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Morphometric characterization of the bovine *os cordis* using computed tomography: Influence of age, sex, and breed

Caracterización morfométrica del *os cordis* bovino mediante tomografía computarizada: influencia de la edad, el sexo y la raza

Rania Ridouh[1]*, Maya Boukerrou[1], Said Boukhechem[1], Nora Bouhsina[2], Nedjoua Lakhdara[1], Baaissa Babelhadj[3], Aurélia Borvon[4], Faiza Tekkouk-Zemmouchi[1], Eric Betti[4], Claude Guintard[4]

[1]University of Constantine 1 Frères Mentouri, Institute of Veterinary Sciences, Laboratory Gestion de la Santé et Productions animales GSPA. Constantine, Algeria.
[2]National Veterinary School of Nantes, Vet Agro Bio Nantes-Oniris, Diagnostic Imaging Department. Nantes, France.
[3]Ecole Normale Superieure de Ouargla, Algeria.
[4]National Veterinary School of Nantes, Vet Agro Bio Nantes-Oniris, Comparative Anatomy Unit. Nantes, France.
**Corresponding author: ridouhrania27@gmail.com*

ABSTRACT

The *os cordis* (dextrum and sinistrum) shows considerable variation in its presence, number, size, shape, and position, not only among species but also among individuals of the same breeds. However, quantitative data in cattle remain limited. This study aimed to determine the frequency, number, and anatomical location of *ossa cordis* in cattle and to explore the influence of age, sex, and breed on the osteometric, weight, and densitometric measurements of the *os cordis* dextrum. The correlations between these measurements and animal's age were also examined. A total of 23 bovine hearts from five breeds, including both sexes and divided into two age groups (young adults and adults), were analyzed. Heart and carcass weights were recorded for each animal. After dissection, the *ossa cordis* were removed, and three osteometric measurements along with bone weight were taken for the *os cordis* dextrum. Computed tomography was used to obtain three densitometric measurements. Data was analyzed in R using univariate, bivariate, and multivariate methods. Results showed that the *os cordis* dextrum was present in all individuals, whereas the *os cordis* sinistrum appeared only in older animals. Furthermore, adults had a significantly larger and heavier *os cordis* dextrum than young adults. Overall, the weight, size, and density of the *os cordis* dextrum increased with age. These findings suggest that the *os cordis* plays a crucial role in supporting and protecting the heart as cattle mature.

Key words: *Os cordis dextrum*; *os cordis sinistrum*; computed tomography; cattle; osteometry

RESUMEN

El *os cordis* (dextrum y sinistrum) presenta una considerable variación en su presencia, número, tamaño, forma y posición, no solo entre especies, sino también entre individuos de una misma raza. Sin embargo, los datos cuantitativos en bovinos siguen siendo limitados. Este estudio tuvo como objetivo determinar la frecuencia, el número y la localización anatómica de los *ossa cordis* en bovinos, así como explorar la influencia de la edad, el sexo y la raza sobre las mediciones osteométricas, de peso y densitométricas del *os cordis dextrum*. También se examinaron las correlaciones entre estas mediciones y la edad de los animales. Se analizaron un total de 23 corazones bovinos pertenecientes a cinco razas, incluyendo ambos sexos y divididos en dos grupos etarios (adultos jóvenes y adultos). Se registraron el peso del corazón y el peso de la canal de cada animal. Luego de la disección, se extrajeron los *ossa cordis* y se realizaron tres mediciones osteométricas, junto con el peso del hueso *os cordis dextrum*. La tomografía computarizada se utilizó para obtener tres mediciones densitométricas. Los datos fueron analizados en R mediante métodos univariados, bivariados y multivariados. Los resultados mostraron que el *os cordis dextrum* estaba presente en todos los individuos, mientras el *os cordis sinistrum* apareció únicamente en los animales de mayor edad. Además, los adultos presentaron un *os cordis dextrum* significativamente más grande y pesado que los adultos jóvenes. En general, el peso, el tamaño y la densidad del *os cordis dextrum* aumentaron con la edad. Estos hallazgos sugieren que el *os cordis* desempeña un papel crucial en el soporte y la protección del corazón a medida que el ganado madura.

Palabras clave: *os cordis dextrum; os cordis sinistrum;* tomografía computarizad; ganado vacuno; osteometría

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INTRODUCTION

The cardiac skeleton, also called heterotopic is the fibrous skeleton of the heart, mainly comprises of the fibrous rings (*annuli fibrosi*) and fibrous trigones (*trigona fibrosa*). The fibrous rings are primarily composed of intertwined bundles of collagen fibers with some elastic fibers, surrounding the atrioventricular orifices as well as the aortic and pulmonary artery orifices. The fibrous trigones correspond to dense connective tissue areas located between the aorta and the atrioventricular orifices. It is within this structure that the musculature of the atrial and ventricular walls attaches. Both the left and right trigones also contain fibrous connective tissue and hyaline cartilage and may occasionally contain one or more bones, known as the *os cordis* [1, 2].

Early hypotheses in the 19th century attributed the formation of the *os cordis* to intramembranous ossification at the level of the aortic fibrous ring. However, by the end of the same century, Vaerst [3] established that the formation of the *os cordis* occurs via endochondral ossification. Subsequent studies, particularly in water buffalo (*Bubalus bubalis*) [4], deer (*Cervidae*) [5], camels (*Camelus*) [6], and other species, confirmed that the presence of *os cordis* is preceded by cartilage in young individuals [1].

