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# CRANIOMETRIC MEASUREMENTS OF THE *FLEMISH GIANT* RABBIT AND THE DWARF PET RABBIT SKULL (*ORYCTOLAGUS CUNICULUS DOMESTICUS*)

MASURATORI CRANIOMETRICE LA IEPURII DIN RASA URIAȘ GERMAN (*FLEMISH GIANT)* ȘI LA IEPURII DIN RASELE PITICE DE COMPANIE (*ORYCTOLAGUS CUNICULUS DOMESTICUS*)

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**ABSTRACT** | **REZUMAT**

Since the number of pet rabbits had raised and they had become popular pets, the dental pathology of these rabbits had multiplied, so it became a very studied subject. Examination of the skull and the oral cavity with the help of Computed Tomography and 3D reconstruction offers valuable data that offers information on predisposition regarding the development of dental disease and also about small isolated lesions that otherwise would have been undiscovered. The aim of this study was to find data that could be considered the golden standard based on the skull's morphometry and the facial index on a reconstructed 3D model skull obtained using Computed Tomography and to compare these values of clinically healthy individuals and rabbits that have been diagnosed with dental pathology. Craniometric measurements and the facial index represent the most important parameters in identifying rabbits with predisposition of developing dental disease, being also an option to select individuals for breeding pet rabbits. Besides the above mentioned parameters, we also used the occlusal surface length and the length of the diastema. The results of this study show that using these parameters can provide statistically relevant data in identifying individuals which can in the future develop dental disease but the occlusal surface length and the length of the diastema does not offer concluding data on this subject. There is no significant difference between the cranial index obtained from female and male rabbits, one exception is the facial index where we found relevant differences. In the Flemish Giant and the Dwarf rabbit breeds which was used as biological material, these craniometric measurements of the skull can be relied on in identifying the severity of the malocclusion of the teeth and the predisposition to develop dental disease. Using CT scans of the skull and the rabbit teeth offers possibility to study in depth the structure of the dentition, the bone structure and the soft tissue as well.

**Keywords**: leporids, dentition, computed tomography, pathology, craniometrics

Odată cu creșterea numărului de iepuri de companie s-a diversificat și multiplicat patologia dentară, aceasta fiind un subiect intens studiat și de actualitate. Examinarea craniului și a cavității bucale la iepuri cu ajutorul CT-ului și a reconstrucției 3D, oferă date pe baza cărora se poate determina predispoziția unui individ la dezvoltarea anumitor patologii dentare, precum și identificarea unor leziuni izolate, de mici dimensiuni. Scopul acestui studiu a fost de găsi anumite valori care să fie considerate etalon, pe baza morfometriei craniului și a indexului facial, având ca model de lucru reconstrucția 3D a craniului cu ajutorul CT-ului și compararea acestui etalon cu valorile obținute, atât la iepurii clinic sănătoși, cât și la cei diagnosticați cu patologii dentare. Măsurătorile craniometrice și indexul facial reprezintă cei mai importanți parametri în identificarea exemplarelor cu o anumită predispoziție în dezvoltarea unor afecțiuni dentare, constituind totodată și o modalitate de selecție a iepurilor de companie Pe lângă cei doi parametri enunțați au mai fost utilizați suprafața ocluzală și lungimea diastemei. Rezultatele obținute au demonstrat faptul că utilizarea acestor parametrii în stabilirea predispoziției unui individ la anumite patologii dentare este relevantă, însă suprafața ocluzală și lungimea diastemei nu oferă date concludente în această privință. Totodată, s-a demonstrat faptul că, nu există diferențe semnificative din punct de vedere statistic în ceea ce privește valorile indecșilor cranieni calculați la femele comparativ cu masculii, cu excepția indexului facial. La iepurii din rasa uriaș german și la cei din rasele pitice, care au constituit materialul biologic luat în studiu, distanțele și indecșii măsurați la nivelul craniului pot constitui metode de lucru adecvate în stabilirea gradului de malocluzie și a predispoziției către alte patologii dentare. Utilizarea CT-ului în examinarea craniului și a dinților la iepuri oferă și posibilitatea de a se studia în detaliu structura dinților, structurile osoase adiacente și țesuturile moi.

