Animal Health Prod and Hyg (2024) 13 (2) : 42 - 54

Animal Health, Production and Hygiene

www.dergipark.or.tr/tr/pub/aduveterinary

Research Article

Comparative Macroscopic and Morphometric Analysis of Mandible in Different Mouse (Balb-c; Cd-1; C57bl/6) and Rat Strains (Wistar Albino; Sprague Dawley; Wag/Rij)

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A B S T R A C T

Since the morphology of the mandible varies among animal species, it is the subject of many studies. The aim of this study was to investigate the macroanatomical and morphometric aspects of the mandible in three different rat (Spague Dawley, Wistar Albino, Wag/Rij) and mouse strains (Balb-c, C57bl/6, CD-1). In this study, which was conducted using a total of 96 mandibles, 8 females and 8 males from each strain, measurements were taken from 6 parameters. Similarities and differences between strains and sexes were revealed by statistical analyses. The mandibles were examined under a stereomicroscope. For Balb-c, the termination of *proc. angularis* at the level of *proc. condylaris* and the shallow *tuberculum masseterica* were identified as distinctive anatomical structures; for Wag/Rij, the termination of *proc. angularis* at the level of *proc. condylaris*, the prominent *tuberculum masseterica*, and the localization of the molar teeth were macroscopically revealed as distinctive features. Specific measurement parameters were *proc. coronoideus* height for Balb-c; mandible length and lower M3 crown length for CD-1, while specific measurement point was no available for C57bl/6. In rats, *proc. coronoideus* height was the specific measurement point for Wag/Rij; lower M3 crown length was decisive for Sprague Dawley. The mandible length parameter was specific for all rat strains. It was concluded that strain determination could be made by looking at these distinctive parameters.

Keywords: *Anatomy, laboratory animals, mandible, morphometry, statistics.*

Farklı Fare (Balb-c; Cd-1; C57bl/6) ve Sıçan Soylarında (Wistar Albino; Sprague Dawley; Wag/Rij) Mandibula'nın Karşılaştırmalı Makroskobik ve Morfometrik Analizi

Ö Z E T

Mandibula'nın morfolojisi hayvan türleri arasında farklılıklar gösterdiği için çok sayıda araştırmaya konu olmaktadır. Yapılan bu çalışma ile üç farklı rat (Spague Dawley, Wistar Albino, Wag/Rij) ve fare soyunda (Balb-c, C57bl/6, CD-1) mandibula'nın makroanatomik ve morfometrik açıdan incelenmesi amaçlandı. Her soydan 8'er dişi ve erkek olmak üzere toplam 96 mandibula kullanılarak yapılan bu çalışmada, 6 parametreden ölçümler alındı. Soylar ve cinsiyetler arasındaki benzerlik ve farklılıklar istatistiksel analizlerle ortaya kondu. Mandibula'lar steromikroskop altında incelendi. Balb-c için, *proc. angularis*'in *proc. condylaris* hizasında sonlanması ve *tuberculum masseterica*'nın sığ oluşu; Wag/Rij soyu için ise *proc. angularis*'in, *proc. condylaris* hizasında sonlanması, *tuberculum masseterica*'nın belirgin oluşu ve molar dişlerin lokalizasyonu makroskobik olarak ayırt edici anatomik yapılar olarak ortaya kondu. Spesifik ölçüm parametreleri Balb-c için *processus coronoideus* yüksekliği; CD-1 için mandibula uzunluğu ve alt M3 taç uzunluğu iken C57bl/6 için herhangi bir spesifik ölçüm noktası mevcut değildi. Ratlarda ise Wag/Rij rat için *proc. coronoideus* yüksekliği spesifik ölçüm noktası iken; Sprague Dawley için alt M3 taç uzunluğu belirleyici oldu. Mandibula uzunluğu parametresi ise tüm rat soyları için spesifikti. Bu ayırt edici parametrelere bakılarak soy tayini yapılabileceği sonucuna varıldı.

Anahtar Kelimeler: *Anatomi, istatistik, laboratuvar hayvanları, mandibula, morfometri.*

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Received Date: 08.11.2024 - Accepted Date: 03.12.2024 DOI: 10.53913/aduveterinary.1581771

Introduction

Knowledge of morphology and morphometry is very important in the evaluation of variation between populations and closely related species (Bookstein, 1991). In studies on the quantitative genetics of shape, the mouse mandible stands out as a highly suitable morphological structure as a model (Boell and Tautz, 2011). There are 400 different mouse strains, including inbred and outbred, which are bred for research purposes in the world (Dikmen, 2011). In addition, rats are another species widely used in experimental research and originated from *Rattus norvegicus*. Today, most of the inbred strains used in research are Wistar Albino. There are approximately 400 inbred and 50 outbred rat strains genetically defined (Dikmen, 2011). Since studies that will be beneficial to humans are carried out on experimental animals, it is important to know the anatomical differences in the bones that make up the cranium in terms of clinical and surgical intervention (Treuting et al., 2017).

The mandible is a flat pair of bones that form the lower part of the facial skeleton, where the teeth in the lower jaw are located, and which forms the jaw joint with the *os temporale* (Dursun, 2008; Bahadır and Yıldız, 2018; Demiraslan and Dayan, 2021). It has two parts, the *corpus mandibulae* and the *ramus mandibulae*, which is curved upwards (Aspinall and O'Reilly, 2004; Dursun, 2008; Ketani et al., 2017; Bahadır and Yıldız, 2018; Dyce et al., 2018; König and Liebich, 2018), and the right and left parts of this structure unite at the front at the *synchondrosis intermandibularis* (Aspinall and O'Reilly, 2004; Dursun, 2008; Bahadır and Yıldız, 2018).

In the literature reviews, there are studies on the mandible in different animals (İnce and Pazvant, 2010; Gürbüz et al., 2016; İlgün and Özüdoğru, 2020; Yılmaz, 2020; Demirtaş et al., 2023). The geometric morphometry of the mandible in the laboratory animals Wistar albino (İnce and Pazvant, 2010), brush-tailed mouse (*Calomyscus*) (Zarei et al., 2013) and *Mus domesticus* and *Mus macedonicus* (Demirtaş et al., 2023) and the morphology and geometric morphometry of the mandible of the Brazilian shrew (Missagia and Perini, 2018) were studied. In addition, although Ağaç et al. (2024a; b) revealed the shape differences of the mandible in different mouse and rat strains using geometric morphometry, these studies did not address the macroscopic structural differences and morphometric data of the strains. In this study, it was aimed to reveal the anatomical structures and parameters that can be used to distinguish strains from each other by performing macroscopic and morphometric analysis of the mandible in different rat and mouse strains.