The presence of cardiac bones (*ossa cordis*) has been documented in various species under two main contexts. It is a normal anatomical structure in certain large mammals, particularly domestic species such as cattle (*Bos taurus*) [7, 8], sheep (*Ovis aries*) [9], goats (*Capra hircus*) [10] and camelids [6]. In contrast, it occurrence is generally a pathological finding in chimpanzees (*Pan troglodytes*) [11], dogs (*Canis lupus familiaris*) [12], cats (*Felis catus*) [13], and horses (*Equus caballus*) [14]. There is also the possibility of the presence of cardiac cartilage (*cartilago cordis*) without development into a bone [15, 16, 17].

In cattle, the cardiac skeleton can contain one or two bones. When present, the larger *os cordis* dextrum and the smaller *os cordis* sinistrum can be easily distinguished. Although the *os cordis* in cattle has been known and described for several decades, the literature remains focused on macroscopic observations and on limited sample sizes or breeds [1, 4].

The objective of this study is to conduct a preliminary examination of the *ossa cordis* in different cattle breeds, confirming the presence of both bones, and evaluating how their dimensions and mass are influenced by age, sex and breed, and exploring correlations between bone morphology and cardiac and body parameters. This study also aims to precisely determine the *in situ* localization of the two *os cordis* using computed tomography (CT) scanning.

MATERIALS AND METHODS

Experimental units

In this study, 23 bovine hearts were collected, including 20 obtained from the Didouche Mourad slaughterhouse and local butcher shops in the municipality of El Hamma Bouziane (Algeria), and 3 from the anatomical collection of the National Veterinary School of Nantes (ONIRIS, France). For each individual, several parameters were recorded: breed, sex, age, and carcass weight (expressed in kg). For the samples obtained from local butcher shops, the data were sourced directly from the butchers, who were also the primary livestock breeders, thus ensuring direct and accurate traceability for each animal.

The bones were collected from five breeds: Holstein (n = 10), Montbeliarde (n = 7), French Simmental (n = 3), Aubrac (n = 2), and Charolais (n = 1). The sample included 14 males and 9 females. Two age classes were defined: young adults under 36 months of age (n = 14) and adults aged 36 months and over (n = 9).

Measurement methodology

After dissection, soft tissues were carefully removed to isolate the large and small cardiac bones (respectively *os cordis* dextrum and sinistrum). The *os cordis* dextrum was weighed using a precision electronic balance (Clatronic, KW 3416, accuracy: ± 0.01 g, Germany), and three linear measurements were obtained using a digital caliper (SMTOP, accuracy: ± 0.01 mm, China): total length (GL), body width (d), and width at the widest extremity (EW) (FIG. 1). All measurements were expressed in millimeters (mm).

Computed tomography analysis was performed using a Siemens SOMATOM Go.Up 32 CT scanner (Siemens Healthineers GmbH, Germany). The helical acquisition was performed with the following parameters: 130 kVp, modulation of the mAs via the Care Dose 4D function, slice thickness of 0.6 mm, revolution time of 1.5s and spiral pitch factor of 0.4. Bone and soft tissue reconstruction algorithms were applied. The following parameters were measured: maximum cortical thickness (MCT), expressed in millimeters, as well as whole bone density (WBD) and cortical bone density (CBD), expressed in Hounsfield units (HU).

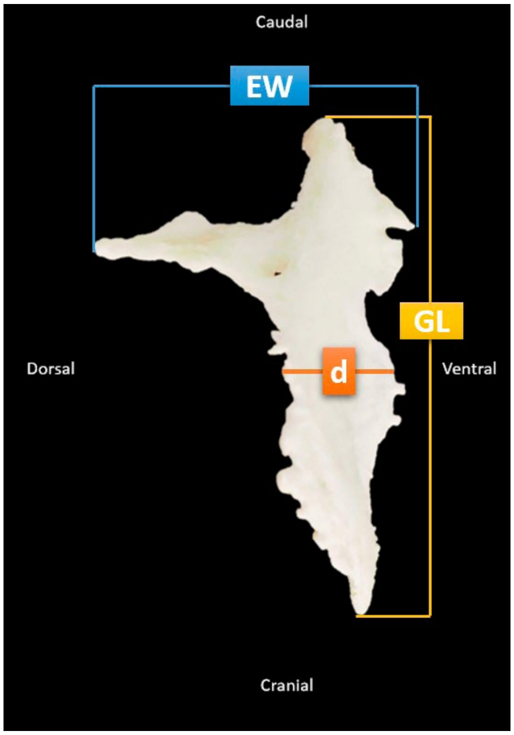

FIGURE 1. Linear measurements taken on the *os cordis* dextrum: total length (GL), body width (d), and width at the widest extremity (EW)

Statistical analysis

The collected data were analyzed using R software via the RStudio interface (version 2025.05.1 + 513) [18]. The normality of the data was verified using the Shapiro-Wilk test ($P<0.05$) and the homogeneity of variances between groups was evaluated using Levene's test ($P>0.05$). For the comparisons among breeds, a one-way analysis of variance (ANOVA) followed by Tukey's HSD post hoc test was performed with the significance threshold set at $P<0.05$. Student t-test was performed in order to compare between sexes and between age classes with a significance threshold of $P<0.05$.

Correlations between variables were assessed using Pearson's correlation coefficient. Absolute values close to 1 indicate strong correlations, whereas values close to 0 indicate no correlation. The relationships between variables were visualized graphically using correlation matrices, represented by heatmaps generated with the ggcorr() function from the «GGally» package in R.