**Cuvinte cheie**: leporide, dentiție, computer tomograf, patologie, craniometrie

The domesticated rabbit, also known as the house rabbit, presents some particularities that are similar to the hare or the wild rabbits but also has characteristics

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that differs from them. The domesticated rabbit is part of the Kingdom *Animalia*, Phylum *Chordata*, Class *Mammalia*, Order *Lagomorpha*, Family *Leporidae*, Genus *Oryctolagus*, Species *Oryctolagus Cuniculus*, Subspecies *Oryctolagus Cuniculus Domesticus*. The Order *Lagomorpha* contains two families these being the Family *Leporidae* and *Ochotonidae*. Both of these families have a common characteristic feature and that is the presence of the third superior incisor pair which remain small and are positioned behind the maxillary incisors also known as the "peg teeth". Because the presence of the "peg teeth" the Order *Lagomorpha* is also called *Duplicidentata* (11). The oral cavity of the domestic rabbit is long and narrow, the tongue is massive and presents an obvious lingual protuberance. Lagomorphs have split upper lip and a long diastema. Leporid teeth are part of the elodont, hypselodont and aradicular teeth. Elodont teeth grow continuously throughout the life of the rabbit, hypselodont because the clinical crown is long and aradicular meaning the absence of the actual root. The cheek teeth are part of the lophodont category because they have occlusal surface and transversal ridges. Elodont dentition anatomy is different of the rest because they present as a singular elongated and homogeneous structure both in the intra and extra alveolar space. The apex of the teeth stays wide open without ever forming a root (2). The enamel of the incisors and the cheek teeth is white because they do not contain any pigment. The occlusion of the cheek teeth is anisognathus type, which means that the jaw is narrower than the maxillary bone. Because of this narrowness of the jaw, while chewing, the occlusion of the teeth only happens on one side at a time, but this keeps changing aprox. 120 times/minute (11). The germinative tissue named pulp or dental apical sac is positioned at the apex of the teeth and it keeps producing new dental substance from ameloblasts, odontoblasts and cementoblasts. There is a difference between the clinical and reserve crown, so the clinical crown is smaller in height, visible and on the outside of the dental alveolus, and the reserve crown is considered the principal part of the teeth which is positioned in the subgingival space, intraosseous. Both of these crowns together form the anatomical crown or the body of the teeth (2). The dental form of the domestic rabbit is as follows: 2(I 2/1, C 0/0, PM 3/2, M 3/3) = 28. For prehention and mastication the rabbits use a vertical movement of the incisors, the edge of the inferior incisors slides alongside the occlusal surface of the principal superior incisors. Once the food is between the cheek teeth the mandible moves laterally for chewing. For this movement the mandible is retracted from its initial position separating the incisors and aligning the cheek teeth. The temporo-mandibular joint acts as a pivot for the masseteric and pterigoidian muscles these being activated on one side at a time (11).

Raising domestic rabbits is quite easy if the right conditions are met regarding the food and the microclimate, they adapt well to the captivity and they are not bothered by the presence of men. Rabbits can be raised as pets, for their meat and also as laboratory animals. For assuring their good health and welfare annual clinical examinations are mandatory together with examination of the oral cavity and the dentition.

Dental disease can be met often in these animals which can be developed or inherited, caused by prognathism, neoplastic processes or trauma of the jaw or the teeth. The teeth can deteriorate progressively which leads to the change of the structure and the position causing the teeth to stop the growth and to lose the clinical crown or the resorption of the apical portion. The aetiology of this syndrome is not yet fully elucidated. The more known theories present the inefficient grinding of the teeth caused by improper food, genetic predisposition or Calcium/Vitamin D deficiency which leads to metabolic disease (7, 9). In diagnosing dental disease CT scanning has a major impact because the resulted image can be examined in 3 sections: sagittal, coronal and axial. Other imagistic methods can be challenging for the practitioner because of the reduced quality of the images, the superimpositions caused by the curvature of the maxillary bone and the small size of the mandible. Cone beam CT scan can provide additional data because of the superior qu-ality of the image offered compared to the unique section models, the high resolution of the images offers- the possibility to zoom in and notice even the smallest anatomical details. Leporids that present with clinical sings of dental disease as anorexia, swelling of soft tissue, epiphora or exophthalmia undergo Computed Tomography nowadays.

