC Press; 2011. p. 211–2.
14. Cohrn KF. Animal Bitemarks. In: Senn DR, Weems RA, editors. Manual of Forensic Odontology. 5th ed. Florida: CRC Press; 2013. p. 334–53.
15. Stavrianos C, Aggelakopoulos N, Stavrianou P, Pantelidou O, Vasiliadis L, Grigoropoulos L. Comparison of human and dog bitemarks. J Anim Vet Adv. 2011;10(20):2649–54. DOI: 10.3923/javaa.2011.2649.2654
16. Kashyap B, Anand S, Reddy S, Sahukar SB, Supriya N, Pasupuleti S. Comparison of the bite mark pattern and intercanine distance between humans and dogs. J Forensic Dent Sci. 2015;7(3):175–9. DOI: 10.4103/0975-1475.172419
17. Adamek A, Minch L, Kawala B, Międzykłowa S, Przegląd Piśmiennictwa –. Intercanine Width – Review of the Literature. Dent Med Probl. 2015 Jan 1;52(3):336–40.
18. Baszak J, Walawska A, Walawska B. Clinical importance of the mandibular intercanine distance – a literature review. Othod Forum. 2015;11:230–7.
19. Bernitz H, Bernitz Z, Steenkamp G, Blumenthal R, Stols G. The individualisation of a dog bite mark: A case study highlighting the bite mark analysis, with emphasis on differences between dog and human bite marks. Int J Legal Med. 2011;126(3):441–6. DOI: 10.1007/s00414-011-0575-4
20. Lewis G. Musculoskeletal development of the puppy: birth – twelve months. Anim Ther Mag. 2019;(15):41–4.
21. Salt C, Morris PJ, German AJ, Wilson D, Elizabeth Lund M, Cole TJ, et al. Growth standard charts for monitoring bodyweight in dogs of different sizes. PLoS One. 2017;12(9):1–28. DOI: 10.1371/journal.pone.0182064
22. Johnson A, Pandey A, Parikh P V. A comparative

study on human and domestic animal bitemark patterns : An aid in forensic investigation. Indian J Vet Res. 2018;27(2):1–6. DOI: 10.5958/0974-0171.2018.00008.0

23. Geiger M, Evin A, Sánchez-villagra MR, Gascho D, Zollikofer CPE. Neomorphosis and heterochrony of skull shape in dog domestication. Sci Rep. 2017;(February):1–9. DOI: 10.1038/s41598-017-12582-2
24. Geiger M, Haussman S. Cranial suture closure in domestic dog breeds and its relationships to skull morphology. Anat Rec. 2016;299(January):412–20. DOI: 10.1002/ar.23313
25. Modina SC, Veronesi MC, Moioli M, Meloni T, Lodi G, Bronzo V, et al. Small-sized newborn dogs skeletal development: radiologic, morphometric, and histological findings obtained from spontaneously dead animals. BMC Vet Res. 2017;13(175):1–10. DOI: 10.1186/s12917-017-1092-6
26. Schoenebeck JJ, Ostrander EA. The genetics of canine skull shape variation. Genetics. 2013;193(2):317–25. DOI: 10.1534/genetics.112.145284
27. Fonseca GM, Mora E, Lucena J, Cantin M. Forensic studies of dog attacks on humans: a focus on bite mark analysis. Res Reports Forensic Med Sci. 2015;5:39–51 DOI: 10.2147/RRFMS.S92068
28. Tarvadi P, Manipady S, Shetty M. Intercanine distance and bite marks analysis using metric method. Egypt J Forensic Sci. 2016;6(4):445–8. DOI: 10.1016/j.ejfs.2016.11.001