Materials and Methods

In this study, 3 different mouse strains (Balb-c; CD-1; C57bl/6) and 3 different rat strains (Wistar Albino; Sprague Dawley; Wag/Rij) and 8 female and 8 male adults (8 weeks old) experimental animal mandibles from each strain were used. The study was carried out with the permission of the Ondokuz Mayıs University Animal Experiments Local Ethics Committee (2021/32).

The mandibles of the animals euthanized under deep anaesthesia "50 mg Ketasol (Interhas-Turkey)-5 mg Xylazinebio (Bioveta-Czech Republic)" were separated from their bodies. The maceration processes of the separated bones were performed using *Dermestes maculatus* larvae. Thus, all soft tissues were removed from the skull and the bone tissue was exposed. The skulls were bleached in 3% hydrogen peroxide (Oktet-Türkiye) to obtain more cleaning. Nomina Anatomica Veterinaria (2017) was used for naming. Morphometric data were taken. For each mandible, measurements were taken with digital caliper (Mitutoyo, Japan) in accordance with the literature (Şeker, 2009) for the length of the mandible, the height of the *proc. coronoideus*, the length of the lower molar alveoli, and the crown lengths of the lower M1, M2 and M3 teeth. The measurement points are indicated below and shown in Figure 1 and Figure 2.

1. Mandibular length: The length of the distance between the anterior edge of the lower incisor alveolus and the most posterior point of the *proc. angularis* (Figure 1-b).

2. *Proc. coronoideus* height: The length of the shortest distance between the most anterior point of the coronoideus and the most inferior point of the mandible (Figure 1-a).

3. Mandibular alveolus length: The length of the most anterior point and the most posterior point of the right mandibular alveolus (Figure 2-a).

4. M1 crown length: The length of the chewing surface of the 1st molar of the mandibular (Figure 2-d).

5. M2 crown length: The length of the chewing surface of the 2nd molar of the mandibular (Figure 2-c).

6. M3 crown length: The length of the chewing surface of the 3rd molar of the mandibular (Figure 2-b).

Statistical analysis

SPSS package program (SPSS 21.0, IBM SPSS Statistics®, Chicago, IL, USA) was used for all calculations and analyses. Normality of variables in the study was checked with Shapiro-Wilk test and homogeneity was checked with Levene's test. Anova analysis was used to evaluate variables showing normal distribution. Posthoc test Duncan was used to detect differences in Anova analysis.

Results

In all rat and mouse strains, the mandible, which forms the lower part of the facial skeleton, was a flat bone with strong protrusions and formed the jaw joint with the *os temporale*, which carries the lower jaw teeth. The right and left two bones were united with *synchondrosis intermandibularis* in all rats and mice. The *corpus mandibulae*, which is the front and lower part, and the *ramus mandibulae*, which continues upwards from here, were present in all animals in the study (Figures 3-4). In all rat and mouse strains, one long incisive tooth and three molar teeth were observed in each half of the corpus part of the mandible, which is located in the lower part of the cranium and carries the teeth (Figures 3-5). Canine and premolar teeth were not found in the strains in the study (Figures 3-4). The tooth arrangement was 1-0-0-3 as incisive, canine, premolar and molar, respectively (Figures 3-5). Again, *dentes canini* was absent in all strains and the distance between the incisive tooth and molar tooth was long (Figures 3-5). While the molar teeth were arranged in a straight position in all mice, they were located with a significant inclination towards the caudoventral in Wag/Rij rats. This inclination in the arrangement of the teeth was slight in Sprague Dawley, but not evident in Wistar Albino. It was present as *margo interalveolaris* in all rats and mice. This part was 7.65±0.4 mm on average in Sprague Dawley male, 7.11±0.3 mm in female rats, 6.32±0.3 mm in Wistar Albino male and 5.89±0.3 mm in females. In the Wag/Rij male, the *margo interalveolaris* was determined as 5.40±0.2 and in the female as 5.21±0.2 mm. The same margin was measured as 2.85±0.1 mm in the Balb-c and 2.13±0.3 mm in the female; 3.01±0.3 mm in the C57bl/6 male and 52.76±0.2 mm in the female; and 2.60±0.1 mm in the CD-1 male and 2.18±0.2 mm in the female.

A *foramen mentale* was seen on the lateral surface of the mandible, close to the molar teeth, in all strains of rats and mice (Figures 3-4). A sharp line starting at the level of the *dentes molares* on the lateral side and continuing along the ventral edge to the *proc. angularis* was also seen in all strains. It was seen that the ventral edge of the corpus indented dorsally at the level of the last molar tooth in all animals.

In the *ramus mandibulae*, a wide and large ramus was observed to be quite high and long from the tooth level and the presence of the *proc. angularis* was observed in all rats and mice (Figures 3-5). While this protrusion was approximately at the level of the *proc. condylaris* in Wag/Rij rats, it exceeded the *proc. condylaris* caudally in Wistar Albino and Sprague Dawley rats (Figure 3). In mice, the *proc. angularis* ended in front of the *proc. condylar*is in CD-1 and C57bL/6 strains, while the *proc. angularis* extended to the level of the *proc. condylaris* in Balb-c strain (Figure 4). The direction of this protrusion was observed to be caudal in rat and mouse strains and its lower edge was convex. There was a very deep concave in the medial part of the *proc. angularis*. This depth was seen as deepest in Wistar Albino rats, then Sprague Dawley and shallower in Wag/Rij rats. In mice, the same depression was observed deeper in the C57bL/6 strain than in the CD-1 and Balb-c strains. The articular surface, the *proc. condylaris*, was present in all strains as a large and strong structure and connected to the rest of the skull by forming the *os temporale* and temporomandibular articulation. The *proc. condylaris* ended with a protuberance in all three strains of mice. In rats, however, there was not such a prominent protuberance as in mice. There was a quite prominent protuberance at the level of the middle of the outer surface of the *ramus mandibulae*. This protuberance, the *tuberculum masseterica*, was less prominent in Wag/Rij rats, while it was a prominent elevation in the others (Figure 3). In mice, it was less prominent in CD-1 and C57bL/6 mice, while it was prominent in Balb-c mice (Figure 4). The *proc. coronoideus* of the *ramus mandibulae* was present in all strains of rats and mice (Figures 3-4). The tip of the *proc. coronoideus* was directed caudodorsally in Sprague Dawley and Wistar albino rats and Balb-c and C57bL/6 strains, while it was directed caudal in Wag/Rij rat and CD-1 strains. The tip of the *proc. coronoideus* was clearly pointed in the Balb-c strain, while it was blunt in C57bL/6 and CD-1 strains. A clearly visible *inc. mandibulae* between the *proc. coronoideus* and *proc. condylaris* was observed in all rats and mice (Figures 3-5). It was seen that the *proc. coronoideus* was higher than the *proc. condylaris* in all animals. The presence of a hole called *foramen mandibulae* at the medial and middle level of the *ramus mandibulae* was present in all rats and mice (Figures 3- 5). There was another hole observed in all rats and mice, in the medial of the *corpus mandibulae* and *ramus mandibulae* border, caudal to the molar teeth (Figure 5).