The CT machines of the latest generation offer DICOM format images with visually and virtually enhanced options. Digital reconstruction of the anatomical planes is highly efficient in diagnosing osseous anomalies in patients with dental disease thus helping in the management of surgical interventions in the pre and postoperative phase. CT scanning, radiology and the clinical examination should all be used together (5). Examination of the skull and oral cavity by Computed Tomography offers also a good alternative option which can offer more precise information compared to radiologic imaging especially in the anomalies of the maxillary bone and the lower jaw. CT scan could also be complementary diagnostic option when the radiographic image offers confusing details. The advantage of the CT imaging is the possibility to examine in detail the bone structure, the soft tissue and the teeth too. 3D reconstruction of the skull also provides information regarding the smallest lesions. (Fig. 1 A and B).

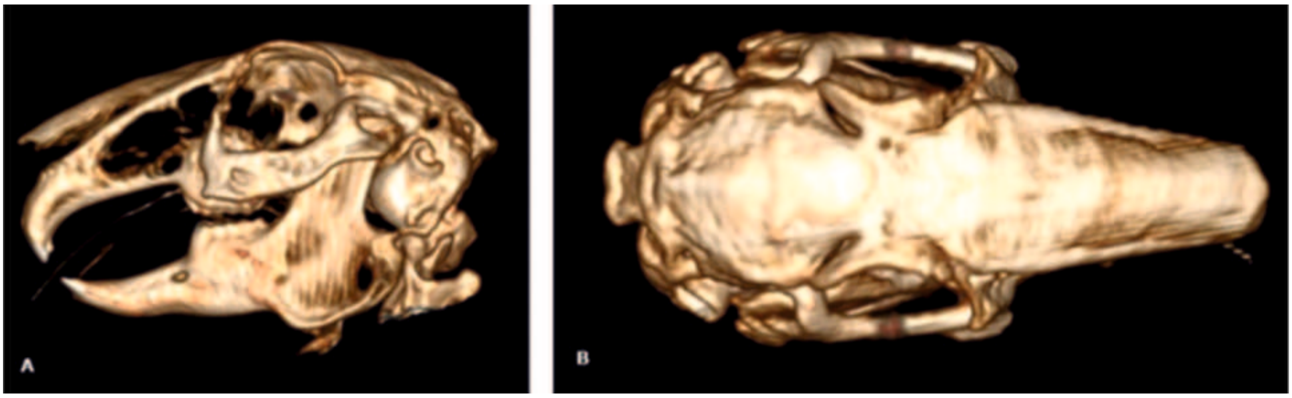


**Fig. 1.** A and B. 3D reconstruction of a rabbit skull from the study: A- Lateral view; B- Dorsal view

In the high resolution images the sections are circa 1 mm wide and even the smallest modifications can be identified and analysed regarding the bone or teeth structure, as well as the pathways of fistulae. Major benefit of the CT scan is that some of the diseases can be identified even before the symptoms show and the time needed for the full scan of the skull is much lower than the time needed for a complete radiological examination (4, 6). CT images are superior quality compared to the radiographic ones and based on those the practitioner can elaborate the correct protocol for the treatment of the disease may it be interventional, conservative or surgical.

Before the study started a bioethical permit with the nr. 204/12.03.2020 was obtained assuring welfare and protection of the animals used for research according to the European Directive 22.09.2010/63/EU and the national law 43/2014.

## MATERIALS AND METHODS

The biologic material used in this study were 4 Flemish giant pet rabbits that were clinically healthy with the age between 1 and 1.5 years, weight between 3.8 and 5 kg, and 4 dwarf breed pet rabbits diagnosed with severe dental disease, age between 5 and 13 years and weight between 1.5 and 3 kg. The study concluded in vivo and none of the animals had been sacrificed. Methods were described by general clinical examination of the skull and the oral cavity and computed tomography of the head using the machine SOMATOM® Scope Siemens (Fig. 2. A and B)

