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Roe deer *(Capreolus capreolus)* age at death estimates: New methods and modern reference data for tooth eruption and wear, and for epiphyseal fusion

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ABSTRACT: Three different ageing methods have been devised and tested in order to improve available reference data for the determination of the skeletal age of West European roe deer (*Capreolus capreolus*): (1) molariform tooth eruption, substitution and wear (scoring procedure), (2) cheek-teeth crown height measurements, and (3) fusion of cranial and postcranial bones. Mandibles from 88 individuals of precisely known ages (± 1 to 4 weeks) from two game populations under control in the Paris basin region (France) have been sampled. Epiphyseal ages have been established on a different sample of 196 complete skeletons from a third area in the Paris Basin. These were aged on the basis of teeth data from to the first two samples.
For tooth ages, the eruption, substitution and tooth-wear sequences appeared to be a more accurate method than that of crown height measurements. These sequences provided age estimates within a ± 1 month accuracy for individuals of less than 2 years. Tables with the morphologies of the wear surfaces of individual cheek teeth and of scores for both mandibular series and isolated teeth are provided. Comparisons with published data show slight discrepancies, mainly due to weakness inherent to most of the previous ageing methods. A table of bone epiphysation for roe deer is presented for the first time.

KEY WORDS: ROE DEER, *CAPREOLUS CAPREOLUS*, SKELETAL CHRONOLOGY, ERUPTION AND TOOTH WEAR, EPIPHYSEAL FUSION, ARCHAEOZOOLOGY

RESUMEN: Tres diferentes métodos de evaluación de edad han sido diseñados y probados a fín de mejorar los datos referenciales disponibles para la determinación de la edad a través del esqueleto en el corzo (*Capreolus capreolus*): (1) Emergencia, reemplazo y desgaste (evaluado a través de registros) de los dientes molariformes, (2) medidas de la altura de la corona de los molariformes y (3) fusión de huesos craneales y postcraneales. Se muestrearon mandíbulas procedentes de 88 individuos de edad conocida con precisión (entre 1 y 4 semanas) de dos poblaciones sometidas a explotación cinegética en la región de la cuenca de París. Las edades epifisarias han sido establecidas en una muestra diferente de 196 esqueletos completos procedentes de una tercera área de la región parisina. La edad de éstos había sido previamente estimada sobre la base de dientes comparados con las dos muestras precedentes.
Para edades dentarias, las secuencias de emergencia, reemplazo y desgaste dentario parecen constituir un método más preciso que el de los valores de las alturas de la corona. Esas secuencias proporcionaban estimaciones de edad con rangos de en torno al mes de error para invididuos de menos de dos años. Se proporcionan las tablas con las morfologías de las superficies de desgaste de los dientes molariformes individualizados así como los registros para tanto las series mandibulares como los dientes aislados. Las comparaciones de nuestros datos con otros previamente publicados evidencian ligeras discrepancias principalmente debido a las deficiencias inherentes a la mayoría de las técnicas previas de estimación de edad. Por vez primera se presenta una tabla de cronología epifisaria para el corzo.

PALABRAS CLAVE: CORZO, *CAPREOLUS CAPREOLUS*, ESQUELETOCRONOLOGÍA, EMERGENCIA Y DESGASTE DENTARIO, FUSIÓN EPIFISARIA, ARQUEOZOOLOGÍA

INTRODUCTION

Human strategies for the procurement of natural resources are a major issue of prehistoric research. This is especially the case of cervid hunting on the part of Mesolithic and Neolithic societies in the temperate and mediterranean areas of Europe. The determination of these strategies leans heavily on mortality profiles (Mithen, 1987; Legge & Rowley-Conwy, 1988; Vigne, 2000). These must be based on a previous accurate determination of ages at death of the archaeological animals that requires reliable present day references for the wild species.

The roe deer (*Capreolus capreolus*) is widely distributed throughout Eurasia, from Western Europe to the shores of the Pacific ocean. Less abundant than the red deer, it is nevertheless often found in european archaeological sites. Available present day ageing references for the roe deer are scarce (Habermehl, 1961; White, 1974; Aiken, 1975; Wagenknecht, 1984; Riech, 1986) being based on animals whose ages were only estimated, never accurately known. In many cases these data exhibit inconsistencies among them.

The present paper aims to discuss the available age reference data and ageing methods for *Capreolus capreolus* and to propose new reference standards based on teeth, favoured in terms of differential preservation, and on the remaining parts of the skeleton. Three methods have been examined:

- Morphoscopic analyses of teeth, with the use of 'scores' (Brown & Chapman, 1990, 1991) that simultaneously take into consideration data on cheek teeth eruption, replacement and wear;
- Measurement of crown heights of cheek teeth, and
- Epiphyseal fusion data for the skull and the postcranial skeleton.

REFERENCE COLLECTIONS

Only lower cheek teeth have been considered in this paper since not only are these less frequently dissociated in archaeological assemblages than the upper cheek teeth, but also because they seem to be more appropriate for age determination in the ruminants (Payne, 1973; Brown & Chapman, 1990, 1991).

Tooth analysis is based on two collections of roe deer mandibles with known ages, from two areas in the Paris Basin: (a) the state forest of Dourdan (Essonne, France) and (b) the national game reserve of Trois Fontaines (Marne, see Figure 1). Six roe deer at Trois Fontaines had been previously tagged between their 2nd and 15th day of life (presence of the umbilical cord or of its scar fold), and were radio-tracked until their death, so that their age is known with an accuracy of ± 1 month. The remaining individuals from Trois Fontaines and Dourdan were also tracked but were tagged only during their first year of life (i.e., within their first 9 months). Their age had been determined by looking at the teeth of yearlings (presence of the 4th milk premolar) and is thus known with a precision of ± 4 weeks.

For Dourdan, 62 individuals, including 29 males and 32 females that died between their 2nd and 91st months of life, young individuals being a majority (i.e., 54.8% of the sample between 2 and 15 months) were taken into consideration. For Trois Fontaines, use was made of 26 individuals, 9 males and 17 females, which died between 7 and 140 months, most of them adults (88.4% of the sample had more than 15 months).

