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Three-dimensional reconstruction and morphometry of the mandible in New Zealand rabbits

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Abstract: This study was conducted to create three-dimensional (3D) models of the lower jaw using computed tomography (CT) images of New Zealand rabbits and to reveal whether there are differences between genders. 12 New Zealand rabbits (6 female, 6 male) were used in the study. Computed tomography (CT) images of the animals were taken, and a three-dimensional model of the mandible was obtained from the two-dimensional images using the MIMICS 20.1 program. Length measurements were performed on the resulting 3D model. When the values measured in male and female rabbits were compared, it was determined that the length between the molars (B) was longer in females, and the corona length of the lower jaw teeth (I) was longer in males and was statistically significant ($p < 0.05$). It is thought that the 3D mandible model and measurements obtained in this study would be a resource for researchers working on experimental mandibular surgery in rabbits, would guide researchers as reference data in creating a rabbit model, would assist the physician in the clinic, and would help learn the anatomy of this region.

Keywords: Computer tomography; mandible; rabbit; 3D reconstruction

1 Introduction

Rabbits are considered analogous and suitable for clinical conditions, widely used for oral surgery and implantology testing. (Wang et al. 2023). The mandible of rabbits is larger than that of rats, and it is also an appropriate size when compared to other experimental animals and rodents. This makes surgical procedures less technically demanding, and it also facilitates rapid data acquisition with microcomputed tomography for applications performed on the mandible. Furthermore, this provides an experimental basis for jaw tissue engineering studies. Additionally, the cortical bone modulus and strength of rabbits are more similar to humans than other animals. Since it has sufficient volume, mandibular defects can be easily created. (Li et al. 2015; Baskin et al. 2021; Kim et al. 2023). The fact that rabbits are cheap and have a physiology comparable to humans in some respects increases their use. One of the rabbit's most important advantages is that it reaches skeletal maturity shortly after reaching sexual maturity at 6 months. (Akbulut et al. 2014, Campillo et al. 2014; Selçuk and Tıpırdamaz 2020).

Although the rabbit mandible is used as an experimental model in implant dentistry and cranio-maxillofacial surgery to evaluate specific tissue responses, tissue regeneration and biomaterial drug delivery in the cranio-maxillofacial region (Schlund et al. 2022), literature reviews on rabbit mandible data in healthy animals are very limited. This study was carried out to create three-dimensional (3D) models of the mandible using computed tomography (CT) images of a New Zealand rabbit and to reveal whether there were differences between genders.

2 Materials and Method

In the study, 12 healthy New Zealand rabbits (14 weeks old, 2580-3160 g) with the same care and feeding conditions, were used. The rabbits were obtained from euthanized animals as a result of a scientific study conducted at Karamanoğlu Mehmetbey University Faculty of Health Sciences.

The skulls of rabbits were scanned using a computerized tomography (Siemens, Somatom Sensation 64, Erlangen, Germany) device at 130 kVp, 300 mA, 330 msec and 0.5 mm slice thickness, and their images were obtained and saved in

DICOM (Digital Imaging and Communications in Medicine) format. Turgut et al. (2023) and Selcuk (2023) were used as references for the CT scan protocol. Three-dimensional modeling of the mandible was performed by importing CT images into MIMICS 20.1 (The Materialize Group, Leuven, Belgium). Morphometric measurements were performed on 3D images. Morphometric measurements and measurement points were determined using the relevant literature and were given in Table 1 and Figure 1 (Akbulut et al. 2014; Remzi et al. 2019). The nomenclature on the mandible was based on Nomina Anatomica Veterinaria (2017).

2.1 Statistical Analysis

The study's morphometric data analysis was performed using SPSS software version 21.0. The compliance of the variables to a normal distribution (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests) were examined and it was determined that the data were parametric. Independent Samples t-test was used to compare the data obtained from female and male rabbits. Each gender was tested separately for correlations using Pearson Correlation coefficient calculations. Data are expressed as mean ± standard error (SE). $p<0.05$ was considered statistically significant.