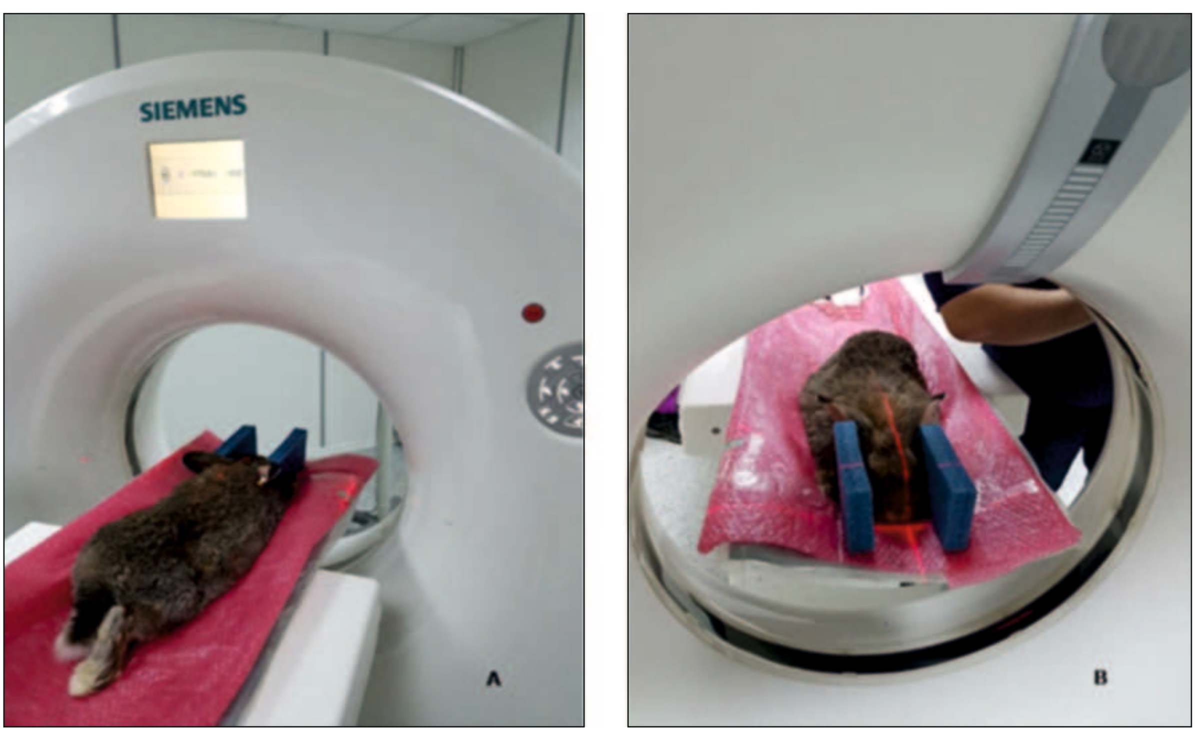


**Fig. 2.** A and B. CT SOMATOM® Scope Siemens – positioning of the patient

**Table 1**

**Distances measured on the skull and the jaw**

| Nr. | Distances | Anatomical Landmarks |
|---|---|---|
| D1 | Length of the skull | From the dorso-lateral nasal cartilage to the occipital protuberance |
| D2 | Width of the skull | Distance between the zygomatic arches |
| D3 | Nasal length | From the dorso-lateral nasal cartilage to the central point of the frontonasal suture |
| D4 | Nasal width | Maximum distance between the naso-maxillary sutures |
| D5 | Cranial length | From the central point of the frontonasal suture to the occipital protuberance |
| D6 | Cranial width | Distance between the two external auditory meatus |
| D7 | Facial length | Distance between the frontonasal suture and the centre of the incisive bone |
| D8 | Facial width | Distance between the zygomatic arches of the temporal bone |
| D9 | Length of the maxillary diastema | Distance measured from the caudal side of the superior incisor to the rostral side of the first premolar |
| D10 | Superior occlusal surface of the cheek teeth | Distance between the rostral side of the first superior premolar and the caudal side of the last molar |
| D11 | Mandibular length | Maximum length of the mandible measured from the caudal part of the inferior incisor to the gonium caudal (the most caudal part of the mandibular ramus) |
| D12 | Length of the mandibular diastema | Distance measured from the caudal side of the inferior incisor to the rostral side of the first premolar |
| D13 | | Distance measured from the caudal side of the inferior incisor to the caudal side of the last inferior molar |
| D14 | Inferior occlusal surface of the cheek teeth | Distance between the rostral side of the first inferior premolar and the caudal side of the last molar |
| D15 | Height of the vertical mandibular ramus | Maximum height of the vertical mandibular ramus measured from the highest point of the condylar process to the *gonium ventrale* (the most dorsal part of the mandibular ramus) |
| D16 | Width of the vertical mandibular ramus in lateral view | Maximum distance measured from the rostral side of the mandibular ramus to the caudal side in lateral view |
| D17 | Width of the mandibular body | Maximum distance measured between the lateral sides of the mandibular body in dorsal view |
| D18 | Intermandibular distance | Distance between the two mandibular ramus, in ventral view |
| D19 | | Distance measured from the caudal side of the inferior incisor and the incisure for vessels |