Since animals aged 0-1 months were absent from both collections, 13 fawn skeletons of unknown sex but of accurate age from the mammal collections at the Muséum d'Histoire Naturelle of Geneva (Switzerland) were added to our sample.

Since the Dourdan and Trois Fontaines collections only included mandibles, for bone fusion data 196 complete skeletons from the Muséum National d'Histoire Naturelle (Paris) were incorporated into the data base. A further 109 males and 87 females were collected by our archaeozoological group between August 1991 and August 1992. These came from different forests, most of them located next to each other in the Oise department (Figure 1).Use was also made of 90 complete skeletons from the mammal and archaezoological collections housed at the Muséum d'Histoire Naturelle of Geneva.The ages of the specimens from these two collections were estimated on the basis of tooth eruption and wear data through comparisons with the mandibles from Dourdan and Trois Fontaines.

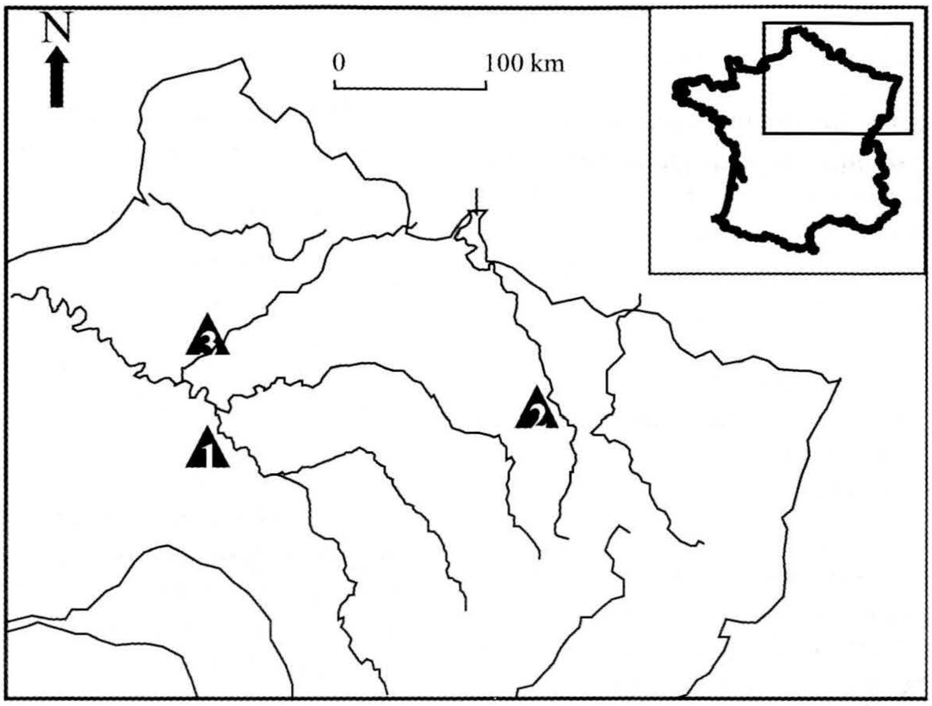


FIGURE 1
Locations where the three main roe deer samples used in this study were collected: (1) Dourdan; (2) Trois-Fontaines; (3) Compiègne Forest and associated Oise forests.

TOOTH ANALYSIS METHODS

One possible cause for the discrepancies among available tooth eruption age tables is that authors rarely specify what they consider an erupted tooth. Eruption lasts from the time when a tooth breaks through the jawbone until the start of its abrasion. In order to restrict such imprecision we adapted the different eruption stages used by Grant (1982; Grant'codes within brackets):

- Er_1, initial perforation of the mandible (= "C"),
- Er_2, the tooth is visible but still inside the mandible (= "V"),
- Er_3, the tooth is just starting to emerge from the mandible (= "E"),
- Er_4, half of the crown is out of the mandible (= "1/2"),
- Er_5, the tooth has completely emerged but is not still in wear (= "U").

The 2nd premolars (PM_2) have not been taken into consideration as their wearing in roe deer exhibits a large degree of morphological variation, ranging from a triangular to a quadrangular shape. For the remaining lower cheek teeth, the wear state on the shape of the dentine areas and of the enamel bridges on the occlusal surface was recorded. The shapes follow the typologies created by Habermehl (1961), Aitken (1975) and Rieck (1986) and were selected on account of the following criteria:

- Convenience and feasibility of observation. In this way the metaconid and entoconid (for tooth nomenclature see Heintz, 1970) wearing stages were disregarded because their key features are fragile and frequently broken on archaeological teeth.
- Objectivity and reproducibility of observation (eg., features such as the colour of the dentine (Rieck, 1986) have not been taken into account.)

An index for the different eruption, replacement and wear stages was created and, in order to quantify the growth stage of the complete tooth row, the method that Brown & Chapman (1990, 1991) used for fallow and red deer was followed.

Following White (1974), Ashby & Henry (1979) and Legge & Rowley-Conwy (1988), using a scale under a binocular stereoscope at x10, measurements were taken of the crown height of the lower cheek teeth for individuals of all ages. To this end the tartar deposits, which hid the collar line from which such measurement is taken, had to be previously scrapped. We also measured the maximum height of the crown (Figure 2), without taking into consideration the position of the tooth in the mandible. Finally, in order to take into account the intrapopulational size variability, the "height: antero-posterior length of the tooth" ratio (the later measured at the level of the collar) was recorded.

BONE FUSION METHODS

More than is the case of either tooth eruption or replacement, epiphyseal fusion is often a long-lasting process taking,on the average, from one to several months. For such reason three stages for the epiphyses are distinguished here: (1) unfused; (2) fusion in progress (fusion line is still visible); (3) fused, without any visible fusion lines.

RESULTS

4.1. Eruption, replacement and wear of teeth

The eruption stages that we can observe for the 37 mandibles of known age are summarized in Table 1. They range from birth to 15 months of age and the main features are:

- One can distinguish three different stages within the first month of life, testifying to a rapid tooth wear at this time
- Wear of the milk teeth starts at 2 months
- M_1 enters into wear between 4 and 5 months
- M_2 enters into wear between 8 and 9 months
- The progressive replacement between the milk and the definitive premolars takes place between 11 and 14 months
- M_3 enters into wear after 15 months.

