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SHAPE VARIABILITY IN THE SKULL OF LONG-TAILED CHINCHILLA (*CHINCHILLA LANIGER*, MOLINA 1782)
PART 1. CRANIAL ANGLES

ZMIENNOŚĆ KSZTAŁTU CZASZKI SZYNSZYLI MAŁEJ (*CHINCHILLA LANIGER*, MOLINA 1782)
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Streszczenie. Celem badań było oszacowanie wielkości zmian wartości kątów czaszki szynszyli małej w okresie wzrostu i rozwoju oraz porównanie wartości ustalonych dla osobników dorosłych zwierząt hodowlanych z wynikami pomiarów czaszek zwierząt bytujących w warunkach naturalnych. Badaniami objęto czaszki hodowlanych 319 samców i samic szynszyli małej w sześciu okresach życia, obejmujących wiek od 1 do ponad 800 dni oraz 32 czaszki zwierząt dorosłych pochodzące z Muzeum Historii Naturalnej w Londynie. Czaszki sfotografowano, na fotografiach wyznaczono 12 kątów wyprowadzonych z punktów stałych czaszki. Różnice między grupami oraz współzależności między cechami szacowano modułami z programu Statistica 9 v.Pl. W wyniku badań stwierdzono, że pomimo różnych warunków życia, okres około stuletniej hodowli nie wykreował nowego morfotypu dla tego gatunku gryzoni.

Key words: angle, chichilla, geometry, measurements, skull.
Słowa kluczowe: czaszka, geometria, kąty, pomiary, szynszyle.

INTRODUCTION

So far, studies on the skull morphology in long-tailed chinchilla (*Chinchilla laniger*, Molina 1782) have aimed at explaining the causes of unnatural thickening of the bone tissue in the maxillary and mandibular region, hypertrophy of the incisors, unnaturally broad surface of the premolars and molars, including the occurrence of pathological forms (Crossley et al. 1998; Crossley 2001). This results in changes in the values of metric traits of such crania and mandibles (Baranowski et al. 2008) and the location and symmetry of epigenetic traits occurring on them when compared to the skulls of animals being caught in natural conditions or living in animal farms (Baranowski and Wojtas 2011 a, 2011 b).

Animal skulls are an excellent object to study morphological variability and they illustrate the course of species evolution which can be also affected by non-genetic factors, including the environment (Ingervall and Bitsanis 1987; Kiliaridis et al. 1985; Kilidaris 1989; Varrela 1992;

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Zuccarelli 2004). The main tool in such studies are metric and non-metric traits being already mentioned above. However, a measurement technique consisting in the examination of geometric correlations between metric traits of the skull, particular parts of which undergo rebuilding together with successive development stages, has not been applied so far with respect to rodents. Postnatal growth and development of particular skull parts have been described in different animal species (Sperber 2001; Baranowski and Furkioti 2007) and humans (Sierpińska et al. 2008). In the puppies of dolichocephalic breeds, such as German Shepherd, the neurocranium has a shape being similar to a circle, while the zygomatic breadth at birth is larger than the total skull length; these proportions change with age (Onar and Güneş 2003).

Changes in the shape of long-tailed chinchilla skull, being distinguished from the skulls of other Rodentia species by its characteristic conformation, have not bee yet described. The skull of these animals is characterised by two very large orbits under which the insertions of masticatory muscles are situated, different structure of the mandibular bones, different position of the lacrimal bones, and different articulation of parietal, temporal and occipital bone (Lavocat 1974).

The skull is an environmentally flexible structure, while the food being taken is an important element affecting the biomechanics of the cranium-mandible complex and contributes to its development, growth and general morphology. Living conditions in captivity and in the wild are the factors determining construction of the skeleton. Answering the question whether origin may be a source of variability for certain traits of long-tailed chinchilla skulls has become an key objective of this study. To achieve this objective, it was decided to estimate the magnitude of changes in the values of angles being determined by craniometric points occurring with time and to determine correlations between these angles and the selected metric traits of long-tailed chinchilla skulls in chosen periods of growth and development and to compare these values with the results being determined on the skulls of animals living under natural conditions.