Evaluation of the digital images was done by using the analysing software RadiAnt DICOM Viewer (64-bit). The data was analysed with the help of Microsoft Excel and the statistics were concluded using the t-student test. All the Flemish giant rabbits were declared clinically healthy based on the general clinical examination. They underwent general anaesthesia for the CT scan using medetomidine 0.1 mg/kg and ketamine 10 mg/kg IM, they received diazepam 0.5 mg/kg through intravenous catheter placed in the auricular vein. Endotracheal tubes were placed for emergency situations and for maintaining the anaesthesia with isoflurane in 100% oxygen. The rabbits were placed in abdominal recumbency on the mobile table of the CT machine and the head was slightly elevated for the scan. At the end of the procedure, they received atipamezole in equal volume to the medetomidine dosage from earlier. The dwarf rabbits were examined at the Exotic animals' clinic (NAC) of the Faculty of Veterinary Medicine, USAMV Cluj Napoca. They were diagnosed with severe dental disease. The owners of these rabbits signed the agreement for these pets to participate in this study and the risk assessment for the anaesthesia and diagnostic imaging procedures. After obtaining the CT scans for both the healthy and the affected rabbits, we used 3D reconstruction of the skulls and measured 19 distances of the anatomical structures in coronal, sagittal and axial position both on the maxillary and the mandible bones. (Table 1; Figs. 3, 4, 5, 6)

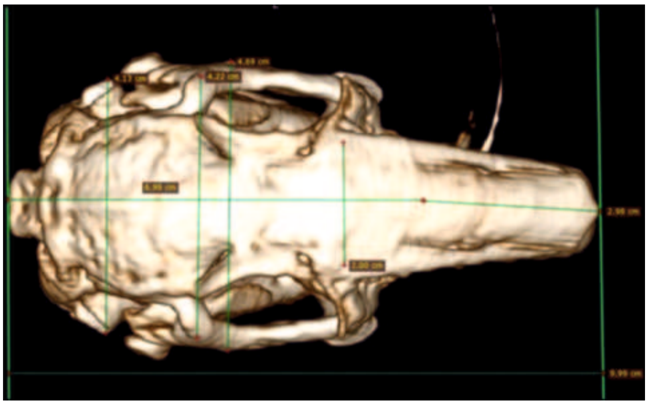

**Fig. 3.** Distances measured on the skull in dorsal view: Length of the skull, Width of the skull, Nasal length, Nasal width, Cranial length, Cranial width, Facial width

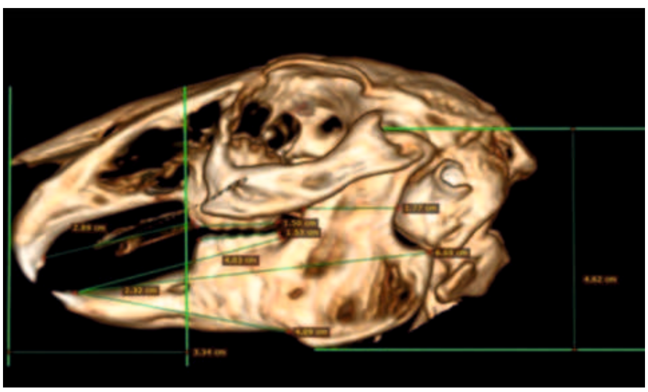

**Fig. 4.** Distances measured on the skull in lateral view: Facial length, Length of the maxillary diastema, Superior occlusal surface of the cheek teeth, Mandibular length, Length of the mandibular diastema, Distance measured from the caudal side of the inferior incisor to the caudal side of the last inferior molar, Inferior occlusal surface of the cheek teeth, Height of the vertical mandibular ramus, Width of the vertical mandibular ramus, Distance measured from the caudal side of the inferior incisor and the incisure for vessels

**Table 2**

**Measured indexes of the skull**

| Nr. | Index | Calculation |
|---|---|---|
| 1 | Skull index | Skull width (D2) / Skull length (D1) *100 |
| 2 | Cranial index | Cranial width (D6) / Cranial length (D5) *100 |
| 3 | Nasal index | Nasal width (D4) / Nasal length (D3) *100 |
| 4 | Facial index | Facial width (D8) / Facial length (D7) *100 |

The anatomical landmarks followed are according to a study by Özkadif and Eken (2016) and Akgün et al., (2019) (1, 12). We added 4 new measurements which are: the length of the diastema, the superior and inferior occlusal surfaces and the distance between the caudal side of the inferior incisor and the vascular dent of the mandible.