Early eruption sequences allow for a rather precise ageing of the younger individuals. For the 1-

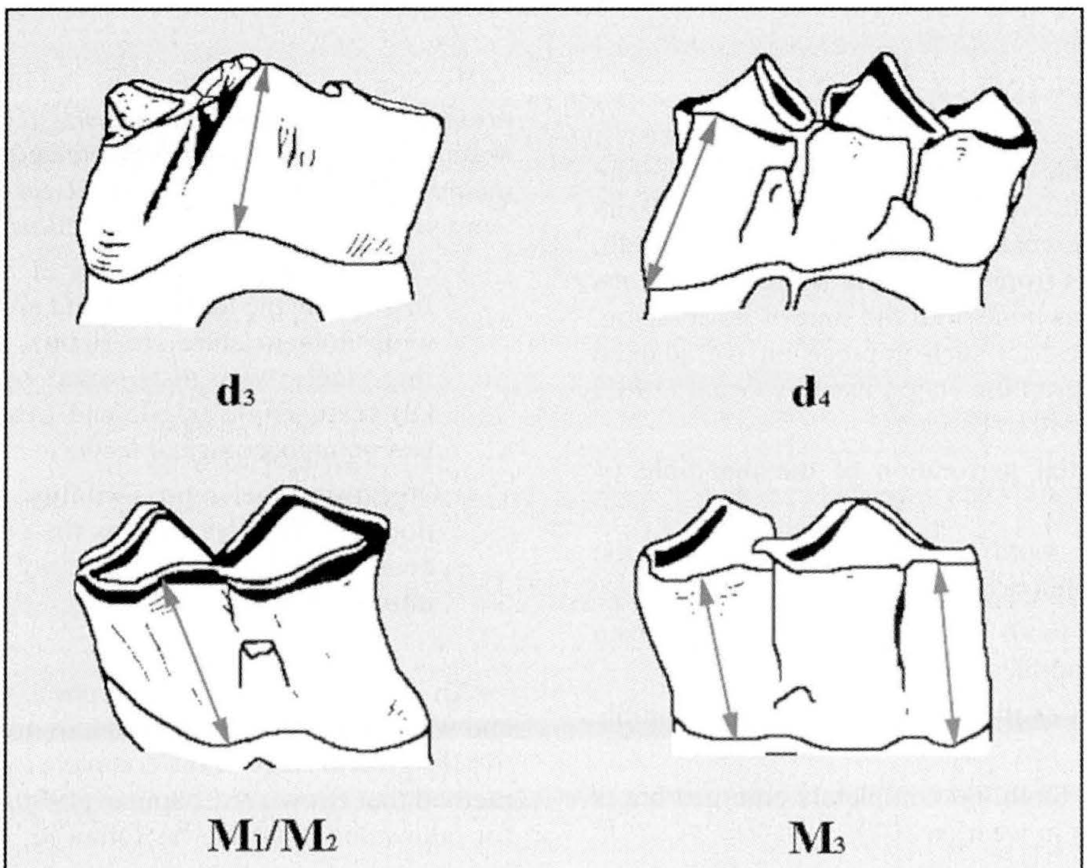


FIGURE 2
Right lower cheek teeth of roe deer (vestibular view): points used for measuring crown height. P_3 and P_4 were measured in the same way as d3.

Age	Tot. number			Teeth								
(months)	G	D	T	d_2	d_3	d_4	P_2	P_3	P_4	M_1	M_2	M_3
0 – 1	3	--	--	Er2/3	Er3	Er3				Er2		
0 – 1	7	--	--	Er4	Er4	Er4				Er2	Er1	
0 – 1	3	--	--	Er5	Er5	Er5				Er2/3	Er1/2	
2	--	1	--	X	X	X				Er3	Er1/2	
3	--	1	--	X	X	X				Er4	Er2	
4	--	1	--	X	X	X				Er5	Er2	
5	--	1	--	X	X	X				X	Er3	Er1
6	--	2	--	X	X	X				X	Er3/4	Er1
7	--	2	2	X	X	X				X	Er4	Er1
8	--	1	1	X	X	X				X	Er5	Er2
9	--	4	--	X	X	X				X	X	Er2/3
10	--	1	--	X	X	X				X	X	Er3
11	--	3	--	(X)	(X)	(X)	(Er1)	(Er2/3)	(Er2/3)	X	X	Er3
12	--	2	--	(X)	(X)	(X)	(Er4)	(Er3)	(Er2/3)	X	X	Er3
14	--	1	--			(X)	Er4	Er4	(Er4)	X	X	Er3
15	--	1	--				Er5	Er5	Er5	X	X	Er4

TABLE 1

Eruption and replacement of the lower cheek teeth of present day roe deer collections from Geneva (G), Dourdan (D) and Trois-Fontaines (T). (Er_1-Er_5 =eruption stages (see text); X= tooth in wear; (..) = tooth may be either erupted or not depending on the individuals in that particular cohort.).

15 months age interval this method provides for a ± 1 month accuracy in all estimations.

4.2. Tooth index scores

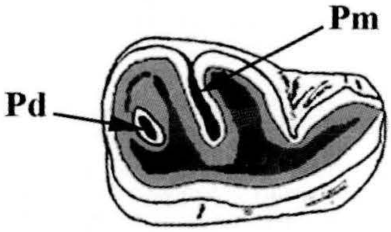
Following the aforementioned criteria and after having tested the different morphological markers, the following features were taken into account (see Tables 2, 3, 4 and 5):

- The shape of the lingual part of the dentine (linear, diamond-shaped, then diffuse)
- The shape of the labial part of the dentine (linear, triangular, oval, then diffuse)
- The progresive fusion between the cusps and the "small columns"
- The progresive narrowing of the enamel folds.