Whether the mouse and rat species and gender used in the study had a statistically significant effect on the length of the mandible, the height of the *proc. coronoideus*, the length of the lower molar alveoli, and the crown lengths of the lower M1, M2 and M3 teeth were evaluated with a two-way ANOVA test and the results are presented in Tables 1 for mice and 2 for rats.

Table 1 shows the results of the partial eta squared test showing the mean, standard deviation, f value, probability value and effect value of change regarding the effect of the species, sex and species-sex interaction of mice on the dependent variables. When Table 1 is examined, it is seen that there are statistically significant differences between mouse strains in the dependent variables of *proc. coronoideus* height, M2 and M3 crown length ($P<0.0001$, $P<0.0001$, $P=0.045$, respectively).

When the differences in terms of gender were examined, it was seen that gender had a statistically significant effect on these variables since the probability (sig.) value of the variables belonging to the length of the mandible and the length of the lower molar alveoli was less than the threshold value of 0.05. When the species-gender interaction results were examined; the P value for the sub-variables of the mandible length, M2 crown length and M3 crown length was found to be below the significance level of 0.05. These results showed that the species and gender interaction had a statistically significant effect on the means of these dependent variables. Since the P values belonging to the species and gender interactions for the other variables were above the significance level of 0.05, it was concluded that these interactions did not create a statistically significant difference on the dependent variables.

Since significant differences were detected between mouse strains according to ANOVA results, Duncan test was performed to examine in more detail which groups these differences were between and to separate the groups into homogeneous subsets. As a result of Duncan test, significant differences were detected between the groups and it was determined which groups were similar to each other and which were different. When Table 1 is examined, it was determined that there was no statistically significant difference between CD-1, C57bl/6 and Balb-c species in terms of the length of the lower molar alveoli, M1 crown length subvariables and M2 crown length subvariables. It was determined that the CD-1 lineage was statistically significant compared to C57bl/6 and Balb-c lines in terms of the mandible length and M3 crown length subvariables; and the Balb-c lineage was statistically significant compared to CD-1 and C57bl/6 lines in terms of the *proc. coronoideus* height variable. Based on all these results of the mice, the parameters that differed between the lines were summarized in Figure 6.

When Table 2 was examined, it was concluded that there was a statistically significant ($P<0.0001$, $P<0.0001$, $P=0.006$, respectively) difference between rat strains for all variables except for the length of the lower molar alveoli, M1 crown length lower and M2 crown length lower. Again, since the probability (sig.) value of all variables except for the length of the lower molar alveoli, M1 crown length lower, M2 crown length lower and M3 crown length sub-variables was less than the 0.05 threshold value ($P<0.0001$), it was determined that there was a significant difference between the rat genders and the means of the dependent variables. When the species-gender interaction results were examined, it was concluded that there were significant differences between the means of this interaction result and the means of the dependent variables, since the probability (sig.) value of all variables except for the M1 crown length lower, M2 crown length lower and M3 crown length sub-variables was less than the 0.05 threshold value. M1 crown length sub-variables and M2 crown length sub-variables were variables that had no significant difference between them in terms of species, sex and species-sex interaction.

Since significant differences were detected between rat strains according to ANOVA results, Duncan test was performed to examine in more detail which groups these differences were between and to separate the groups into homogeneous subsets. As a result of Duncan test, significant differences were detected between the groups and it was determined which groups were similar to each other and which were different. In this direction, homogeneous subgroups in terms of dependent variables according to rat strain variable are presented in Table 2.

When Table 2 was examined, it was seen that there was a statistically significant difference between the Wag/

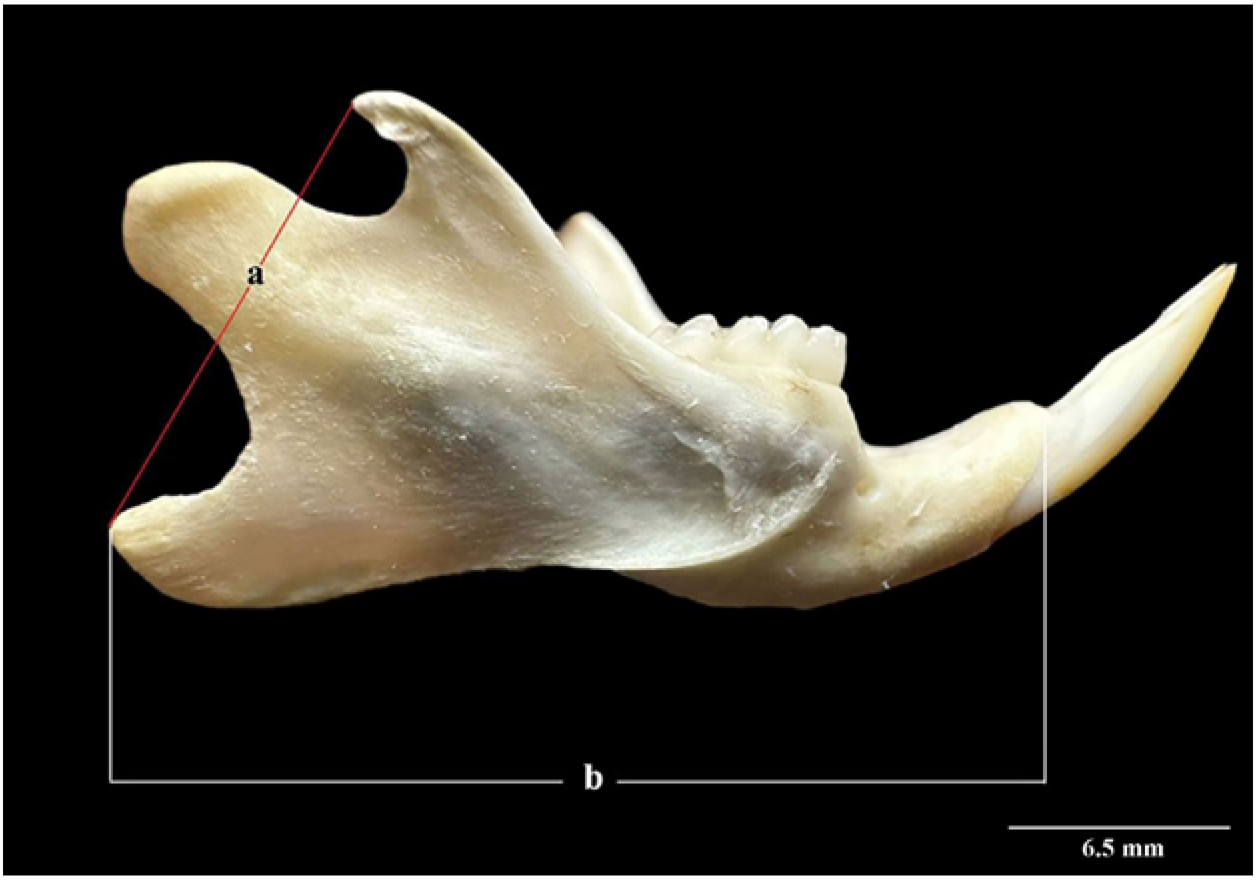

Figure 1. Measurement locations taken from the lateral view of the Wag/Rij mandible. a: *Proc. coronoideus* height, b: Mandibular length