Principal component analysis was carried using R software on the osteometric parameters of the dextrum bone (GL, d, EW) and weight measurements (BW, HW, CW), with «FactoMineR» and «factoextra» packages. This analysis enabled the construction of the correlation circle, illustrating the contribution of variables to the first factorial plane (I-II), as well as a scatter plot visualizing the distribution of individuals according to age class and sex within the first factorial plane, along with their 95% confidence ellipses.

RESULTS AND DISCUSSION

Localization and frequency of the *ossa cordis*

The *ossa cordis* are located at the base of the heart (FIG. 2). The larger bone, the *os cordis* dextrum, is positioned on the right side within the right fibrous trigone, between the atrioventricular rings and at the junction of the interatrial and interventricular septa. It presents a broad dorso-caudal extremity and an obliquely oriented body extending in a cranio-ventral direction. The smaller *os cordis* sinistrum is located on the left side, within the left fibrous trigone, between the left atrioventricular ring and the aortic ring (FIG. 3).

The anatomical location of the *ossa cordis* suggests that they have a mechanical role in support and protection: they support the atrioventricular valves by enhancing cardiac contractions and stabilizing the heart through the insertion of cardiac muscle into the bone [7, 8, 19], and they protect the cardiac tissue located between these valves from damage during systole [7, 9].

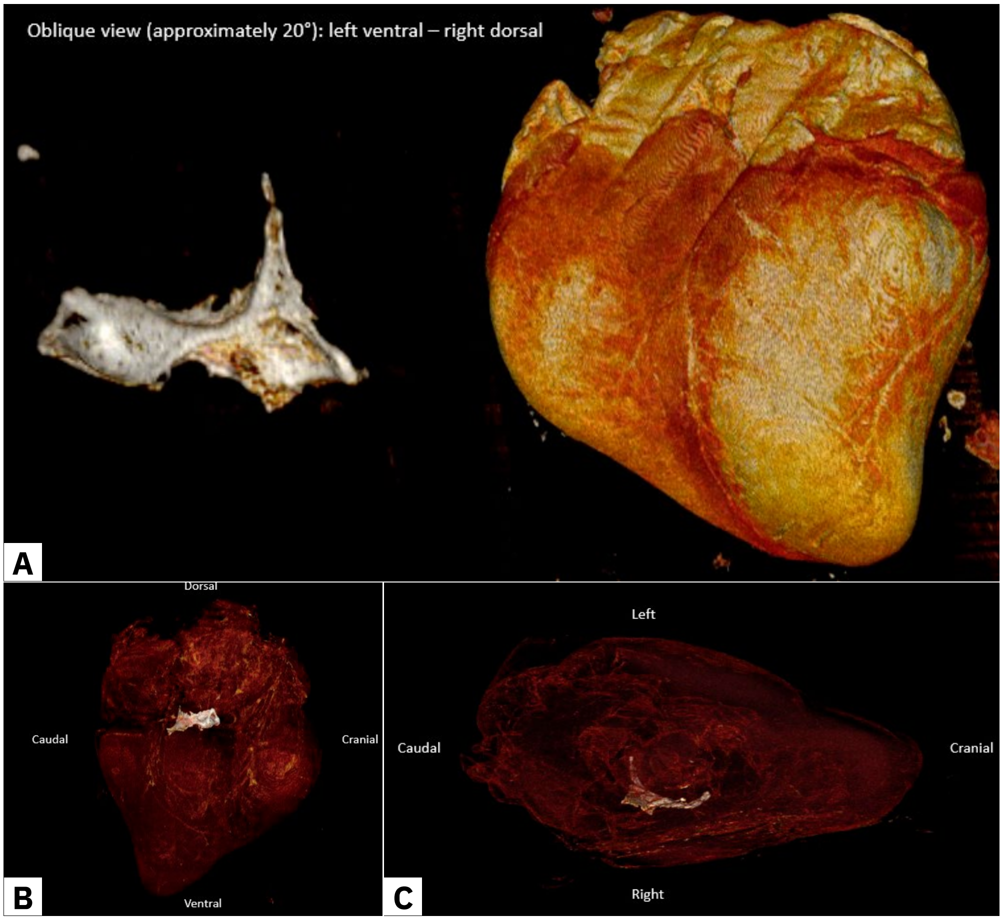

FIGURE 2. Computed tomography (CT) 3D reconstruction of the heart and ossa cordis of an eight-year-old Holstein female. A: Oblique plane of the heart (right) and the corresponding orientation of the isolated *ossa cordis* (left). B: Sagittal and C: dorsal CT 3D volume rendering of the bovine heart with its *ossa cordis*