In the case of the complete mandibles (Table 6), the successive stages of tooth eruption and wear were quantified through the use of indexes that exhibit good correlations with known ages until *circa* 24 months (N = 41; Figure 3). Between 24 - 72 months (N = 12) the global scores do not change any longer according to the age of the animal and appear to be noticeably smaller than those from individuals older than 72 months (N = 6). Though less accurately the data in Table 6 do allow for an age estimation of isolated teeth.

4.3. Metrical approach

Table 7 provides both the linear coefficient of correlation and the standard deviation of the slope of the correlation straight line for crown heights and for the ratio between crown height and the antero-posterior length of the tooth, as related to the age of each specimen. Both parameters are highly significantly correlated ($p < .001$) taking into account their respective degrees of freedom.



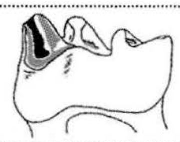
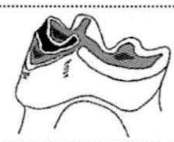
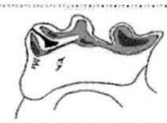
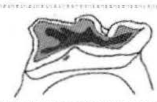
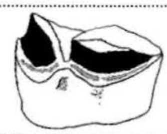
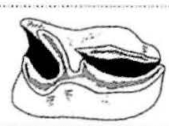
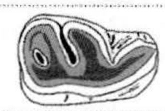
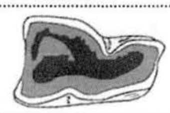
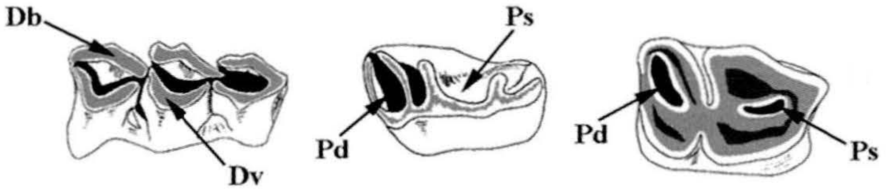
Stages	Age (months)	Tooth	Distal part	Proximal part	Distal enamel fold (Pd)	Medial enamel fold (Pm)	Lateral / occlusal view of a right tooth dist. | prox.
0	0-1	(d_3)	--	--	--	--	
1	1	d_3	no wear	no wear	--	--	
2	2-3	d_3	slightly wear	no wear	open	--	
3	4	d_3	strongly wear	slightly wear	open	--	
4	5-8	d_3	strongly wear	strongly wear	narrow to closed	--	
5	8-9	d_3	dentine on a large area	dentine on a large area	closed or vanished	--	
6	11	d_3 / P_3 (Er2)	--	--	--	--	
7	12-14	d_3 / P_3 (Er3)	--	--	--	--	
8	14-17	P_3 (Er5)	--	--	--	--	
9	17-19	P_3	continuous dentine line	broken dentine line	open	open	
10	20-72	P_3	continuous dentine line	broken dentine line	open	open	
11	81-109	P_3	dentine on a large area	dentine on a large area	closed	narrow	
12	138-140	P_3	dentine on the whole area	dentine on a large area	vanished	vanished	

TABLE 2

Eruption, replacement and wear stages of the third lower milk premolar (d_3) and the third permanent lower premolar (P_3). (Black =enamel fold; dark grey = secondary dentine; light grey =primary dentine; (..) = see Table 1).



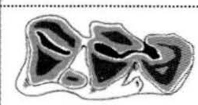
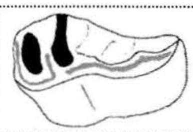
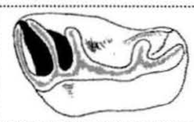
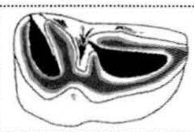
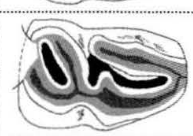
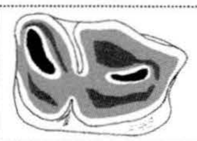
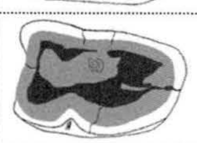
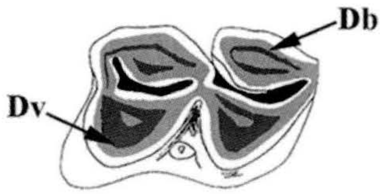
Stages	Age (months)	Tooth	Lingual part of the dentine (Db)	Vestibular part of the dentine (Dv)	Proximal and distal halves	Distal enamel fold (Pd)	Proximal enamel fold (Ps)	Lateral / occlusal view of a right tooth dist. | prox.
0		(d_4)	--	--	--	--	--	
1	1	d_4	no wear	no wear	--	--	--	
2	2-3	d_4	slightly wear	slightly wear	--	--	--	
3	4	d_4	linear	small triangles	--	--	--	
4	5-9	d_4	thick lines or small diamond	large triangles	--	--	--	
5	11-12	d_4/P_4 (Er2)	dentine on the whole area	dentine on the whole area	--	--	--	
6	14	d_4/ P_4 (Er3)	dentine on the whole area	dentine on the whole area	--	--	--	
7	14-17	P_4 (Er5)	--	--	--	--	--	
8	17-19	P_4	--	--	broken dentine line	open	widely open	
9	20-29	P_4	--	--	broken dentine line	open	widely open	
10	31-72	P_4	--	--	continuous dentine line	open	closed on the medial edge	
11	56-72	P_4	--	--	continuous dentine line	closed	closed on the medial edge	
12	81-138	P_4	--	--	dentine on a large area	closed or vanished	almost closed	
13	140	P_4	--	--	dentine on the whole area; crackled area	vanished	vanished	

TABLE 3
Eruption, replacement and wear stages of the fourth lower milk premolar (d_4) and of the fourth permanent lower premolar (P_4). Captions as in Table 2.