MATERIAL AND METHODS

The study was conducted on 319 skulls of male and female long-tailed chinchillas, in six periods of life, covering the age from 1 day to more than 800 days (1–18 days, n = 29; 30–58 days, n = 9; 258–360 days, n = 126; 366–399 days, n = 65; 400–507 days, n = 52; more than 800 days, n = 38). The skulls originated from carcasses being skinned on a chinchilla farm in Poland (53º40’N; 15º08’E) and from 32 wild animals, the skeletons of which are housed at the Natural History Museum in London. Based on the analysis of cranial suture obliteration and comparison with the skulls of farm chinchillas of known age from Poland, the museum long-tailed chinchilla skulls were found to came from mature animals (*subadult*). The age of farm animals at slaughter was determined based on their record cards. Skull specimens with pronounced hypertrophic defects of the cranium and the mandible were removed from both the museum and the farm groups and excluded from further analysis. The skulls of farm chinchilla are being housed in the collection of the Department of Animal Anatomy, Faculty of Biotechnology and Animal Husbandry, Western Pomeranian University of Technology, Szczecin (Poland).

Each of the skulls was placed under digital camera lens, receiving its frontal aspect. Photographs were taken with a digital camera (Canon EOS-1000D with Macro EFS60 mm f/2.8 lens) installed on a calibrated frame. The skull position obtained this way was exactly the one so its frontal plane was perpendicularly to the camera lens and image sensor. Photographs were transferred to MultiScan 8.0 computer software by means of which the values of angles being determined with the lines connecting the following craniometric points: ZPZ, SmPSm, EuPEu, ZNZ, SmNSm, EuNEu, AZP, AZN, EuAEu, ZAZ, AEuP and NSmP, where A (*Akrokranion*) is the highest point on the occipital bone in the middle plane; Eu (*Euryon*) is the most lateral point of the braincase; N (*Nasion*) is the median point of the naso-frontal suture (intersection with the sagittal suture); P (*Prosthion*) is the most oral point of the praemaxillae; Sm (*Supramolare*) is the most oral point of the facial crest; and Zyg (*Zygion*) is the most lateral point on the zygomatic bone were estimated.

The empirical results obtained from measurements of metric traits and angles were entered into a database of Statistica v.9 PL software package by means of which the distribution o traits was checked. Since no normal distribution of traits was observed, differences between groups were evaluated with a non-parametric Mann-Whitney's U test for two independent samples and the Kruskal-Wallis test for many independent samples. Relationships between selected skull traits were estimated using the Spearman's rank correlation coefficient. When evaluating the differences and the values of correlation coefficients, two levels of significance were used, i.e. $P \leq 0.01$ and $P \leq 0.05$. The terminology being applied conforms to Veterinary Anatomical Nomenclature (Milart 2002).

RESULTS AND DISCUSSION

The analysis of all obtained data being carried out showed no statistically significant effect of sex on the values of chinchilla cranial angles. Based on the animal birth and death (i.e. slaughter or natural death) data, the research material was divided into six age groups. The values of cranial angles and four metric traits being estimated, illustrating changes in the length of certain skull areas being determined by craniometric points (Table 1), present the dynamics of changes in its respective parts. A decreasing value of the ZPZ angle (from 61.73° to 56.78°; $P \leq 0.01$) was accompanied by an increase in the length of dorsal surface of the cranium (*Bregma-Prosthion*; $P \leq 0.01$). In the viscerocranium region, the angle being determined by the points on the facial crest and the oral point of the praemaxilla (SmPSm) underwent a significant decrease ($P \leq 0.01$) in next skull groups, with an increasing ($P \leq 0.01$) breadth across *Rostrum* up to the age between 366 and 399 days. Thereafter, this angle became smaller, like the breadth across *Rostrum*. No statistically significant difference was found between the value of the SmPSm angle being determined in farm chinchilla skulls and that of museum specimens, whereas the breadth across *Rostrum* in museum skulls was significantly smaller ($P \leq 0.01$) than that of farm animals. This region of chinchilla skull does not have teeth, thus its development in chinchillas is probably affected by ever-growing incisors.