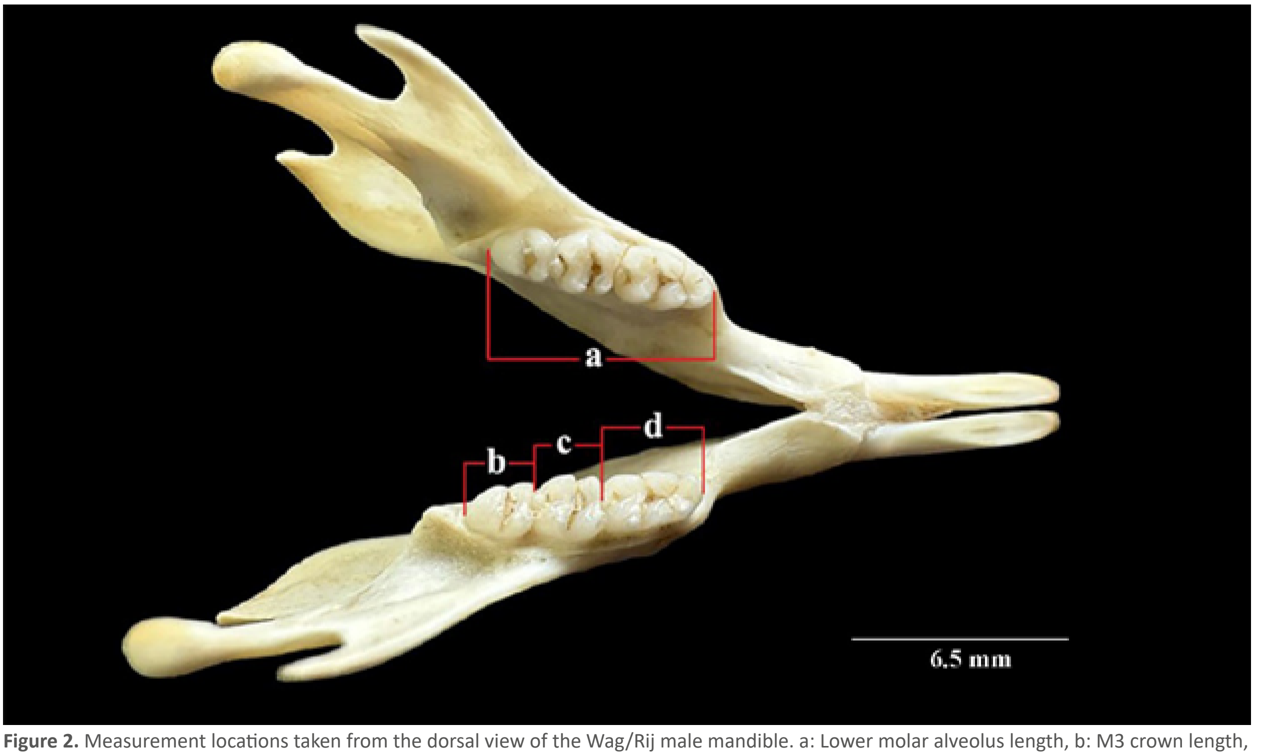

Figure 2. Measurement locations taken from the dorsal view of the Wag/Rij male mandible. a: Lower molar alveolus length, b: M3 crown length, c: M2 crown length, d: M1 crown length