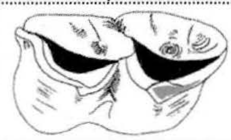
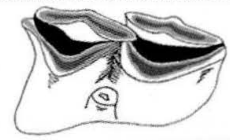
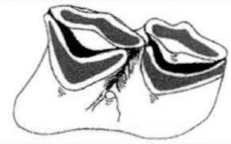
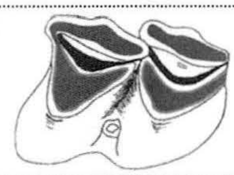
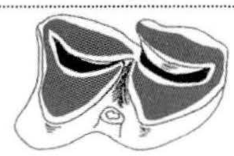
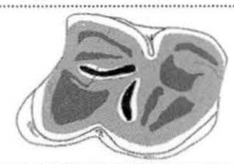
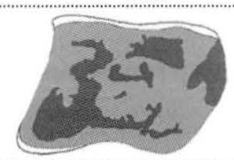
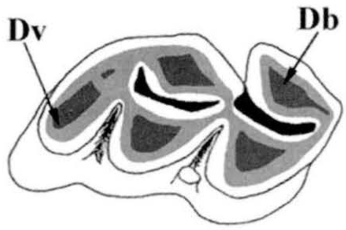
Stages	Age M_1 (months)	Age M_2 (months)	Dentine bridge	Enamel fold	Lingual part of the dentine (Db)	Vestibular part of the dentine (Dv)	Lateral / occlusal view of a right tooth dist. prox.
6	5	7-11	--	present	missing or broken line	line	
7	6-7	12	--	present	line	line	
8	8-12	14-19	--	present	line	small triangles	
9	14-29	19-29	the distal fold begins to close	present	thick lines or small diamonds	more or less wide triangles	
10	31-32	31-72	the prox. fold begins to close and the folds begins to fuse	present	small diamonds	wide triangles	
11	32-72	81-103	the distal fold is completely closed	present	more or less wide diamonds	oval	
12	81-103	109-138	closure of the vestibular small column	the anterior fold vanishes	on wide area	on wide area	
13	103-140	140	vanished	the folds completely vanished	on the whole area; the area is concave	on the whole area; the area is concave	

TABLE 4
Wear stages of the first (M_1) and second (M_2) lower molars. Eruption stages and captions as in Table 2.



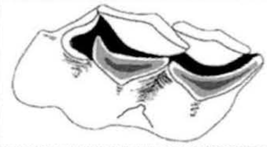
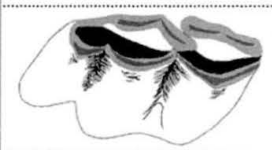
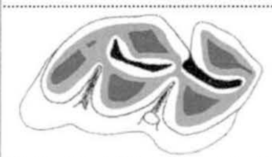
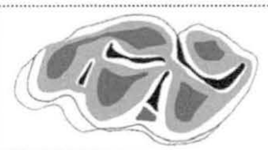
Stages	**Age (months)**	**Dentine bridge**	**Enamel fold**	**Lingual part of the dentine (Db)**	**Vestibular part of the dentine (Dv)**	**Lateral / occlusal view of a right tooth** dist. prox.
6	--	--	present	missing or broken line	line	
7	17-19	--	present	line	line	
8	20-29	--	present	line	small triangles	
9	31-81	closure of the posterior fold	present	more or less wide diamond	wide triangles	
10	103	closure of the medial fold	the posterior fold vanishes	wide diamonds	oval	
11	109	closure of the vestibular small columns	posterior fold has vanished	wide diamonds	oval	
12	138-140	closure of the anterior fold	the medial and anterior fold vanished	dentine on a very wide area ; crackled area	dentine on a very wide area ; crackled area	

TABLE 5

Wear stages of the third molar (M_3). Eruption stages and captions as in Table 2.

Age (months)	Sample	Index for individual teeth					Indices score for mandibles
		d_3 / P_3	d_4 / P_4	M_1	M_2	M_3	
0-1	13	1	1	2-3	0-2	0	4-7
2	1	2	2	3	1	0	8
3	1	2	2	4	2	0	10
4	1	3	3	5	2	0	13
5	1	4	4	6	3	1	18
6	2	4	4	7	4	1	20
7	3	4	4	7	5-6	1-2	21-23
7.5	1	4	4	7	6	2	23
8	3	4-5	4	5	6	2	24-25
9	4	5	4	8	6	3	26
11	3	6	5	8	6	3	28
12	2	7	5	8	7	3	30
14	1	7	6	9	8	3	33
17	1	9	8	9	8	7	41
18	1	9	8	9	8	7	41
19	2	9	8	9	8-9	7	41-42
20	1	10	9	9	9	8	45
29	1	10	9	9	9	8	45
31	1	10	10	10	10	9	49
32	3	10	10	10-11	10	9	49-50
44	2	10	10	11	10	9	50
46	1	10	10	11	10	9	50
56	2	10	10-11	11	10	9	50-51
57	1	10	11	11	11	9	51
72	1	10	11	11	11	9	51
81	1	11	12	12	11	9	55
103	2	11	12	12-13	11	10	56-57
109	1	11	12	13	12	11	59
138	1	12	12	13	12	12	61
140	1	12	13	13	13	12	63

TABLE 6
Index and total scores for the lower cheek teeth of mandibles from present day roe deer.

However, standard deviations are all greater than 10 % and some of them (i.e. d_3 and d_4) reach to 20 %. The percentages of error are higher than the acceptable 5 % threshold suggesting that crown height values are not good age estimators for roe deer. The best correlation, which is obtained for M_1 (Figure 4), confirms that this method is not accurate enough for animals younger than 24 months (Table 8). For these age classes then, the morphological criterion seems to constitute the most reliable ageing method.