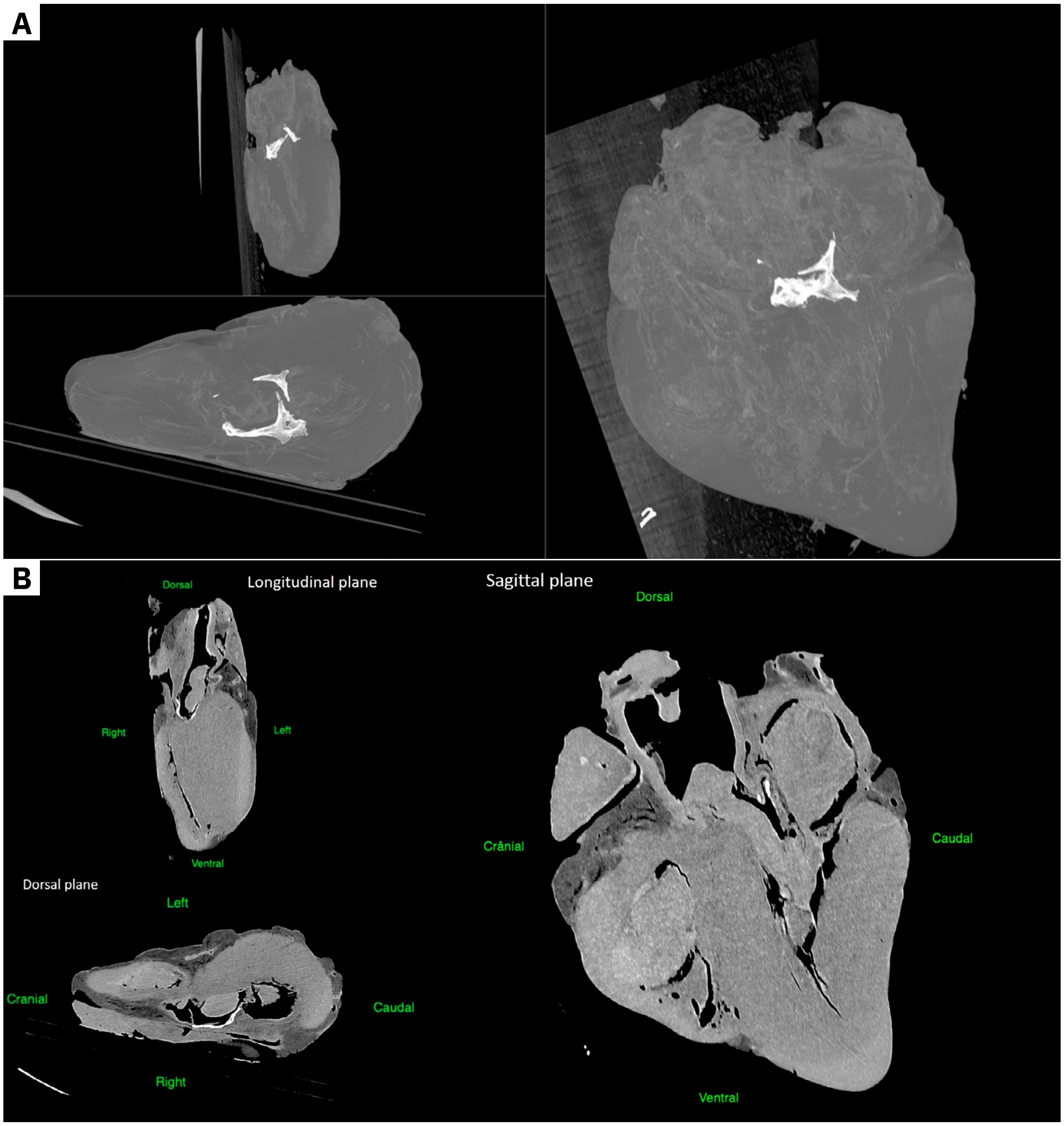

FIGURE 3. Localization of the *ossa cordis* (Dextrum and Sinistrum) within the fibrous trigones using computed tomography (CT) multiplanar reconstruction with A: maximal intensity projection and bone reconstruction algorithm and with B: soft tissue reconstruction algorithm

The *os cordis* does not typically form during embryonic development but ossifies after birth, which appears to be a response to heart's increased mechanical stress [1]. It is also important to note that there is a relationship between the *ossa cordis* and the cardiac conduction system; the *os cordis* dextrum was located above the atrioventricular bundle of (bundle of His) and opposite the atrioventricular node [1].

In the total population studied (n = 23), the *os cordis* dextrum was present in all individuals, resulting in a frequency of 100%. Morphometric analyses of the dextrum were performed after exclusion of one Charolais female showing extreme values (discussed below); in the remaining sample, the *os cordis* dextrum exhibited a mean length of 46.51 mm (GL), a mean body width (d) of 9.72 mm, and a mean width of 18.65 mm at its widest extremity (EW).

In contrast, the *os cordis* sinistrum, smaller than the dextrum, was found only in some adult females of the Holstein, French Simmental, and Charolais breeds. However, it was not absent in males, likely due to the presence of only one adult male in the sample. Within the adult subsample (n = 9), its frequency reaches 56%. These observations suggest that the presence of the sinistrum bone is mainly age-related.

In the Charolaise female aged 16–17 years, the showed an atypical shape characterized by a pronounced curvature of its dorso-caudal extremity (EW) (FIG. 4). This measurement reached 32.1 mm and the bone showed a total length (GL) of 71.25 mm, values substantially higher than the corresponding sample means (18.65 mm and 46.51 mm, respectively). This may be explained by the continued development of the *os cordis* dextrum in older individuals, leading to an accentuation of its natural curvature,