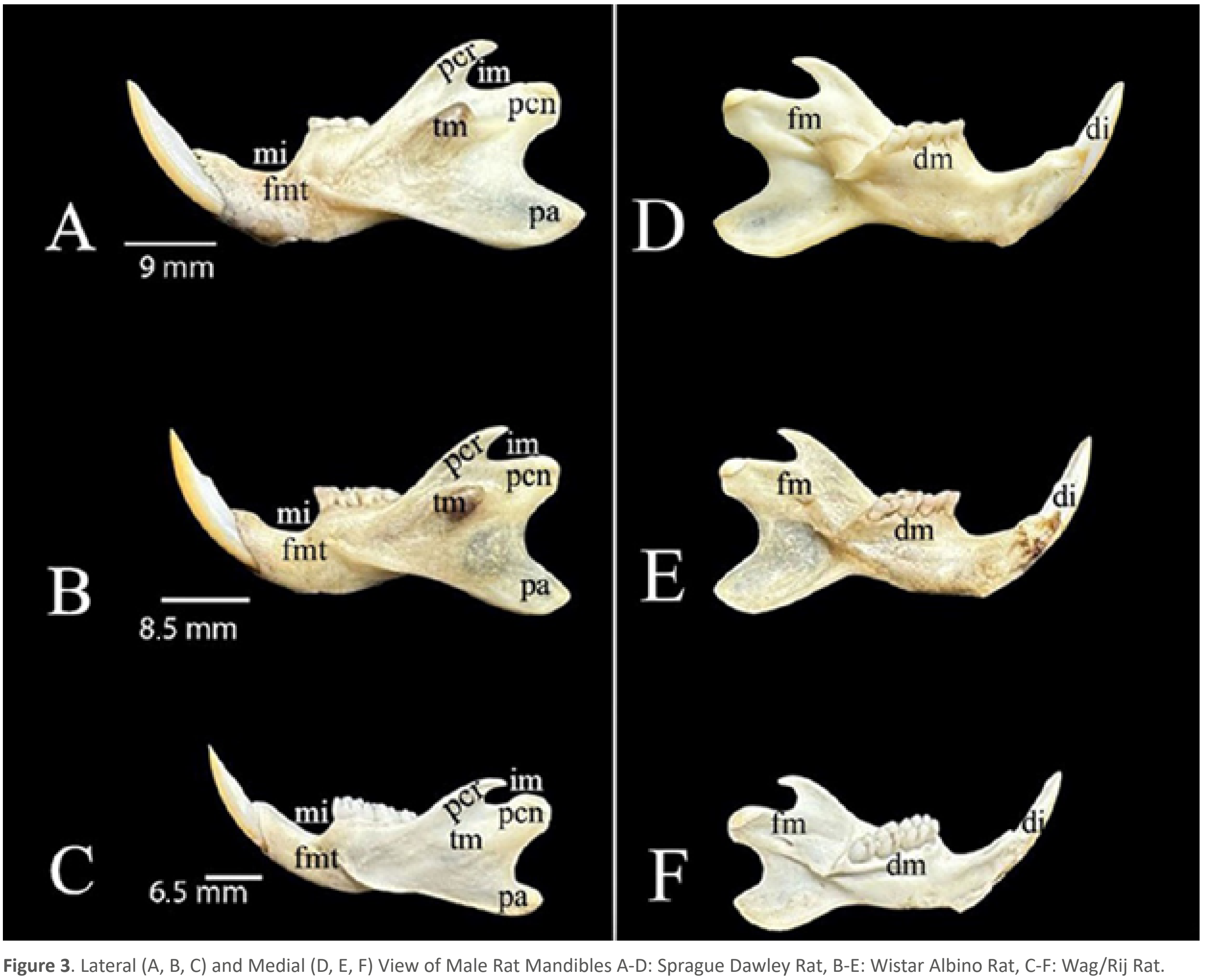

Figure 3. Lateral (A, B, C) and Medial (D, E, F) View of Male Rat Mandibles A-D: Sprague Dawley Rat, B-E: Wistar Albino Rat, C-F: Wag/Rij Rat. fmt: *For. mentale*, tm: *Tuberculum masseterica*, pcr: *Proc. coronoideus*, pcn: *Proc. condylaris*, pa: *Proc. angularis*, fm: *For. mandibulae*, dm: *Dentes molares*, di: *Dentes incisivi*, mi: *Margo interalveolaris*, im: *Inc. mandibulae*

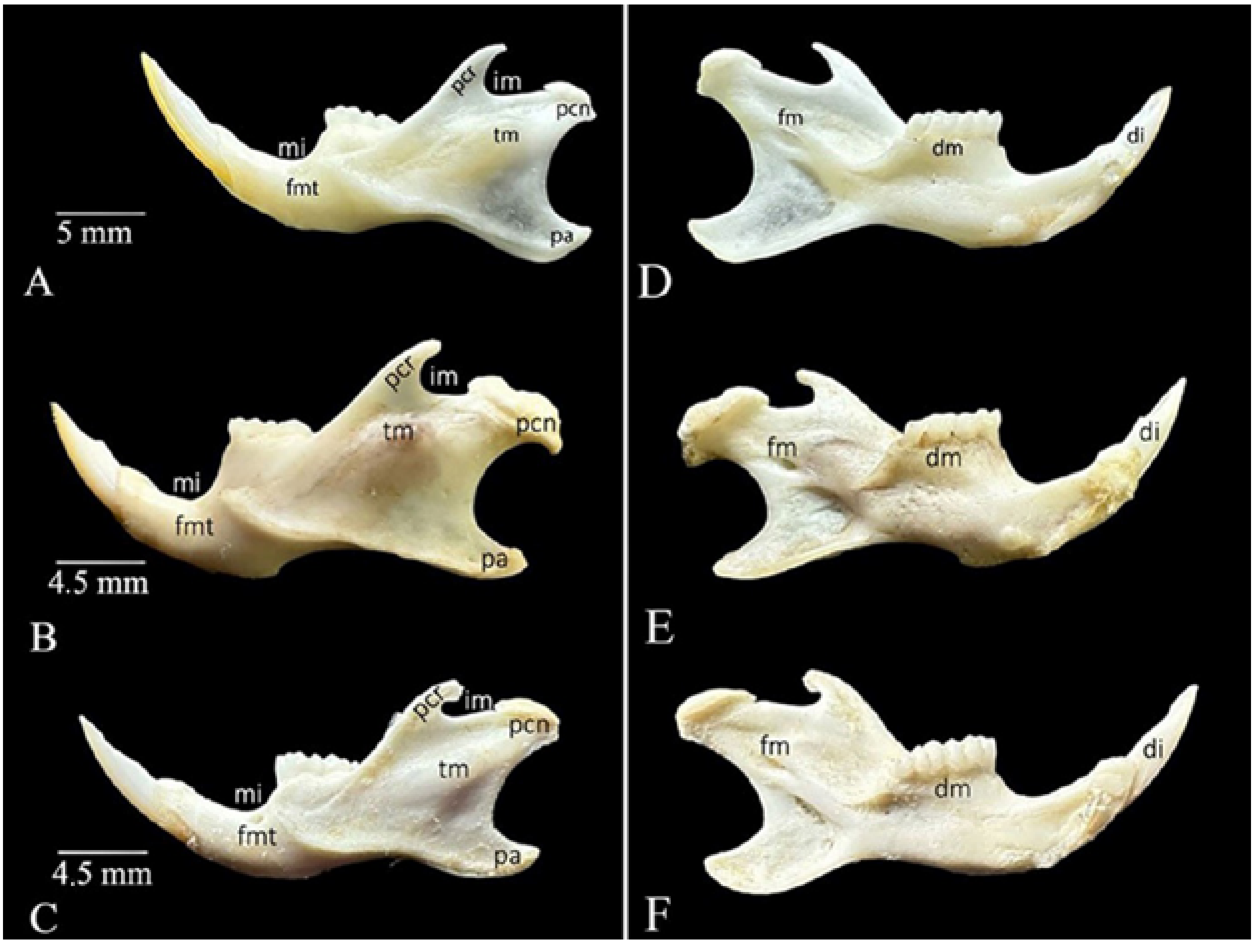

Figure 4. Lateral (A, B, C) and Medial (D, E, F) View of Female Mouse Mandibles, A-D: Balb-c, B-E: C57bL/6, C-F: CD-1. fmt: *For. mentale*, tm: *Tuberculum masseterica*, pcr: *Proc. coronoideus*, pcn: *Proc. condylaris*, pa: *Proc. angularis*, fm: *For. mandibulae*, dm: *Dentes molares*, di: *Dentes incisivi*, mi: *Margo interalveolaris*, im: *Inc. mandibulae*