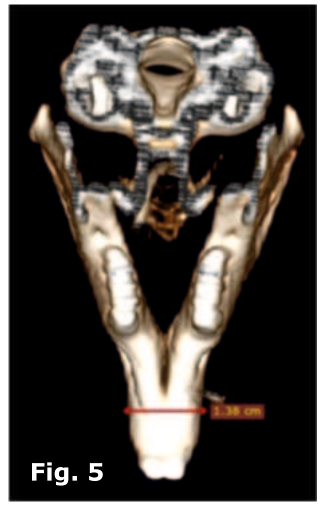



**Fig. 5.** Width of the body of the mandible

**Fig. 6.** Distance between the two mandibular ramus in ventral view

## RESULTS AND DISCUSSIONS

Congenital malformations can appear at the early age of 8-10 weeks and they are usually discovered only at the age of 12-18 months after the elongation of the dental crown had already occurred. Most of all, the brachiocephalic breeds are predisposed to develop prognathism or brevignathism. The primary malocclusion and the elongation of the incisors together with the secondary malocclusion of the cheek teeth cannot be corrected at an advanced age. Incisors presented with rotational curvature of the crown can penetrate the hard palate or the cheek if untreated (8).

Akgün et colab., 2019 in their study demonstrate that the measurements done on the 3D reconstruction of the skull of a rabbit are efficient and accurate and they reflect the reality. Studies show that in the case of New Zealand White rabbits there is a statistically significant difference between the indexes of the skull of a female and a male subject, the females presenting a higher cranial index (1, 3, 12). But in our study, we could not demonstrate this affirmation nor in the case of the healthy Flemish giants nor in the case of dwarf rabbit breeds with dental disease.

The female rabbits from the dental disease lot had a significant difference compared to the male rabbits from the same lot based on the average value of the 19 lines we measured, the females had higher values than the males ($p<0.05$) (Table 3).

The average values of the measured distances present undeniable differences between the healthy rabbits (Table 4) and the ones diagnosed with pre-existent dental disease, exceptions being the distances

**Table 3**

**Average values of the distances measured in the lot of rabbits presenting dental disease**

| Measured distances | Average (cm) | Standard deviation | Average females (n=2) | Average males (n=2) |
|---|---|---|---|---|
| D1* | 7.7325 | 0.460389328 | 7.785 | 7.68 |
| D2* | 4.0325 | 0.221265301 | 4.02 | 4.045 |
| D3* | 2.2675 | 0.316372671 | 2.31 | 2.225 |
| D4* | 1.41375 | 0.384824094 | 1.5 | 1.3275 |
| D5* | 5.48 | 0.284253408 | 5.49 | 5.47 |
| D6* | 3.1725 | 0.100457288 | 3.205 | 3.14 |
| D7* | 2.6675 | 0.229981883 | 2.66 | 2.675 |
| D8* | 3.585 | 0.209523268 | 3.605 | 3.565 |
| D9* | 2.035 | 0.208726296 | 2.07 | 2 |
| D10 | 1.405 | 0.159269164 | 1.325 | 1.485 |
| D11* | 5.2625 | 0.47717048 | 5.44 | 5.085 |
| D12* | 1.6725 | 0.215619263 | 1.78 | 1.565 |
| D13* | 3.125 | 0.407308237 | 3.305 | 2.945 |
| D14 | 1.1975 | 0.202710796 | 1.355 | 1.04 |
| D15* | 3.515 | 0.081853528 | 3.495 | 3.535 |
| D16* | 1.4475 | 0.110867789 | 1.46 | 1.435 |
| D17* | 1.115 | 0.073257537 | 1.105 | 1.125 |
| D18* | 3.6 | 0.273861279 | 3.56 | 3.64 |
| D19* | 3.1075 | 0.237258649 | 3.19 | 3.025 |