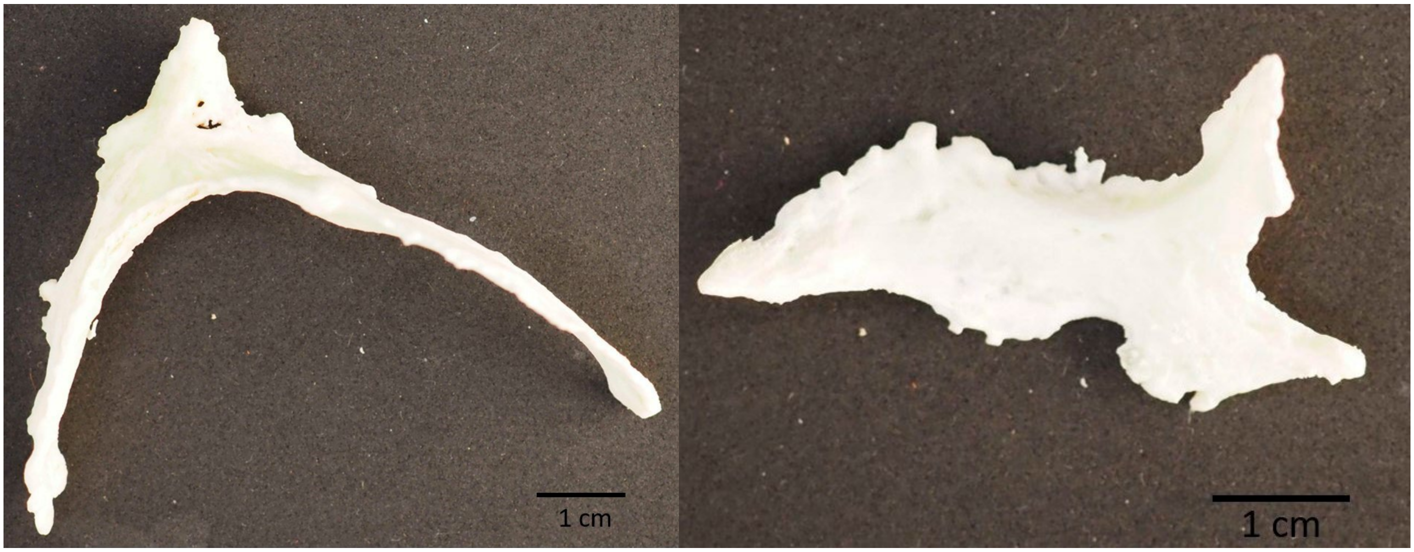

FIGURE 4. ***Os cordis*** **dextrum in adult females, aged 16–17 years (left) and 8 years (right)**

whereas in younger individuals this curvature is only moderately expressed. Due to these outlying values, this individual was excluded from the statistical analyses of morphometric data to avoid biasing the results.

TABLE I
Osteometric and weight measurements according to sex and age class: Descriptive statistics and Student's t-test results

Classes	GL	d	EW	BW	HW	CW
Young adults	44.25	8.90	17.30	0.65	1.57	313.43
	5.70	1.87	2.66	0.17	0.43	86.58
	35.86–55.32	6.21–13.38	13.28–21.22	0.42–0.89	0.94–2.50	188.00–500.00
	12.90	21.00	154.00	25.30	27.60	27.60
Adults	51.03	11.35	21.35	1.12	1.29	258.57
	5.83	1.57	4.09	0.25	0.28	55.81
	45.14–59.92	8.69–13.28	17.78–29.07	0.81–1.58	0.90–1.65	180.00–330.00
	11.43	13.82	19.15	22.46	21.58	21.58
P-value	**0.0196**	**0.0079**	**0.0128**	**0.0001**	0.1451	0.145
Males	44.67	9.41	17.73	0.69	1.60	319.14
	5.60	2.03	2.64	0.17	0.42	84.70
	35.86–55.98	7.23–13.38	13.28–24.58	0.43–1.16	0.94–2.50	188.00–500.00
	12.53	21.60	14.89	23.96	26.54	26.54
Females	50.20	10.34	20.50	1.05	1.24	247.14
	6.96	2.25	4.88	0.37	0.23	46.08
	40.29–59.92	6.21–12.72	14.39–29.07	0.42–1.58	0.90–1.50	180.00–300.00
	13.86	21.73	23.79	34.81	18.65	18.65
P-value	0.0633	0.2792	0.1033	**0.0051**	**0.041**	**0.0417**
Total population	46.51	9.72	18.65	0.81	1.48	295.14
	6.48	2.10	3.67	0.30	0.40	80.68
	35.86–59.92	6.21–13.38	13.28–29.07	0.42–1.58	0.90–2.50	180.00–500.00
	59.92	13.38	29.07	1.58	2.50	500.00
	13.93	21.58	19.67	36.70	27.34	27.34

GL: Total length, d: Body width, EW: Width at the widest extremity, BW: Bone weight, HW: Heart weight, CW: Carcass weight. GL, d, and EW measurements are in mm, HW and CW are in kg and BW is in g. Values are presented as mean, standard deviation, minimum-maximum, and coefficient of variation (%)

Osteometric and weight measurements by sex, age, and breed

The Shapiro-Wilk test (P>0.05) and Levene's test (P>0.05) confirmed the normality of the data and the homogeneity of variances, respectively.

According to sex, weight measurements (bone weight, heart weight, and carcass weight) exposed significant differences (TABLE I).

Heart weight (HW) and carcass weight (CW) were significantly higher in males (1.60 kg and 319.14 kg, respectively), whereas bone weight (BW) was significantly higher in females (0.96 g). Thus, although males were generally heavier, females had larger *os cordis* dextrum, suggesting that heart and carcass weight do not directly influence bone weight.

According to age class, several parameters of the dextrum, including length (GL), body width (d), width at the widest extremity (EW), and bone weight (BW), showed significant differences (TABLE I). Adults exhibited significantly higher mean values comparing to young adults, indicating an increase in both size and mass of the bone with age.

Analysis of variance revealed no significant differences between breeds for bone length (GL; P = 0.743), body width (d; P = 0.310), width at the widest extremity (EW; P = 0.943), and bone weight (BW; P = 0.215). In contrast, highly significant differences were observed for heart weight (HW; P = 0.0031) and carcass weight (CW; P = 0.00341). Tukey HSD post hoc tests showed that the Aubrac, a beef breed, had significantly higher mean HW and CW than the Montbeliarde (P = 0.0136), Holstein (P = 0.00156), and French Simmental (P = 0.0168), which are primarily dairy breeds. No significant differences were found among the Montbeliarde, Holstein, and French Simmental (P>0.4) (TABLE II). Thus, breed does not influence the size or mass of the *os cordis*, unlike heart and carcass weights, which reflect the animals' production type [20].