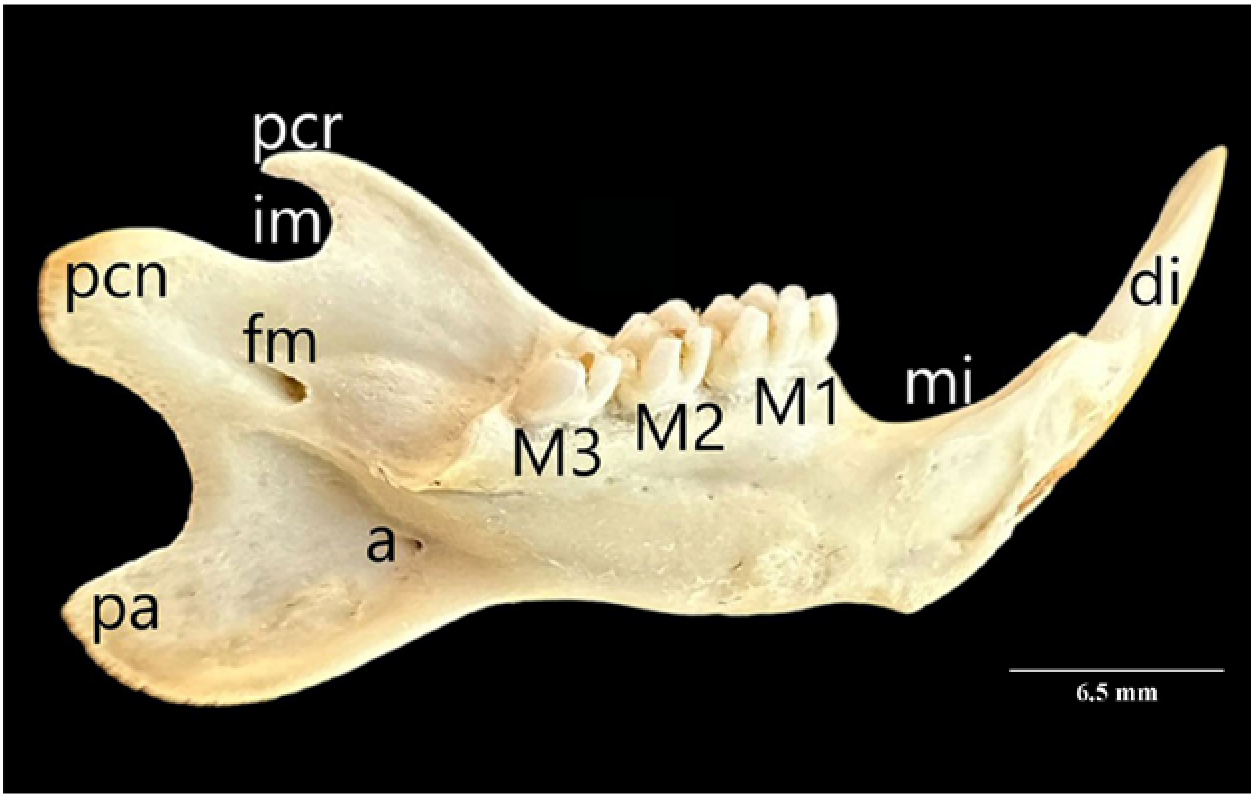

Figure 5. Medial view of the mandible of the Wag/Rij male rat, a: Mentioned hole, pa: *Proc. angularis*, pcn: *Proc. condylaris*, pcr: *Proc. coronoideus*, fm: *For. mandibulae*, im: *Inc. mandibulae*, mi: *Margo interalveolaris*, di: *Dentes incisivi*, M1: First molar, M2: Second molar, M3: Third molar

Table 1. Two-way analysis of variance (ANOVA) test results for mice

Dependent Variable	Species/Gender/ Species*Gender	N	Mean	Standard Deviation	F Value	P Value	Partial Eta Squared
Mandible Length	Balb-c	16	12.43	0.54	3.04	0.058	0.13
	C57bL/6	16	12.53	0.72			
	CD-1	16	12.16	0.32			
	Female	24	12.17	0.47	9.87	0.003	0.19
	Male	24	12.58	0.58			
	Species*Gender	48	12.37	0.56	8.24	0.001	0.28
Proc. coronoideus Height	Balb-c	16	6.89[a]	0.29	20.05	<0.0001	0.49
	C57bL/6	16	6.39[b]	0.28			
	CD-1	16	6.22[b]	0.34			
	Female	24	6.45	0.41	1.15	0.290	0.03
	Male	24	6.55	0.42			
	Species*Gender	48	6.50	0.41	0.65	0.527	0.03
Molar Alveolus Length	Balb-c	16	3.14	0.20	2.32	0.111	0.10
	C57bL/6	16	3.24	0.18			
	CD-1	16	3.12	0.18			
	Female	24	3.10	0.15	8.84	0.005	0.17
	Male	24	3.24	0.20			
	Species*Gender	48	3.17	0.19	1.79	0.180	0.08
M1 Crown Length	Balb-c	16	1.47	0.15	2.33	0.110	0.10
	C57bL/6	16	1.48	0.08			
	CD-1	16	1.55	0.10			
	Female	24	1.51	0.09	0.25	0.619	0.006
	Male	24	1.50	0.14			
	Species*Gender	48	1.50	0.12	4.93	0.012	0.19
M2 Crown Length	Balb-c	16	0.95[a]	0.10	9.47	<0.0001	0.31
	C57bL/6	16	0.91a	0.08			
	CD-1	16	1.03a	0.08			
	Female	24	0.96	0.08	0.20	0.654	0.005
	Male	24	0.97	0.12			
	Species*Gender	48	0.96	0.10	7.72	0.001	0.27
M3 Crown Length	Balb-c	16	0.63[b]	0.11	3.33	0.045	0.14
	C57bL/6	16	0.63[b]	0.06			
	CD-1	16	0.68[a]	0.09			
	Female	24	0.66	0.08	2.11	0.154	0.05
	Male	24	0.63	0.09			
	Species*Gender	48	0.65	0.09	13.52	<0.0001	0.39

[a,b,c] The difference between means in the same column is statistically significant (P<0.05).

Rij, Sprague Dawley and Wistar Albino strains in terms of mandible length. This difference was Sprague Dawley> Wistar Albino> Wag/Rij. No statistically significant difference was observed between the strains in terms of M1 crown length sub-variables and M2 crown length sub-variables. While the *proc. coronoideus* height variable was a statistically significant variable in the Wag/Rij strain compared to other strains, the M3 crown length sub-variable showed a statistically significant difference for the Sprague Dawley strain. Based on all these results, the parameters that differ between the strains are shown in Figure 7.