Table 1. Angles and elements of the skull determined by selected craniometric points in different periods of life in long-tailed chinchilla
Tabela 1. Kąty i elementy szkieletu czaszki wyznaczone wybranymi punktami kraniometrycznymi w różnych okresach życia szynszyli małej

Traits Cechy	Age (days) – Wiek (dni)						sd min. –max.	NHM1) specimens Okazy z MHN1)
	1–18	30–58	258–360	366–399	400–507	>800		
ZPZ	61.73^{ABCD}	59.96^{abc}	56.37^{Aa}	56.00^{Bb}	55.88^{Cc}	56.78^{D**}	2.22–3.75	54.70** ±1.62
Br-P	29.07^{ABCDE}	35.40^{AFGHI}	47.62^{BFJ}	47.37^{CGK}	47.43^{DHL}	$58.59^{EIJKL**}$	1.65–3.71	46.31** ±3.98
SmPSm	48.69^{ABCF}	42.43^{DEH}	35.41^{ADa}	36.72^{BI}	35.61^{CE}	33.98^{FHaI}	2.57–5.46	34.36 ±2.02
Rostrum	6.92^{AB}	8.45^{EHIa}	10.11^{AEJK}	10.02^{BHL}	9.69^{CIJ}	9.39^{DaKL**}	0.51–0.80	8.82** ±0.66
EuPEu	43.85^{ABCG}	39.94^{DEFH}	33.08^{ADI}	33.14^{BEJ}	33.02^{CFK}	31.67^{GFIJK}	1.43–3.00	32.33 ±1.94
Eu-Eu	19.23^{ABCD}	22.28^{EabF}	24.37^{AEG}	24.09^{BaH}	24.06^{CbI}	$25.42^{DFGHI**}$	0.59–1.42	22.75** ±0.95
ZAZ	52.12^{ABab}	53.63	55.83^{A}	54.91^{B}	54.80^{a}	54.64^{b**}	2.27–3.25	57.25** ±2.02
ZNZ	101.58^{AC}	100.31^{b}	102.29^{aBD}	99.34^{aE}	97.45^{ABF}	$113.37^{bCDEF**}$	4.99–8.37	99.68** ±4.34
Z-Z	20.79^{ABCDE}	25.14^{AFGHI}	32.14^{BF}	32.29^{CG}	32.06^{DH}	32.66^{EI**}	0.77–3.11	30.91** ±1.69
SmNSm	165.52^{AB}	162.63	157.96^{AaD}	161.17^{E}	163.00^{aF}	146.34^{BDEF**}	8.06–16.34	162.30** ±10.70
EuNEu	64.32^{ABCF}	61.63^{aDEb}	53.24^{Aa}	52.19^{BD}	52.05^{CE}	53.50^{Fb}	2.48–4.89	52.77 ±2.87
AZP	123.39	123.28	123.31	123.13	123.48	123.51	1.90–2.96	124.17 ±1.81
AZN	103.34^{AE}	101.47	100.06^{ABF}	101.54^{G}	102.13^{BH}	97.85^{EFGH**}	2.96–5.35	102.46** ±2.49
EuAEu	74.83^{ABCG}	72.48^{DEFH}	66.08^{AD}	66.00^{BE}	65.34^{CF}	64.93^{GH**}	2.67–4.10	66.62** ±3.43
AEuP	119.88^{ABCG}	123.47^{DEFH}	130.19^{AD}	130.35^{BE}	130.24^{CF}	130.00^{GH}	1.69–4.05	130.50 ±2.23
NSmP	81.52^{ABCD}	86.50	91.25^{A}	92.01^{B}	93.02^{C}	94.99^{D}	8.11–8.98	97.26 ±8.63

Explanations: 1)NHM – Natural History Museum; mean values marked in the Table with the same letters differ significantly: lowercase at $P \leq 0.05$, uppercase at $P \leq 0.01$; mean values marked in a row with asterisks differ significantly: * at $P \leq 0.05$, ** at $P \leq 0.01$.

Objaśnienia: 1)Muzeum Historii Naturalnej; średnie oznaczone w tabeli tymi samymi literami różnią się istotnie: małe litery $P \leq 0,05$; wielkie litery $P \leq 0,01$; średnie oznaczone w wierszach gwiazdkami różnią się istotnie: * $P \leq 0,05$; ** $P \leq 0,01$.

In the neurocranium region, where the points determining the greatest neurocranium breadth (*Euryon-Euryon*) and the utmost point of viscerocranium in the middle plane of the oral edge of praemaxillae (*Prosthion*) and creating the EuPEu angle were taken into consideration, its value significantly decreased ($P \leq 0.01$) in next age groups, with a simultaneously increasing ($P \leq 0.01$) neurocranium breadth (Eu-Eu). Thereby, the braincase of adult animals was significantly broader ($P \leq 0.01$), whereas the angle smaller (statistically non-significant) than those of museum skulls. Quite similar were changes in the value of EuNEu angle on the shorter segment of the surface of the skull. The skull origin was not a source of variability for the value of the EuNEu angle. Lengthening of the skull caused that the EuAEu angle decreased to the value of about 10º ($P \leq 0.01$) in the time period from suckling to full somatic development. This angle being estimated on museum skull specimens was significantly larger ($P \leq 0.01$) when compared to those of farm animals.