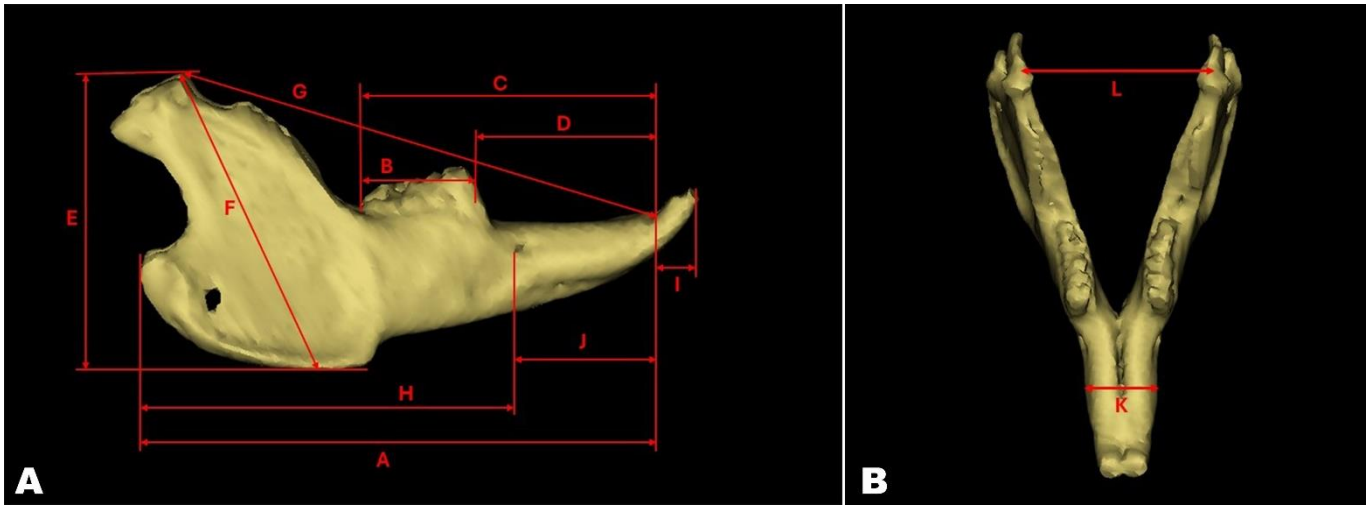

Fig. 1 A- Right side view of the mandible; **B-** Craniodorsal view of the mandible

Table 1 Mandible measurement points

Measurement	Measuring Points
A	Length between infradentale and gonion caudale
B	Length between molar teeth
C	The length between the infradentale and the alveolar aboral edge of the 3rd molar tooth
D	The length of the diastema (The length between the infradentale and the alveolar oral edge of the first premolar tooth)
E	Ramus mandibulae height (length between Gonion ventralis and the extreme point of processus condylaris)
F	The length between the plane passing parallel to the facies articularis of the processus condylare and the gonion ventrale
G	The length between infradentale and the extreme point of the processus condylare
H	The length between the caudal edge of the foramen mentale and the gonion caudale
I	Corona length of the mandibular tooth (The length between the tip of the mandibular incisive teeth and the tip of the alveolus of these teeth)
J	The length from incisor to oral border of foramen mentale
K	Width of mandibular body
L	Distance between left and right processus condylaris: measured from middle point

3 Results

Length measurements of the New Zealand rabbit mandible were given in Table 2, and correlation values of morphometric data were given in Table 3. When the measured values were compared for males and females, it was determined that the length between the molar teeth (B) was larger in females, and the corona length of the mandibular tooth (I) was larger in males and was statistically significant ($p<0.05$). No difference was detected between other measured length values ($p>0.05$).

In the correlation analysis in female rabbits, it was determined that A value was positively correlated with C, F, G, H and K values, D was positively correlated with F, G, H values, and H and K values were positively correlated ($p<0.05$). Additionally, it was determined that there was a strong positive correlation between C and D values, F and G, H values ($p<0.01$). When the values of male rabbits were examined, it was determined that A value showed a positive correlation with C, D, H values, C with J values, and J with D, G values ($p<0.05$). It was also determined that A and G values, C and D values had a strong positive correlation ($p<0.01$).