Figure 6. Mandibular parameters distinguishing mouse strains from each other

Table 2. Two-way analysis of variance (ANOVA) test results for rats

Dependent Variable	Species/Gender/ Species*Gender	N	Mean	Standard Deviation	F Value	P Value	Partial Eta Squared
Mandible Length	Sprague Dawley	16	26.47[a]	1.80	202.19	<0.0001	0.91
	Wag/Rij	16	21.75[c]	0.77			
	Wistar Albino	16	24.50[b]	0.82			
	Female	24	24.49	2.92	6.88	0.012	0.14
	Male	24	23.99	1.46			
	Species*Gender	48	24.24	2.30	51.49	<0.0001	0.71
Proc. coronoideus Height	Sprague Dawley	16	13.05[a]	1.03	95.04	<0.0001	0.82
	Wag/Rij	16	10.56[b]	0.63			
	Wistar Albino	16	12.81[a]	0.54			
	Female	24	12.43	1.62	12.44	0.001	0.23
	Male	24	11.86	0.98			
	Species*Gender	48	12.14	1.36	14.21	<0.0001	0.40
Lower Molar Alveolus Length	Sprague Dawley	16	6.93	0.23	3.04	0.059	0.13
	Wag/Rij	16	7.00	0.00			
	Wistar Albino	16	7.13	0.34			
	Female	24	7.00	0.14	0.17	0.682	0.004
	Male	24	7.03	0.32			
	Species*Gender	48	7.02	0.25	3.44	0.042	0.14
M1 Crown Length Lower	Sprague Dawley	16	2.94	0.14	2.25	0.118	0.10
	Wag/Rij	16	3.00	0.00			
	Wistar Albino	16	3.06	0.25			
	Female	24	2.99	0.10	0.24	0.630	0.006
	Male	24	3.01	0.22			
	Species*Gender	48	3.00	0.17	1.22	0.304	0.06
M2 Crown Length Lower	Sprague Dawley	16	1.99	0.15	0.80	0.455	0.04
	Wag/Rij	16	2.06	0.25			
	Wistar Albino	16	2.00	0.00			
	Female	24	1.99	0.08	1.30	0.260	0.03
	Male	24	2.05	0.23			
	Species*Gender	48	2.02	0.17	0.55	0.580	0.03
M3 Crown Length Lower	Sprague Dawley	16	1.74[b]	0.14	5.79	0.006	0.22
	Wag/Rij	16	2.00[a]	0.00			
	Wistar Albino	16	1.88[a]	0.34			
	Female	24	1.85	0.25	0.26	0.611	0.006
	Male	24	1.88	0.22			
	Species*Gender	48	1.87	0.24	0.26	0.770	0.01

[a,b,c] The difference between means in the same column is statistically significant (P<0.05).

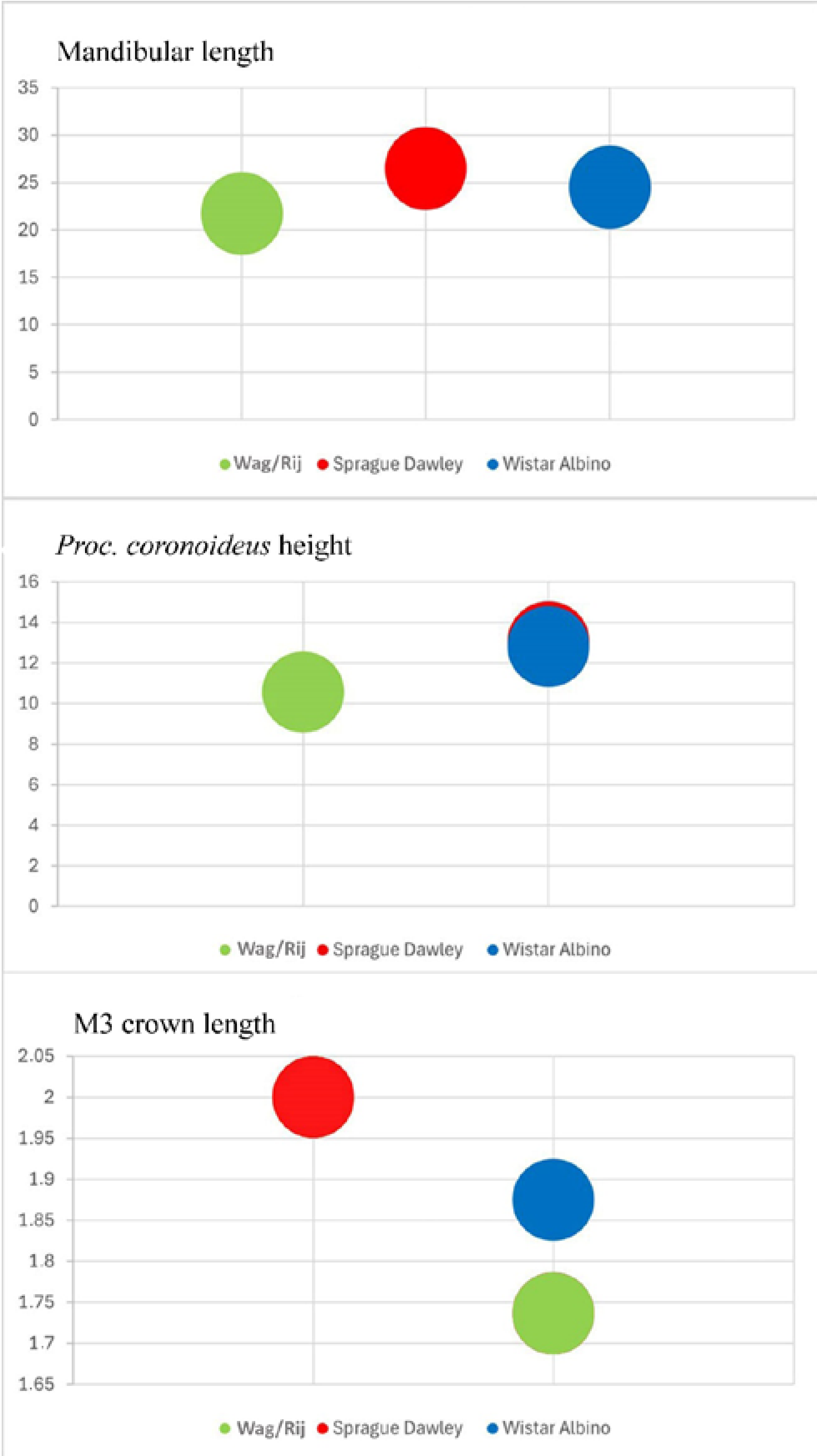

Figure 7. Parameters distinguishing rat strains from each other.

Discussion

Studies have reported that the differences observed in the mandible between animal species develop depending on various factors such as nutrition, stress, breed, hormones, masticatory joint and genetic factors (Rohlf and Marcus 1993; Bodner et al., 1998; Luca et al., 2003; Fujita, 2004). Luca et al. (2003) and McFadden et al. (1986) evaluated the development and morphometry of the mandible by applying different diet types to rats and determined that more growth was observed in the dimensions of the mandible of those fed a solid diet compared to liquid and soft food. Odman et al. (2008) similarly reported differences in the condylar base inclination in animals fed a solid diet. Enomoto et al. (2010) mentioned that diet affects the growth and development of the mandible and chewing function in mice. Akbulut et al. (2014) reported that there was a slight difference in the length and width of the mandible in males and females in rabbits with the same feeding and housing conditions. Ince and Pazvant (2010) concluded in their study on rats that the total mandibular length and mandibular incisive corona length of males were greater than those of females. In the study, the parameters of the mandible length and lower molar alveolus were statistically greater in males than in females in mouse strains; and the parameters of the *proc. coronoideus* and mandible length were statistically greater in rat strains.