The zygomatic arch is a bridge between the neurocranium and the viscerocranium and its most lateral points (*Zygion-Zygion*) together with the highest point on the occipital bone in the middle plane of the skull (*Akrokranion*) allowed determination of the ZAZ angle. Changes in the value of this angle on the chinchilla skulls being analysed were statistically significant ($P \leq 0.01$) in the time period from birth to about one year of age. Much higher variability is observed in the area being determined by the cranial points *Zygion* and *Nasion* (ZNZ) and *Eurion* and *Nasion* (EuNEu). The angles being determined by these points decreased with age. The highest value of the ZNZ angle at the age of more than 800 days (113.37º ±5.80) is probably due to the development of teeth and layers of muscles participating in the food grinding on the occlusal surface of teeth. The power of correlation between the ZNZ and ZAZ angles in farm chinchilla skulls ($r_{xy} = 0.441$) was similar to that estimated for the chinchilla skulls from the Natural History Museum, intermediate ($r_{xy} = 0.481$) and statistically significant ($P \leq 0.01$), which may point to similar development of that region of skull in farm animals and those living under natural conditions.

The value of the SmNSm angle showed differences in successive periods, while comparison of its value in the skulls of adult animals of both sets showed a smaller value ($P \leq 0.01$) in those of farm chinchillas than in museum ones, which may be caused by significantly shorter nasal bone ($P \leq 0.05$) of the latter (Baranowski et al. 2013), which is also indirectly confirmed by the AZN angle.

The AZP angle, the value of which did not differ in both skull groups, proved to be most stable, while the AEuP and NSmP angles increased significantly ($P \leq 0.01$), although the skull origin was not after all a source of variability for their values.

Tables 2 and 3 present the values of Spearman's rank correlation coefficients being estimated for the values of angles and certain metric traits of skulls in respective age groups of farm chinchillas and those of museum specimens. These coefficients illustrate clear significant correlations between selected cranial angles and points, being chosen to determine them, during the growth of dermal bones in chinchilla skulls. The power of correlation repeatedly increases with reaching successive stages of maturity.

Table 2. Values of statistically significant Spearman’s rank correlation coefficients for the analysed traits of long-tailed chinchilla skulls

Tabela 2. Wartości statystycznie istotnych współczynników korelacji rang Spearmana badanych cech czaszki szynszyli małej

Traist Cechy	Age (days) Wiek (dni)	AZP	AZN	ZAZ	EuAEu	AEuP	EuBrEu
	Farm long-tailed chinchilla specimens – Okazy szynszyli małej z hodowli						
ZPZ	1–18	–0.471*					
	30–58						
	258–360	–0.374**	–0.377**	0.237**			
	366–399		–0.307*				
	400–507	–0.481**				–0.357**	–0.289*
	>800	–0553**	–0.461**				
SmPSm	1–18						
	30–58						
	258–360				–0.176*	–0.291**	
	366–399				0.275*	–0.310*	
	400–507	–0.354*				–0.302*	
	>800						
EuPEu	1–18					–0.518*	
	30–58						
	258–360	–0.302**			0.294**	–0.418**	
	366–399					–0.386**	
	400–507	–0.443**				–0.494**	
	>800		0.399*			–0.488**	
ZNZ	1–18		–0.431*				
	30–58						
	258–360		–0.512**			0.196*	
	366–399		–0.586**	0.385**			
	400–507		–0.292*		0.309*		
	>800	–0.357*	–0.555**	0.441**			
SmNSm	1–18			–0.415*			
	30–58						
	258–360		0.241**			–0.204*	
	366–399		0.345**				
	400–507						
	>800			0.351*		0.418**	0.530**
EuNEu	1–18						–0.394*
	30–58						
	258–360		–0.194*				
	366–399		–0.324**				
	400–507		–0.335*	0.285*	0.306*		
	>800						
	NHM1) long-tailed chinchilla specimens – Okazy szynszyli małej z MHN1)						
ZPZ		–0.409*				–0.463**	
SmPSm						–0.358*	
EuPEu						–0.565**	
ZNZ		–0.524**	–0.649**	0.483**			
SmNSm			0.558**				
EuNEu							

Explanations: 1) NHM – Natural History Museum; correlation coefficient values marked with asterisks differ statistically significantly: * at P ≤ 0.05, ** at P ≤ 0.01.