Table 2 Morphometric measurement values of the mandible obtained from 3D reconstruction

Measurement	Female	Male	p
A	62.553±1.146	61.468±0.978	0.488
B	14.077±0.218	14.803±0.217	**0.040***
C	34.972±0.572	34.838±0.629	0.879
D	20.953±0.422	20.470±0.514	0.484
E	38.297±0.482	39.330±0.595	0.207
F	40.435±0.590	41.255±0.569	0.341
G	59.720±1.349	57.748±0.993	0.267
H	44.512±0.862	44.655±0.398	0.883
I	5.875±0.269	4.713±0.116	**0.003***
J	14.700±0.198	14.527±0.473	0.742
K	10.422±0.238	10.447±0.085	0.923
L	31.587±0.504	32.408±0.393	0.229

*$p<0.05$; independent samples t test

Table 3 Correlation analyses of the mandible

	A	B	C	D	E	F	G	H	I	J	K	L
A	1	0.449	0.851*	0.810	0.131	0.880*	0.880*	0.916*	0.806	0.481	0.860*	-0.539
B	0.035	1	0.707	0.448	0.601	0.155	0.158	0.216	0.801	0.343	0.236	0.327
C	0.858*	0.359	1	0.936**	0.485	0.723	0.773	0.797	0.803	0.191	0.685	-0.420
D	0.876*	0.255	0.990**	1	0.486	0.833*	0.898*	0.882*	0.625	0.051	0.651	-0.636
E	-0.234	-0.756	-0.574	-0.521	1	0.237	0.240	0.200	0.458	-0.029	-0.127	0.189
F	0.304	-0.520	-0.148	-0.104	0.789	1	0.982**	0.985**	0.634	0.233	0.799	-0.731
G	0.963**	-0.058	0.786	0.836*	-0.161	0.370	1	0.987**	0.574	0.187	0.770	-0.781
H	0.897*	0.168	0.687	0.658	-0.199	0.374	0.793	1	0.652	0.187	0.858*	-0.769
I	0.352	-0.183	0.057	0.006	0.461	0.660	0.199	0.615	1	0.494	0.659	-0.059
J	0.780	0.276	0.842*	0.876*	-0.366	0.094	0.846*	0.527	-0.133	1	0.126	0.295
K	0.014	0.258	-0.165	-0.258	-0.113	0.069	-0.152	0.434	0.563	-0.446	1	-0.693
L	-0.146	0.644	-0.009	-0.148	-0.348	-0.290	-0.371	0.225	0.404	-0.358	0.780	1

*$p<0.05$, **$p<0.01$; Gray cells in the table are data for female New Zealand rabbits.

4 Discussion

Rabbit mandible is used as an experimental model in interventional applications such as dentistry and implants (Schlund et al. 2022; Kim et al. 2023). In this study, length measurements were made by three-dimensional modeling of the mandible on CT images in a healthy New Zealand rabbit.

In the study examining the effect of the gender factor in New Zealand rabbits, it was determined that the morphometric measurements of the mandible in male rabbits were larger than in female rabbits (Akbulut et al. 2014). The measured magnitude in male rabbits was not observed in our study. Akbulut et al. (2014) also found that the length between infradentale and gonion caudale was 66.62±3.32 mm in males and 66.15±2.10 mm in females (Akbulut et al. 2014). These values were found by Remzi et al. (2019) on mandible CT images of New Zealand rabbits as 62.260±0.224 mm in males and 66.960±0.224 mm in females. Similar results were obtained in our study. In Akbulut et al. (2014) study, they found that the length between the molar teeth was 16.55±0.44 mm in males and 16.28±0.56 mm in females, the length between the infradentale and the alveolar aboral edge of the 3rd molar was 38.24±1.31 mm in male rabbits and

38.01±1.36 mm in female rabbits, the length of the diastema was 21.97±1.02 mm in male rabbits and 21.51±0.92 mm in female rabbits, ramus mandibulae height was 44.86±1.79 mm in male rabbits and 44.82±2.11 mm in female rabbits, the length between the plane passing parallel to the facies articularis of the processus condylare and the gonion ventrale was 42.05±1.36 mm in male rabbits and 41.32±0.82 mm in female rabbits, the length between the caudal edge of the foramen mentale and the gonion caudale was 48.76±1.75 mm in male rabbits and 48.01±1.19 mm in female rabbits. In Remzi et al. (2019) study, these values were 15.740±0.266 mm, 35.060±0.127 mm, 19.780±0.232 mm, 37.020±0.245 mm, 40.000±0.289 mm, 46.100±0.216 mm in male rabbits and 16.260±0.266 mm, 38.160±0.127 mm, 21.960±0.232 mm, 41.180±0.245 mm, 42.760±0.289 mm, 47.280±0.216 mm in female rabbits, respectively. The findings of these two studies were consistent with the results of our study.