4.4. Epiphyseal fusions

Table 9 proposes an epiphysation timetable for use in archaeozoology, based on the 196 complete skeletons from the Oise collection, which have been aged according to the tooth eruption, replacement and wear stages data previously discussed. The most accurate (i.e. ± 1 to 2 months) criteria for age determination are those relying on: (i) the alisphenoid and the basispenoid, (ii) the disks and the centra of the lumbar verte-

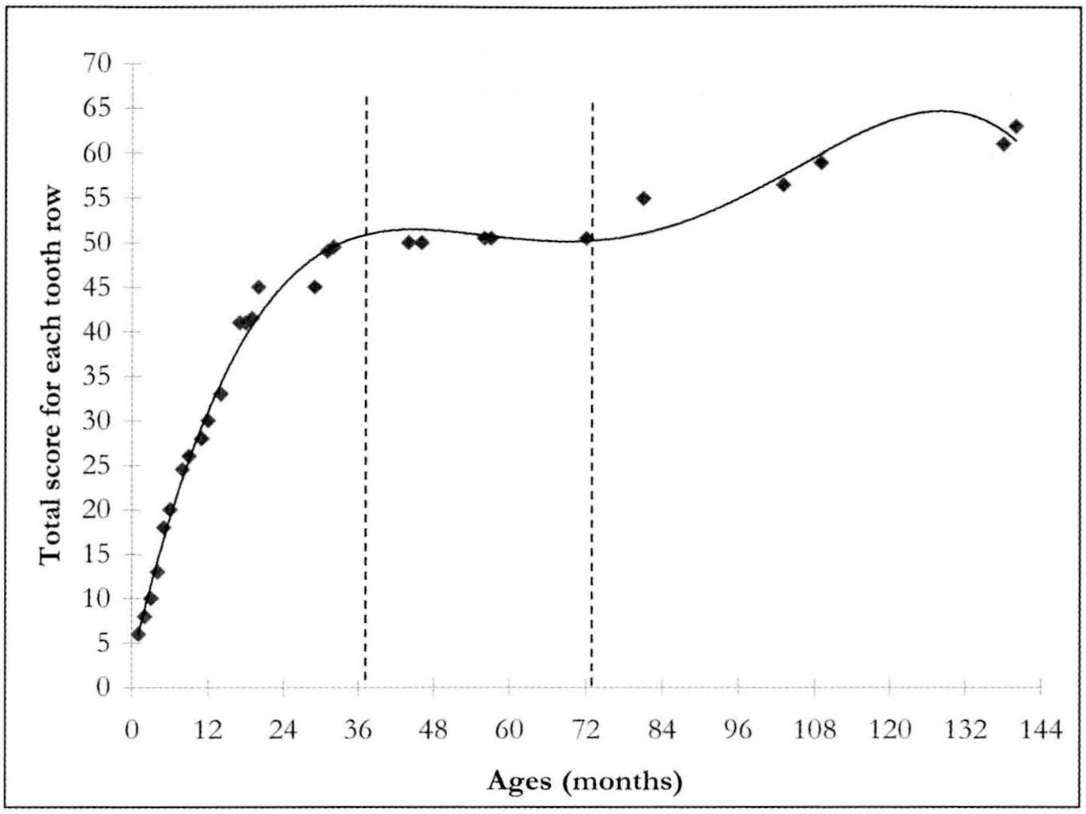


FIGURE 3
Correlation between the total scores for the lower cheek teeth (Table 6) and the age of the roe deer from the reference collections with a 4th degree polynomial regression curve.

Collection	Tooth	df	$r_{(ratio\ 1)}$	$r_{(ratio\ 2)}$	$e_{(ratio\ 1)}$ %	$e_{(ratio\ 2)}$ %
Dourdan	d_3	21	0.70	0.74	22.29	19.86
Dourdan	d_4	13	0.78	0.79	21.77	21.26
Trois Fontaines	P_3	20	0.88	0.88	11.85	11.77
Trois Fontaines	P_4	21	0.89	0.90	11.10	10.38
Trois Fontaines	M_1	24	0.89	0.89	10.41	10.18
Trois Fontaines	M_2	21	0.88	0.86	11.61	12.52
Trois Fontaines	M_3 ant. part	16	0.89	0.91	12.62	11.36
Trois Fontaines	M_3 post. part	10	0.92	0.91	13.38	14.14

TABLE 7
Correlations between the ages of present day roe deer and their: (1) cheek teeth crown heights (ratio 1), (2)"crown height vs. antero-posterior length at the collar" ratio (ratio 2) (*df* =degrees of freedom; *e* = standard deviation of the slope of the regression line; *r* = correlation coefficient.) All *r* values are highly significant ($p < .001$).

brae, (iii) the coracoid process of the scapula, (iv) the proximal and distal epiphyses of the radius and the ulna, (v) the distal epiphyses of the metapodials, (vi) the three bones that form the pelvic *acetabulum*, (vii) the distal epiphysis of the femur and (viii) the proximal epiphysis of the 1st phalanx.