Objaśnienia: 1) Muzeum Historii Naturalnej; wartości współczynników korelacji oznaczone gwiazdkami różnią są istotnie statystycznie: * – P ≤ 0,05; ** – P ≤ 0,01.

Table 3. Values of statistically significant Spearman's rank correlation coefficients for selected angles and metric traits of long-tailed chinchilla skulls from Natural History Museum and chinchilla farm animals

Tabela 3. Wartości wskaźników korelacji rang Spearmana wybranych kątów i cech metrycznych czaszek szynszyli małej pochodzących z Muzeum Historii Naturalnej i hodowli krajowej

NHM1) specimens Okazy z MHN1)	Correlations of selected cranial angles and metric traits Korelacje wybranych kątów i cechy metryczne czaszek	Farm specimens in selected periods of life Okazy z hodowli krajowej w wybranych okresach życia					
		Age (days) Wiek (dni)					
		1–18	30–58	258–360	366–399	400–507	>800
0.01	ZPZ x Br-P	–0.23	–0.75*	–0.10	0.06	–0.16	0.10
0.10	SmPSm x Rostrum	–0.38*	0.57	0.12	0.37**	0.50**	0.05
–0.05	EuPEu x Eu-Eu	–0.25	–0.13	0.13	0.17	0.11	–0.18
0.05	ZAZ x Z-Z	0.66*	0.61	0.33**	0.39**	0.01	–0.06
–0.32	ZNZ x Z-Z	0.44	–0.31	0.26**	0.30*	0.11	0.07

Explanations: 1) NHM – Natural History Museum; correlation coefficient values marked with asterisks differ statistically significantly: * at P ≤ 0.05, ** at P ≤ 0.01.

Objaśnienia: 1) Muzeum Historii Naturalnej; wartości współczynników korelacji oznaczone gwiazdkami są istotne statystycznie: * – P ≤ 0,05; ** – P ≤ 0,01.

RECAPITULATION

The fact that farm chinchilla skulls are longer and broader and are different in profile than those of wild animals has been referred to by the authors comparing the skeletons of chinchillas living under conditions of unlimited access to high-value food to those of animals being kept in captivity (Crossley and Miguélez 2001; O'Regan and Kitchener 2005). This is affected, among others, by earlier maturation being stimulated by very good alimentary conditions to which animals respond in an increase in body size (Poole et al. 1980; Tamlin et al. 2009) as well as in earlier maturation (Altmann et al. 1981; Phillips-Conroy and Jolly 1988). Living in the wild results in periodic food shortages or periodic occurrence of deficiencies in fodder components that may affect morphological differences between populations at their adult age (Zuccarelli 2004).

However, the skulls of long-tailed chinchillas of the farm population, despite significant changes occurring in the relationships between viscerocranium and neurocranium during the growth and development, preserve the correlations similar to those in the skulls coming from animals living under natural conditions. Despite diametrically opposite living conditions, which has been commonly accepted as a factor determining the development and formation of skeleton, including the skull, the period of approximately one hundred years of breeding did not create a new morphotype for that rodent species.

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REFERENCES

Altmann J., Altmann S., Hausfater G. 1981. Physics maturation and age estimates of yellow baboons *Papio cynocephalus* in Amboseli National Park Kenya. Am. J. Primatol., 1, 389–399.

Baranowski P., Furkioti K. 2007. Selected craniometrical features and cranial indices of the Polish Heath sheep rams in the first year of life. Folia Univ. Agric. Stetin., Agric., Aliment., Pisc., Zootech. 257, 3, 39–50.

Baranowski P., Wojtas J., Cis J., Musiał G., Wróblewska M., Sulik M. 2008. Value of craniometrical traits in chinchilla (*Chinchilla laniger*) skulls considering teeth defects. Bull. Vet. Inst. Pulawy 52, 2, 271–280.

Baranowski P., Wojtas J. 2011 a. Effect of hypertrophic defect on the occurrence of foraminal, shape and cribrosity features in the cranium and mandible of wild and farm chinchillas (*Chinchilla laniger*). Bull. Vet. Inst. Pulawy 55, 2, 247–260.