Akbulut et al. (2014) stated that the length between the infradentale and the extreme point of the processus condylare was 71.00±2.96 mm in males and 70.18±3.13 mm in females, and the corona length of the mandibular tooth was 13.89±3.75 mm in males and 12.97±1.81 mm in females. In our study, these values were found to be 57.748±0.993 mm and 5.875±0.269 mm in males, and 59.720±1.349 mm and 4.713±0.116 mm in females, respectively. In Remzi et al. (2019), it was found that the length from the incisor of the mental foramen to the edge of the mouth was 13.780±0.303 mm in males and 15.960±0.303 mm in females, the width of the mandibular body was 10.980±0.408 mm in males and 10.894±0.408 mm in females, the distance between the left and right processus condylaris was 26.740±0.662 mm in males and 28.260±0.662 mm in females. In our study, these values were 14.527±0.473 mm, 10.447±0.085 mm and 32.408±0.393 mm in males, and 14.700±0.198 mm, 10.422±0.238 and 31.587±0.504 mm in females, respectively. Upon comparing the data from two studies, while the measurements of the width of the mandibular body showed agreement, a discrepancy was observed between the length from the incisor of the mental foramen to the edge of the mouth and the distance between the left and right processus condylaris. The disparity in the studies was thought to have resulted from the age difference among the used rabbits.

In the length measurements Salih (2016) made on the mandibles of adult healthy rabbits, the length between the infradentale and the gonion caudale in males was 4.648±0.153 cm, the length between the caudal edge of the foramen mentale and the gonion caudale was 1.655±0.109 cm, and the length from the incisor of the foramen mentale to the edge of the mouth was 1.201±0.017 cm. stated that the width of the mandibular body was 0.955±0.143 cm and the distance between the left and right processus condylaris was 2.695±0.938 cm. These values in female rabbits were 5.248±0.133 cm, 2.178±0.098 cm, 1.202±0.032 cm, 1.068±0.140 cm, 2.968±0.079 cm, respectively. When these data were compared with our study, they showed incompatibility with the measurements of the length between the infradentale and gonion caudale and the distance between the left and right processus condylaris. It was thought that the current difference was due to age and breed differences.

In a study on male New Zealand rabbit mandibles using ultrasound, El-Bialy et al. (2003) stated that the height of the ramus mandible in healthy rabbits was 29.5±1.11 mm. In our study, this value was found to be 39.330±0.595 mm. It was thought that the current difference might be due to the difference in the method used and the inconsistency in the ages of the rabbits.

In a study in which no sexual dimorphism was performed by Borie et al. (2017) that used a caliper to evaluate different anatomical regions for implantation and oral surgery, the largest length of the mandible was 67.2±2 mm. In our study, these values were determined as 61.468±0.978 in male rabbits and 62.553±1.146 in female rabbits.

In a study conducted on New Zealand rabbits over two years old, without specifying gender, Monfared (2013) stated that the length of the foramen mentale from the incisor to the edge of the mouth was 18.9±0.4 mm, the length between the caudal edge of the foramen mentale and the gonion caudale was 53±4.3 mm, and the length between the infradentale and the gonion caudale was 75±5.5 mm. Our study found lower measurement values than reported in Monfared (2013) study, which we attributed to the use of younger rabbits.

In a study on adult female New Zealand rabbits, Campillo et al. (2014) reported that the diastema between the incisors and premolars was approximately 19 mm long. In our study, this value was 20.470±0.514 mm in male rabbits and 20.953±0.422 mm in female rabbits.

When the length measurements obtained as a result of our study were compared, it was concluded that they could not be used in sex discrimination of the New Zealand rabbit due to the small difference in morphometric values (Akbulut et al. 2014).

5 Conclusion

The use of three-dimensional anatomical models has increased with the development of methods such as microCT and MRI (Selcuk 2023). These methods, which use X-rays or a magnetic field, scan images of the bones, soft tissues, organs and vessels in the body from different angles and display them in sections (Dayan et al. 2019). With 3D models created from the images obtained, the structures of organs can be observed, measurements can be made, animal research models can be developed, and it helps the physician in the diagnosis of bone diseases and surgical operations (Haleem and Javaid 2019). It is anticipated that the 3D mandible model and measurements obtained in this study will be a resource for scientists working on experimental mandible surgery in rabbits, will guide researchers as reference data in creating a rabbit model, will assist the physician in the clinic, and will help in learning the anatomy of this region.

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Authors' contributions

MLS: conceptualization, methodology, investigation, writing original draft and editing.

Conflict of interest disclosure

The authors declare that they have no conflict of interest

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