In the studied sample, the average length of the *os cordis* dextrum is 46.51 mm. This value is close to those reported in Egyptian Baladi cattle (43.68 mm) [21], and in beef cattle (51 mm) [7]. In contrast, it is higher than the values observed in Holstein cattle (40.85 mm) [8] and Iranian cattle (30.92 mm) [8], but lower than the value reported for Holstein in the study by Alsafy, El-Gendy [21] (55.71 mm).

The average width of the *os cordis* dextrum in the studied population (18.65 mm) is very close to that reported in Holstein cattle (18.36 mm) [8]. However, it is markedly higher than the values observed in Egyptian Baladi cattle (12.59 mm) [21], Iranian cattle (10.99 mm) [8], and beef cattle (8.4 mm) [7]. Conversely, it remains lower than the width described in Holstein in the study by Alsafy, El-Gendy [21] (26.86 mm).

Correlations between osteometric, weight measurements and age

Regarding osteometric parameters, the strongest correlation is observed in the total population (r = 0.51, P = 0.02) and in young adults concerns bone length (GL) and width at the widest extremity (EW) (r = 0.52). In contrast, in adults, the strongest correlation is observed between bone length (GL) and body width (d) (r = – 0.71) (FIG. 5).

TABLE II
Osteometric and weight measurements according to breed: Descriptive statistics and Tukey's HSD post hoc results

Breed	GL	D	EW	BW	HW	CW
Aubrac	47.24	10.30	18.00	0.85	2.33[(a)]	465.00[(a)]
	1.79	4.35	3.33	0.05	0.25	49.50
	45.97–48.50	7.23–13.38	15.65–20.36	0.81–0.89	2.15–2.50	430.00–500.00
	3.79	42.23	18.50	5.88	10.73	10.65
Montbeliarde	44.77	8.89	18.05	0.63	1.50[(b)]	300.57[(b)]
	7.67	1.48	2.81	0.16	0.22	43.35
	35.86–55.32	7.65–11.80	13.57–21.22	0.43–0.87	1.14–1.80	228.00–360.00
	17.12	16.65	15.57	25.40	14.67	14.42
Holstein	46.56	9.60	19.10	0.88	1.64[(b)]	266.40[(b)]
	6.94	2.08	5.03	0.39	1.15	71.81
	39.43–59.92	6.21–12.72	13.28–29.07	0.42–1.58	0.90–4.78	180.00–362.00
	14.92	21.68	26.35	44.26	70.50	26.96
French Simmental	49.93	11.61	19.14	1.02	1.42[(b)]	283.33[(b)]
	4.49	1.56	1.07	0.08	0.28	56.86
	46.09–54.87	10.19–13.28	18.29–20.34	0.92–1.06	1.10–1.65	220.00–330.00
	9.00	13.43	5.59	7.84	19.72	20.08

GL: Total length, d: Body width, EW: Width at the widest extremity, BW: Bone weight, HW: Heart weight, CW: Carcass weight. GL, d, and EW measurements are in mm, HW and CW are in kg and BW is in g. Values are presented as mean, standard deviation, minimum-maximum, and coefficient of variation (%). Means followed by different letters within the same column differ significantly according to the Tukey HSD test (P<0.05). Aubrac differs from the other breeds[(a)], whereas the remaining breeds (Montbeliarde, Holstein, and French Simmental) do not differ significantly from each other[(b)]