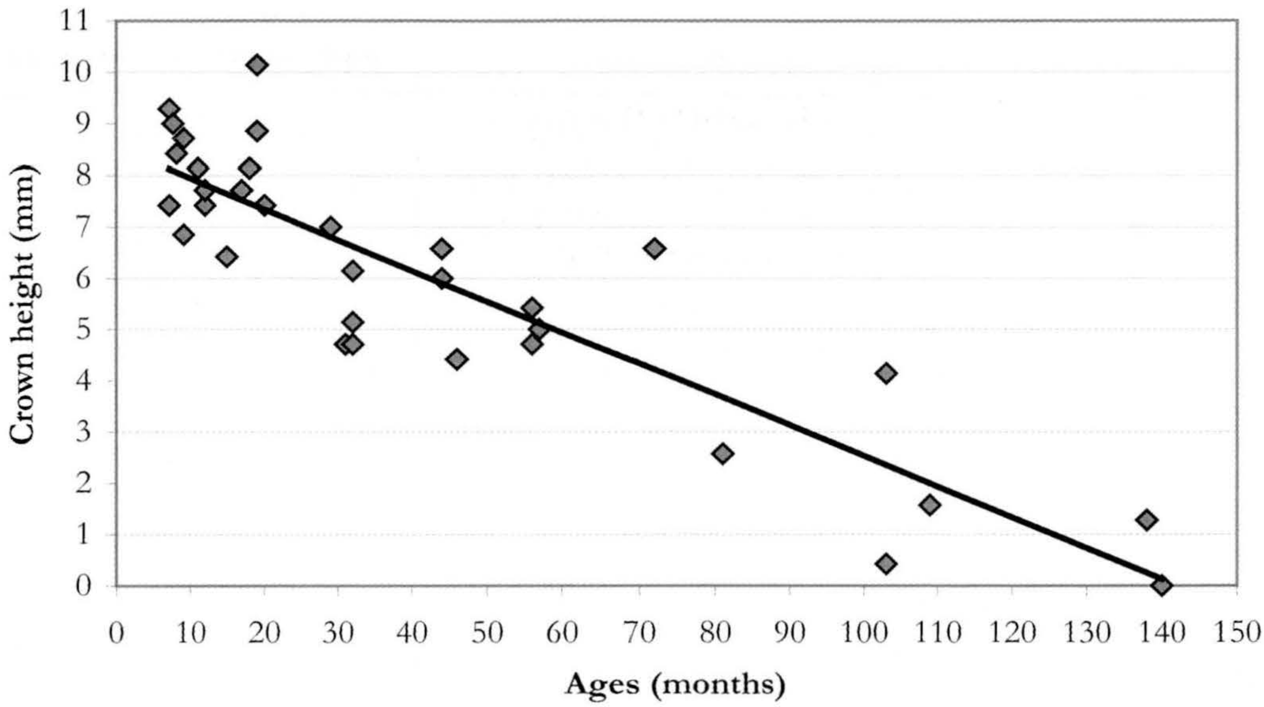


FIGURE 4
Correlation between crown height values of the first lower molar and the age of the roe deer from the reference collections.

Sample	df	$r_{(ratio\ 1)}$	$r_{(ratio\ 2)}$	$e_{(ratio\ 1)}$ %	$e_{(ratio\ 2)}$ %
< 24 months	6	0.12	0.84	326.04	329.85
> 24 months	16	0.12	0.86	16.12	14.85

TABLE 8
Statistical comparisons of crown height values between the 7-20 months and the 29-140 months present day roe deer cohorts. Captions as in Table 7.

DISCUSSION

5.1. Morphoscopic characters and typological classification

Morphoscopic examination and typological classification of the abrasion surfaces of cheek teeth has confirmed that ageing is less accurate as age increases. This is especially true for age classes between 30 and 72 months of age, whose wear indexes essentially remain equal to about 50 (Figure 3).

However, for the two first years of life, morphological indexes show a rather good correlation between the wear stages and the real ages of the animals, so that it may be possible to age, though less precisely, even isolated teeth. This method should therefore be of particular use in archaeozoological materials (Tomé, 1999).

A comparison between our tooth eruption, replacement and wear timetables and those from previous publications evidences discrepancies of up to three months (Table 10). Most of these do not seem to result from variations in the evolution of the dentine in *Capreolus capreolus*. We believe they are instead caused by differences in the way of callibrating the eruption stage of the teeth. This justifies the *a posteriori* specifications that were done for distinguishing the various eruption stages (Er_1 to Er_5), and encourages one to record them in all future analyses.

Skeletal parts	Epiphysation zone	Epiphysation date (months)
Skull	Alisphenoïd - Basisphenoïd	30
	Basioccipital - Basisphenoïd	11 - 16
	Exoccipital -Basioccipital	8 - 11
	Supraoccipital - Parietal	81 - 122/132
	Parietal -Frontal	106 - 122
	Interfrontal	106 - 122
Vertebrae	Atlas	4 - 7
	Cervical disks	18 - 24
	Thoracic disks	16 - 30
	Lumbar disks	15 - 17
	Sacrum	15 - 23
Scapula	Coracoid apophysis	4 - 6
Humerus	Proximum	15 - 16
	Head – Tuberculum major	5 - 15
	Distum	4 - 9
Radius/ulna	Proximum radius	4 - 6
	Distum radius	15 - 16
	Proximum ulna	14 - 16
	Distum ulna	16 - 17
	Distum radius/ulna	15 - 28
Metacarpals III & IV	Distum	13 - 15
Pelvis	Acetabulum	5 - 7
	Pubis part	5 - 11
	Ischiatic tuberosity	23 - 30
	Iliaque spine	24 - 31
	Pubian symphysis	16 - 31
Femur	Proximal head	11 - 15
	Trochanter major	12 - 15
	Distum	14 - 15
Tibia	Proximum	15
	Distum	12 - 15
Calcaneus	Proximal tuberosity	12 - 15
Metatarsals III et IV	Distum	15 - 16
Vestigial metapodials	Distum	5 - 12
1st Phalanges	Proximum	5 - 7
2nd Phalanges	Proximum	12 -16

TABLE 9

Roe deer epiphysation stages in the 196 skeletons from the Oise forests. Two or three of the seven sternal elements start to fuse at around 18 months of age. The number of fused sternal elements increases sharply after 30 months. Six elements fused at an age of six years.

Ages (month)	d_2 f	d_3 f	d_4 f	P_2 f	P_3 f	P_4 f	M_1 f	M_2 f	M_3 f
0 – 1	Er2 Er3	Er3	Er3				Er2		
0 – 1	Er4	Er4	Er4				Er2	Er1	
0 – 1	Er5	Er5	Er5				Er2 Er3	Er1 Er2	
2							Er3	Er1 Er2	
3							Er4	Er2	
4							Er5	Er2	
5								Er3	Er1
6								Er3 Er4	Er1
7								Er4	Er1
8								Er5	Er1 Er2
9									Er2 Er3
10									Er3
11									Er3
12									Er3
14				Er4	Er4	Er4			Er3 Er4
15				Er5	Er5	Er5			Er4 Er5

TABLE 10

Eruption and replacement ages of roe deer lower cheek teeth according to: (a) Habermehl (1961); (b) Varin (1980); (c) Wagenknecht (1984); (d) Rieck (1986); (e) Boisaubert & Boutin (1988); (f) this paper (N = 42). (White = non-erupted tooth; Er_1-Er_5 = eruption stages (see text); light grey = tooth either completely erupted or not, depending on the individual; dark grey = erupted tooth.)