Similar to what was reported for rabbits in the literature (Çalışlar, 1978), the *ramus mandibulae* was large and wide in rat and mouse strains. In addition, it was reported that the *ramus mandibulae* was short and barely exceeded the molar tooth level in guinea pigs (Çalışlar, 1978). In all rat and mouse strains in the study, unlike guinea pigs, the *ramus mandibulae* considerably exceeded the molar tooth level. In the literature (Çalışlar, 1978), it was stated that the *proc. angularis* was short and blunt in rabbits, and extended caudally in guinea pigs, and had a more or less rounded, distinct structure. It was also reported that the *proc. angularis* had a distinct protrusion and extended caudolaterally in the mole rat (Özkan, 2007). In the examined rat and mouse strains, there was a distinct *proc. angularis* and its direction extended caudally, similar to the literature. The depression located medially to this structure was seen the deepest in Wistar Albino rats, moderately deep in Sprague Dawley rats, and shallower in Wag/Rij rats. In addition, it was observed that the *proc. angularis* was outside the *proc. condylaris* alignment in Sprague Dawley and Wistar Albino rats, while it was in line with the *proc. condylaris* in Wag/Rij rats. It has been reported that the *foramen mandibulae* is located medially to the last molar tooth in guinea pigs and medially to the *ramus mandibulae* in rats (Çalışlar, 1978). In the mole rat, the *foramen mandibulae* has been reported to be at the base of the *proc. condylaris* and on the medial side (Özkan, 2007). In the study, the location of this hole was consistent with that reported in the literature for rats (Çalışlar, 1978) and mole rats (Özkan, 2007).

In a study conducted on Brazilian shrews and Akodontini rodents (Missagia and Perini, 2018), it was reported that variations in the skull were related to nesting habits, soil digging, and diet differences. In addition, the prominence and position of the *tuberculum masseterica*, which is the origin of the superficial masseter muscle, has been associated with diet (Ağaç et al., 2024). In the study conducted by Ağaç et al. (2024), it was shown that the *tuberculum masseterica* differed in terms of position among Balb-c, C57bl/6, and CD-1 strains. While the *tuberculum masseterica* was a prominent elevation in Sprague Dawley and Wistar Albino rats and Balb-c mice, it was shallow in Wag/Rij rats and CD-1 and C57bL/6 mice. Based on this, it can be said that the muscle attached here is shaped more strongly in Sprague Dawley and Wistar Albino rats and Balb-c mice compared to other strains.

It has been reported that the *proc. coronoideus* is short and tapered in guinea pigs and is located just behind the last molar tooth (Çalışlar, 1978). In the study, the tip of the *proc. coronoideus* was clearly pointed only in the Balb-c strain, while it was blunt in the C57bL/6 and CD-1 strains. In the study, the tip of the *proc. coronoideus* was observed to be oriented caudodorsally in Sprague Dawley and Wistar albino and in the Balb-c and C57bL/6 strains, similar to that reported in the mole rat (Özkan, 2007). In addition, the prominence of the *inc. mandibulae* and the level of the *proc. coronoideus* being higher than the *proc. condylaris* in all species examined were similar to those in the mole rat (Özkan, 2007). Although it has been reported in the literature (Ellerman, 1948; Ellerman & Morrison-Scoot, 1951; Ketani, 2017) that there is an extra protrusion called *proc. alveolaris* on the *ramus mandibulae* in rodents of the *Nannospalax* genus, such a protrusion was not present in the strains examined in the study. It has been reported that there are two wedge-shaped incisors in the mandible in guinea pigs and a pair of long incisors in rats (Çalışlar, 1978). In the study, there was a long pair of incisors in all strains of rats and mice, similar to what has been reported in the literature (Çalışlar, 1978).

There are differences in the number of teeth in the mandible and the number of these teeth among species. In each half of the mandible, incisor, canine, premolar and molar are reported as 1-0-1-3 in tree and ground squirrels (Yalçın and Arslan, 2009); 1-0-0-3 in Sprague Dawley rats (Yalçın et al., 2007); and 1-0-0-3 in blind mole rats (Ketani et al., 2017). The dental formula of the otter was reported as 3-1-3-2 (Yılmaz et al., 2000), while it was expressed as 3-1-4-3 in the raccoon (Hidaka et al., 1998), 1-0-1-3 in the hedgehog (Yılmaz, 1998), chinchillas (Brenner et al., 2005), and 3-1-3-2 in the badger (Dinç, 2001). In our study, the 1-0-0-3 dental arrangement reported in the literature in the blind mole rat (Ketani et al., 2017) and the Sprague Dawley rat (Yalçın et al., 2007) was present in both rat and mouse strains. In addition, in the study conducted, it was striking that there was a significant inclination towards the caudoventral in the arrangement of the molar teeth in Wag-Rij. This feature was evaluated as an important parameter that can be used in strain determination.

Conclusion

In conclusion, this study found that there were significant differences in parameters such as height of the *proc. coronoideus*, crown lengths of lower M2 and M3 teeth, and length of the mandibular and length of the mandibular molar alveolus between strains in mice, but no differences in other variables. It was concluded that there were significant differences in parameters such as length of the *proc. coronoideus*, crown lengths of lower M3 teeth, and length of the mandibular and height of the *proc. coronoideus* in rats, and there were significant differences in parameters such as length of the *proc. coronoideus*, crown lengths of lower M3 teeth, and length of the mandibular and height of the *proc. coronoideus* in macroscopic examination. For Wag/Rij, termination of the *proc. angularis* at the level of the *proc. condylaris*, shallowness of the *tuberculum masseterica*, and localization of the molar teeth were found to be distinguishing parameters for the Balb-c strain.

Acknowledgments

This study is a part of the doctoral thesis supported by the Ondokuz Mayıs University Scientific Research Projects Commission with the project number PYO. VET.1904.21.037. Special thanks to Assistant Professor Serhat Arslan and Assistant Professor Fahrettin Pala for their help in the statistical analysis phase of the study. In addition, a part of this study was presented as a poster presentation at the 12th National and 3rd International Veterinary Anatomy Congress.

Author contribution statement

BO designed and planned the experiments. DKA conducted the experiments, performed the analyses, interpreted the results, and took the lead in writing the manuscript. BO contributed to the interpretation of the results. All authors provided critical feedback and contributed to shaping the investigation, analysis, and manuscript.

Conflict of interest

None of the authors has any financial or personal relationships that could inappropriately influence or bias the paper's content.

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