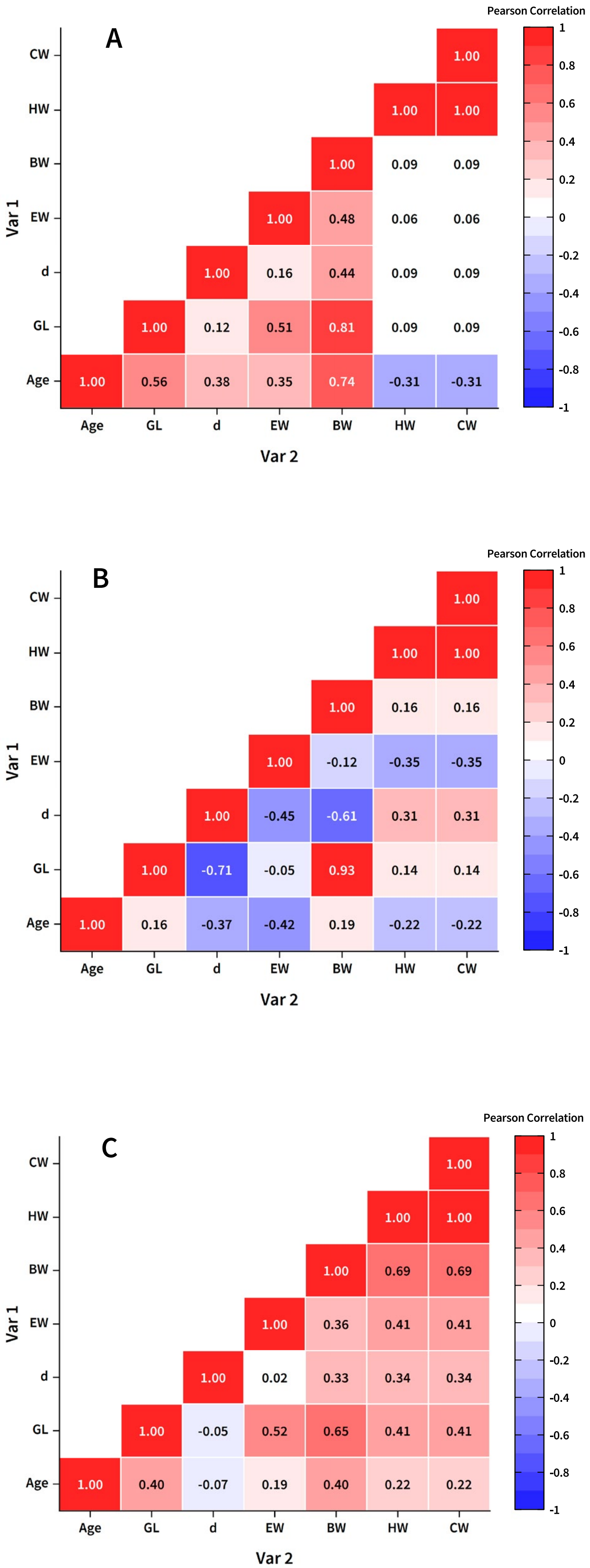

FIGURE 5. Correlation matrices represented as heatmaps. A: Total population, B: Adults, C: Young adults. GL: Total length, d: Body width, EW: Width at the widest extremity, BW: Bone weight, HW: Heart weight, CW: Carcass weight

Among osteometric parameters, bone length (GL) shows the strongest correlation with bone weight (BW), with a coefficient of r = 0.81 ($P = 1.48^{e-05}$) in the total population, indicating that bone mass increases as the bone lengthens. This correlation was strong in young adults (r = 0.65) and very strong in adults (r = 0.93) (FIG. 5).

Age-related analysis reveals a strong positive correlation between age and bone weight in the total population (r = 0.74, *P* = 0.0001), showing that bone mass increases with age. Consistently, the mean weight of bones increases from 0.65 g in young adults to 1.05 g in adults. Upon separate analysis of the age classes, this correlation decreases drastically (r = 0.40 in young adults and r = 0.19 in adults).

Moderate positive correlations are observed between age and bone length (GL) (r = 0.56, *P* = 0.010), as well as between age and body width (d) (r = 0.38) and width at the widest extremity (EW) (r = 0.35), indicating that the size of the *os cordis* dextrum increases with age. Overall, both the size and mass of the dextrum increase with age (FIG. 5).

In adults, negative correlations are observed for bone body width (d), particularly between bone length (GL) and d (r = – 0.71), and between body width and bone weight (r = – 0.61) (FIG. 5). These findings reflect a differential growth pattern: bone length continues to increase with age, whereas bone width shows limited variation. Therefore, growth is more pronounced along the longitudinal axis than the transverse axis.

In young adults, bone weight strongly correlates with heart weight and carcass weight (r = 0.69) (FIG. 5), suggesting that the development of the *os cordis* follows overall cardiac and body growth. Although this bone is rarely recognized in archaeological contexts, its presence in archaeological remains may allow the estimation of carcass weight and, subsequently, the body mass of ancient animals. Furthermore, its presence in articulated skeletons may provide additional evidence indicating that the animal was buried intact.

Principal component analysis: Dimorphism and age-class distinction

The principal component analysis using osteometric and weight variables (GL, d, EW, BW, HW, and CW) revealed two main axes explaining 72.6% of the total variance (FIG. 6). The first axis (41%) primarily reflects bone size and mass, showing positive correlations with bone weight (BW), bone length (GL), and width at the widest extremity (EW).

The second axis (31.6%) is associated with variables reflecting weight, particularly heart weight (HW) and carcass weight (CW). The distribution of individuals shows a separation, with some overlap between young adults and adults. Adults cluster in the lower-right quadrant, corresponding to higher values of BW, GL, and EW, indicating larger and heavier bones, along with higher heart weight (HW) and carcass weight (CW).

In contrast, young adults are mostly positioned in the upper-left areas of the factorial plane, characterized by lower bone weight (BW) and bone length (GL) values, but still related to heart weight