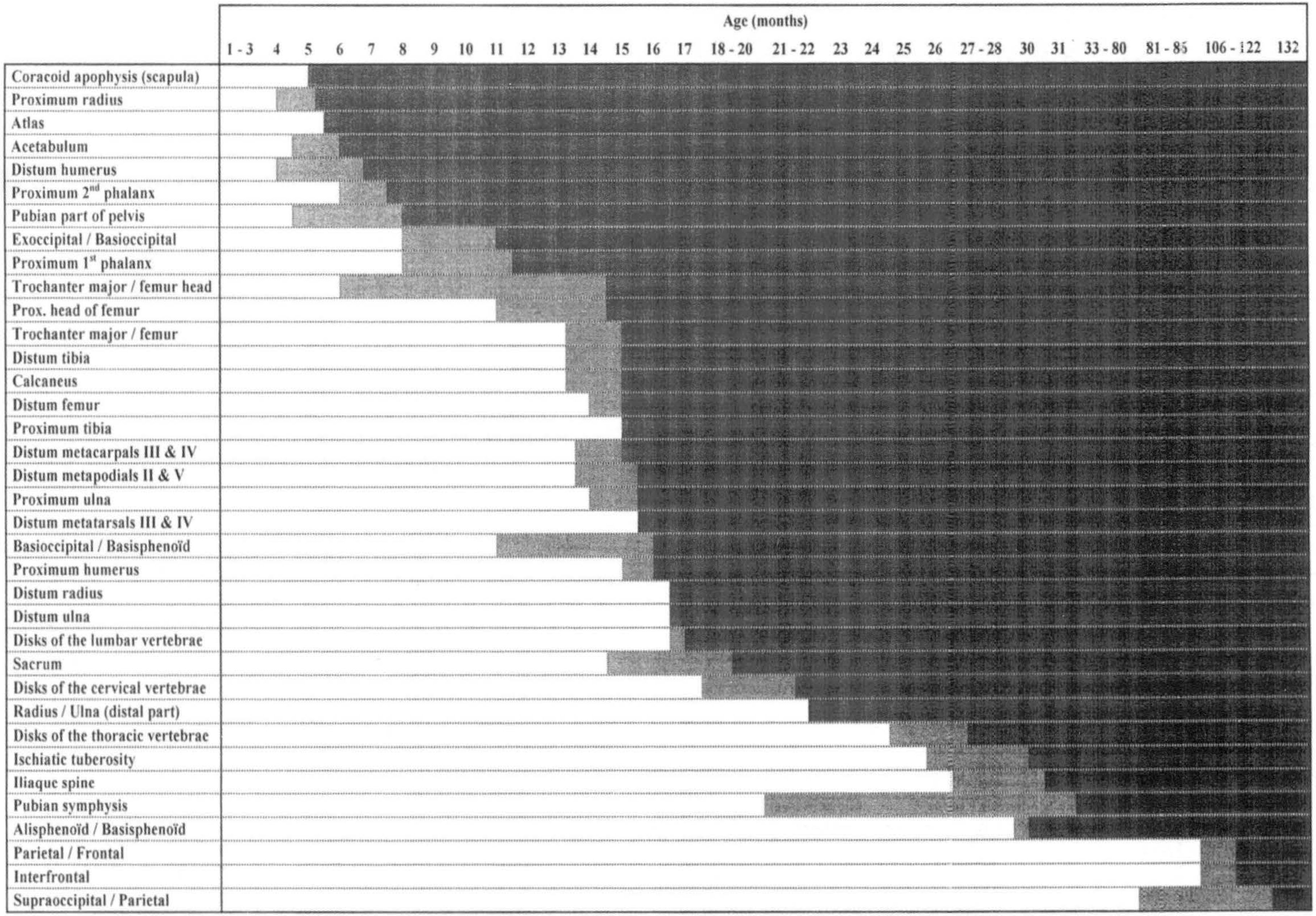


TABLE 11

Chronology of the skeletal fusion calendar for complete roe deer skeletons (White = unfused; Light grey = fusion under way (fusion line is still visible); Dark grey = fused).

5.2. *Metrical approach*

The application of the metrical method met with a series of difficulties among them: (i) the imprecise location of the measuring points that generate such large confidence intervals for the measurements, (ii) the restricted visibility of the tooth collar, often hidden by tartar deposits, (iii) the necessity for using of magnifying system with a micrometric scale vernier, and (iv) the slowness of the procedure.

It was also found that allometric phenomena greatly restrict the performances of the method. Crown height values not only correlate with the wear stage of a tooth but also with tooth size, (i.e., with body size). Size variation is particulary large in roe deer for twin litters are frequent and systematically produce a second twin which is markedly smaller than the first-born, remaining so all along its life. This generates high intrapopulational variability in the size of the teeth as was indeed recorded on our reference collections.Use of the crown height vs. the antero-posterior length of the tooth ratio has clearly not been sufficient to get rid of such bias. This suggests that this technique is strongly influenced by imprecissions when making measurements. On the whole, the relative age determination error ranges between 10 and 20 % of the real age for yearlings and increases when older animals are considered. Though very accurate in the case of the hypsodont molars (Ducos, 1968; Helmer, 2000), this method appears far less accurate than the typo-morphological one in the case of brachyodont teeth, at least for roe deer.

5.3. *Epiphyseal stages*

Previous investigations using the same collections than those analysed in the present paper, evidence a lack of correlation between the sex and the skeletal epiphysation chronology of the individual animals (Tomé, 1999).

Table 11 provides a simplified presentation of the skeletal fusion calendar for roe deer. Most of the fusion events take place during the second year of life, only skull and pelvis allowing for the ageing of the older individuals.

CONCLUSIONS

The new table for growth and wear of cheek teeth as well as the first complete epiphyseal fusion calendar presented in this paper, should help in generating more accurate mortality profiles for studying hunting strategies in the past.

In addition, in the case of well preserved mandibles from yearlings, the dental methodology should also prove useful for the determination of the season at death with an error of about ± 2 months, since its precision is around ± 1 month and since it can be reasonably postulated, at least for the Holocene, that roe deer births have always taken place ± 1 month around the month of May (Boisaubert & Boutin, 1988).

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