Baranowski P., Wojtas J. 2011 b. Asymmetry of selected foraminal, shape and cribrosity features in the head skeleton of wild and farm chinchillas (*Chinchilla laniger*). Bull. Vet. Inst. Pulawy 55, 4, 787–793.

Baranowski P., Wróblewska M., Nowak P., Pęzińska-Kijak K. 2013. Biometry of the skull of wild and farm long-tailed chinchilla (*Chinchilla laniger*, Molina 1782). Int. J. Morphol. 31, 3, 1003–1011.

Crossley D.A., Jackson A., Yates J., Boydell I.P. 1998. Use of computed tomography to investigate cheek tooth abnormalities in chinchillas (*Chinchilla laniger*). J. Small. Anim. Pract. 39, 385–389.

Crossley D.A. 2001. Dental disease in chinchillas in the UK. J. Small. Anim. Pract. 42, 12–19.

Crossley D.A., Miguéles M. 2001. Skull size and cheek-tooth length in wild-caught and captive-bred chinchillas. Arch. Oral. Biol. 46, 919–928.

Ingervall B., Bitsanis E. 1987. A pilot study on the effect of masticatory muscle training on facial growth in long-face children. Eur. J. Orthod. 9, 15–23.

Kiliaridis S., Engetröm C., Thilander B. 1985. The relation between masticatory function and and craniofacial morphology. I. A cephalometric longitudinal analysis in the growing rat fed soft diet. Eur. J. Orthod. 7, 273–283.

Kiliaridis S. 1989. Muscle function as a determination of mandibular growth in normal and hypocalcaemic rat. Eur. J. Orthod. 11, 298–308.

Lavocat R. 1974. What is an hystricomorph? [In:] The biology of hystricomorph Rodents. Ed. W.I. Rowlands, B.J. Weir. Symposia Zool. Soc. London. Academic Press, London 34, 7–21.

Milart Z. 2002. Anatomiczne Mianownictwo Weterynaryjne [Veter. anat. nomen.]. PWRiL Warszawa. [in Polish.]

Onar V., Güneş H. 2003. On the variability of skulls shape in German Shepherd (Alsatian) puppies. Anat. Rec. 272A, 460–466.

O'Regan H.J., Kitchener A.C. 2005. The effects of captivity on the morphology of captive, domesticated and feral mammals. Mammal Rev. 35, 3/4, 215–230.

Phillips-Conroy J.E., Jolly C.J. 1988. Dental eruption schedules of wild and captive baboons. Am. J. Primatol. 15, 17–29.

Poole W.E., Carpenter S.M., Simms N.G. 1980. Multivariate analyses of skull morphometrics from the two species of Grey Kangaroos, Macropus giganteus and M. fuliginosus. Austr. J. Zool. 28, 591–605.

Tamlin A.L., Bowman J., Hackett D.F. 2009. Separating wild from domestic American mink Neovison vison based on skull morphometrics. Wild Biol. 15, 266–277.

Sierpińska T., Kuc J., Gołębiewska M. 2008. Ocena parametrów morfologicznych twarzoczaszki u osób bezzębych podczas wymiany protez całkowitych [The evaluation of craniofacial morphology parameters at edentulous patients during complete dentures exchange]. Protet. Stomatol. LVIII, 4, 227–234. [in Polish.]

Sperber G.H. 2001. Craniofacial development. London BC Decker Inc.

Varrela J. 1992. Dimensional variation of craniofacial structures in relation to changing masticatory-functional demand. Eur. J. Orthod. 14, 31–36.

Zuccarelli M.D. 2004. Comparative morphometric analysis of captive vs. wild African lion (*Panthera leo*) skulls. Bios. 75, 4, 131–138.

Abstract. The aim of this study was to estimate the magnitude of changes in the values of cranial angles in long-tailed chinchilla during growth and development and comparing the values being determined for adult farm animals with the results of cranial measurements in animals living under natural conditions. The research material comprised 319 skulls of farm male and female long-tailed chinchillas in six periods of life, covering the age from 1 day to more than 800 days, and 32 skulls of adult animals from the Natural History Museum in London. The skulls were photographed and 12 angles led from fixed cranial points were determined on photographs. Differences between groups and correlations between traits were estimated by the modules of Statistica v.9 PL software package. As a result of the study, it was found that the period of approximately one hundred years of breeding did not create a new morphotype for that rodent species despite different living conditions.