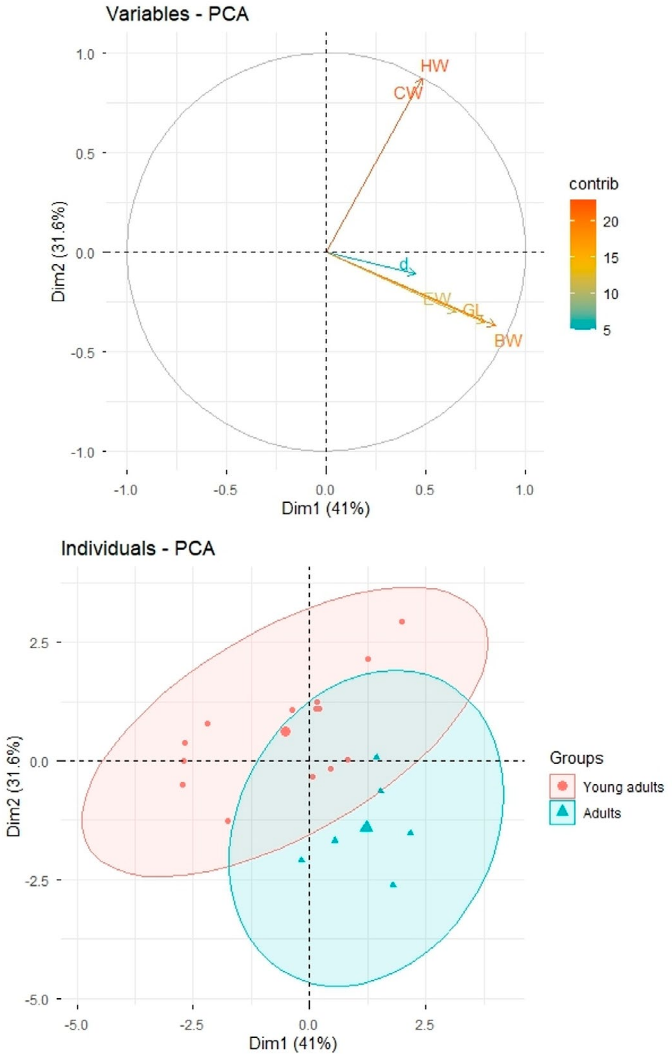

FIGURE 6. Principal component analysis according to age classes: Correlation circle of the variables (left). Scatter plot of individuals on the factorial plane (right). GL: Total length, d: Body width, EW: Width at the widest extremity, BW: Bone weight, HW: Heart weight, CW: Carcass weight

(HW) and carcass weight (CW). Additionally, young adults show greater dispersion, indicating heterogeneity within this class (FIG. 6). Regarding sex distribution, the pattern is similar, as almost all females are adults and most males are young adults. Osteometric parameters show the most pronounced sexual dimorphism, particularly bone weight (BW) and length (GL), which are higher in adults.

CT-Scan analysis of *Os cordis* dextrum: Density and age-related correlations

Computed tomography analysis of the sample (n = 23) reveals no significant differences in the following parameters: maximum cortical thickness (MCT), whole-bone density (WBD), and cortical bone density (CBD) between age classes (*P* = 0.2856, *P* = 0.1557, *P* = 0.1469, respectively), gender (*P* = 0.4465, *P* = 0.2077, *P* = 0.1371, respectively), or breeds (*P* = 0.334, *P* = 0.86, *P* = 0.561, respectively) (TABLE III).

TABLE III
Densitometric parameters according to sex and age class: Descriptive statistics and Student's t-test results

Classes	MCT	CBD	WBD
Young adults	1.05	848.45	-247.63
	0.13	212.91	217.06
	0.90–1.37	610.23–1282.78	-592.10–235.78
	11.99	25.09	-87.66
Adults	1.14	1022.17	-60.69
	0.27	355.65	380.65
	0.83–1.80	785.40–1854.80	-451.63–507.91
	23.71	34.79	-627.18
P-value	0.2856	0.1557	0.1469
Females	1.12	1010.75	-58.01
	0.28	364.49	378.38
	0.83–1.80	717.20–1854.80	-451.63–507.91
	24.61	36.06	-652.26
Males	1.06	855.79	-249.36
	0.12	209.79	217.88
	0.90–1.37	610.23–1282.78	-592.10–235.78
	11.69	24.51	-87.38
P-value	0.4464	0.2077	0.1371
Total population	1.08	916.43	-174.48
	0.19	283.37	298.72
	0.83–1.80	610.23–1854.80	-592.10–507.91
	17.97	30.92	-171.20

MCT: maximum cortical thickness, WBD: whole-bone density, CBD: cortical bone density. MCT expressed in mm, while CBD and WBD are expressed in HU. Values are presented as mean, standard deviation, min–max, and coefficient of variation (%)

The CT-scan results show an average maximum cortical thickness of 1.08 mm (range: 0.83–1.80 mm) and a mean cortical density of 916.4 HU (range: 610.23–1854.80 HU). In contrast, the whole bone density exhibits considerably lower values, with a mean of −174.48 HU (range: −592.1 to + 507.91 HU), reflecting a dense cortical (compact) outer layer, surrounding a central region of spongy bone. Furthermore, in adults, the medullary region appears more ossified, with thicker and more numerous trabeculae.

Correlation analysis reveals a strong relationship between age and bone density parameters. Strong positive correlations are observed for maximum cortical thickness (r = 0.66), cortical density (r = 0.67), and whole bone density (r = 0.62), indicating that the density of the *os cordis* dextrum increases with age. For example, the dextrum bone of the oldest individual in the sample, a 16–17–year-old Charolaise female, shows a mean cortical density of 1854.8 HU and a maximum thickness of 1.8 mm. Additionally, bone weight (BW) shows strong correlations with density parameters: maximum cortical thickness (r = 0.75), cortical density (r = 0.74), and whole bone density (r = 0.61), indicating that both bone mass and density increase with age.

The lack of significant differences between age groups suggests that the *os cordis* reaches mineral maturity relatively early, although the positive correlations indicate that mineralization continues with age. As this is a preliminary study, including a larger number of older individuals will be necessary to better characterize this relationship and confirm differences between age groups.

CONCLUSION

This study shows that the frequency, number, and morphology of the *ossa cordis* in bovine vary with age. The *os cordis* dextrum is consistently present in all individuals examined, whereas the *os cordis* sinistrum is observed only in older animals. The anatomical position of the *ossa cordis* within the fibrous trigones confirms their mechanical role in supporting and protecting cardiac structures.

In addition, adult individuals exhibit a larger and heavier dextrum compared to young adults. Overall, the weight, size, and density of the *os cordis* dextrum increase with age. A larger sample of adults, particularly older males, will be needed to better assess the effect of sex and further investigate the bone density of the *ossa cordis*.

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Conflict of interest

The authors declare that they have no conflicts of interest related to this work.

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