**Table 4**

**Average values of the distances measured in the lot of clinically healthy rabbits**

| Measured distances | Average (cm) | Standard deviation | Average females (n=2) | Average males (n=2) |
|---|---|---|---|---|
| D1 | 9.9775 | 0.429059048 | 10.105 | 9.85 |
| D2 | 4.7775 | 0.075443135 | 4.715 | 4.84 |
| D3 | 2.96 | 0.254950976 | 3.025 | 2.895 |
| D4 | 1.9975 | 0.102753751 | 2.065 | 1.93 |
| D5 | 6.985 | 0.169803808 | 7.06 | 6.91 |
| D6 | 4.1375 | 0.037749172 | 4.115 | 4.16 |
| D7 | 3.27 | 0.302103735 | 3.33 | 3.21 |
| D8 | 4.285 | 0.154380482 | 4.18 | 4.39 |
| D9 | 2.8175 | 0.114127122 | 2.89 | 2.745 |
| D10 | 1.4675 | 0.039475731 | 1.475 | 1.46 |
| D11 | 6.8125 | 0.265879045 | 6.74 | 6.885 |
| D12 | 2.3 | 0.162685791 | 2.34 | 2.26 |
| D13 | 4.0175 | 0.188569174 | 4.07 | 3.965 |
| D14 | 1.62 | 0.149888848 | 1.655 | 1.585 |
| D15 | 4.735 | 0.188414437 | 4.58 | 4.89 |
| D16 | 1.7125 | 0.128679188 | 1.66 | 1.765 |
| D17 | 1.305 | 0.07 | 1.3 | 1.31 |
| D18 | 4.4825 | 0.351887766 | 4.24 | 4.725 |
| D19 | 3.9625 | 0.28929512 | 4.06 | 3.865 |

**Table 5**

**Average values of the indexes calculated in the lot of rabbits presenting dental disease**

| Calculated indexes | Average | Standard deviation | Average females | Average males |
|---|---|---|---|---|
| Skull index | 52.16456253 | 0.656414532 | 51.643132 | 52.6859926 |
| Cranial index | 57.94262736 | 1.439313525 | 58.382236 | 57.5030189 |
| Nasal index | 62.66333955 | 17.31027568 | 66.796455 | 58.5302237 |
| Facial index* | 299.0210422 | 109.1442774 | 366.1624 | 231.879682 |

**Table 6**

**Average values of the indexes calculated in the lot of clinically healthy rabbits**

| Calculated indexes | Average | Standard deviation | Average females | Average males |
|---|---|---|---|---|
| Skull index | 47.96113806 | 2.544149357 | 46.568333 | 49.3539431 |
| Cranial index | 59.26042667 | 1.537238953 | 58.343734 | 60.1771198 |
| Nasal index | 67.71796482 | 4.324638524 | 65.725037 | 69.7108931 |
| Facial index | 132.2071981 | 17.34289335 | 122.29338 | 142.121021 |

measured at the level of the occlusal surfaces. In the indexes category, only the facial index ($p<0.05$) showed significant difference between the healthy and the affected rabbits. The facial index is the most important criteria in separating the breeds,because most of the dwarf rabbits are also brachiocephalic (Table 5).

The average values of the indexes calculated on the rabbit skulls that are affected by dental disease have shown a relevant difference when compared to the ones calculated on the healthy lot (Table 6).

Related studies demonstrate that dwarf rabbit breeds show the highest predisposition rate to developing dental disease because of the modified facial index, these being significantly different in the subjects with dental disease compared to the clinically healthy ones (8).

## CONCLUSIONS

Our research shows that examining the head and the teeth of the rabbit with the help of Computed Tomography as a diagnostic tool offers higher value data compared to radiography identifying the anomalies of the mandible and the maxilla, and 3D reconstruction of the skull gives access to a better understanding of the dental lesions that are isolated and small in size. The facial index can be considered one fundamental parameter in accurate selection of the rabbits that may present predisposition to dental disease in the future. The occlusal surfaces and the length of the diastema have no correlation to the above-mentioned predisposition. This study shows that there are no differences between the female and the male skull, the only exception being the facial index. Both in the Flemish giant and the dwarf rabbit breeds, these values and distances that we measured could be considered base work methods in identifying rabbit patients that later may develop dental pathologies. Using computed tomography to examine the rabbit head can offer valuable data and in depth details about the osseous and soft tissue as well as the dental structures so it cannot be looked over during and examination when the patient presents specific symptomatology.

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