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Teeth eruption pattern in red deer (*Cervus elaphus hispanicus*) in southern Spain

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Resumen

Patrón de erupción dental del ciervo (Cervus elaphus hispanicus) *del sur de España.*

Se ha establecido el patrón de erupción de la dentición permanente del Ciervo de Sierra Morena (*Cervus elaphus hispanices*) a partir de 158 ciervos cazados desde 1993 hasta 1997, y a partir de 15 gabatos nacidos en cautividad. La secuencia de erupción resultó ser la siguiente: M_1, I_1, M_2, I_2, C, I_3, I_4, los premolares, y M_3. La edad de erupción fue: M_1 a los 6 meses, I_1 a los 14-15, e I_2 a los 17-18. I_3 erupciona antes que I_4, pero ambos entre los 19 y los 25 meses de edad. M_3 es el último diente en emerger, y lo hace a los 31-32 meses; completando su erupción a los 42-44. A partir del reemplazamiento dental es posible determinar la edad hasta los tres años y medio. En el presente estudio han sido detectados casos de retraso en la erupción de la dentición permanente. El 18,75% de los ciervos estudiados presentó un retraso de la erupción del primer incisivo (I_1). Los resultados obtenidos han sido comparados con los obenidos por otros autores, observándose diferencias en el tiempo de erupción del primer molar (M_1) y la tercera cusp del tercer molar (M_3). En cuanto a la secuencia de erupción, al contrario de lo encontrado por otros autores, en la mayoría de los ciervos estudiados en Sierra Morena (85,71% de los casos) el segundo molar está en fase de erupción cuando el primer incisivo ya es funcional.

Palabras clave: Reemplazamiento dentario, Determinación de edad, Sierra Morena.

Abstract

Permanent teeth eruption pattern for deer has been established by examining the jaws of 158 animals harvested in Sierra Morena between 1993 and 1997, and of 15 fawns living in captivity. The permanent teeth eruption sequence is as follows: M_1, I_1, M_2, I_2, C, I_3, I_4, premolars, and M_3. Eruption time is: M_1 at 6 months of age; I_1 at 14-15 months of age and I_2 at 17-18 months of age. I_3 appears before I_4, but both between 19 and 25 months of age. M_3 is the last tooth to grow, at 31-32 months, full eruption being completed at 42-44 months of age. Age can be determined in this species up to the age of three and a half years by studying gradual changes in teeth. In the present paper we report cases of delay in the replacement of some permanent teeth. 18.75% showed a delay in the replacement of the first incisor (I_1). Results have been compared with other studies and the differences found are discussed. Great differences in eruption time were observed for the first molar (M_1) and for the third cusp of the third molar (M_3). As for the eruption

sequence, our data indicate that 85.71% of the deer are still developing the second molar while their incisors are already functional.

Keywords: Tooth eruption, Tooth replacement ageing, Aging, Sierra Morena.

Introduction

Milk teeth shedding and permanent teeth eruption patterns have long been used for determining the age of mammals in their first years of life. Nowadays, this method still proves useful both for domestic animals and for wild animals living in hunting grounds, such as deer. Teeth eruption has also been used for interpreting growth marks in dental tissues in skeletochronologic studies (Morris 1972, 1978, Grue & Jensen 1979). Dental eruption and replacement patterns in Central European deer have been described by researchers in Germany (Wagenknecht 1980, Müller-Using 1981, Drescher 1989), Great Britain (Mitchell 1963, 1967, Lowe 1967) and France (Lotze 1968, ONC 1984). However, in the Iberian Peninsula the only studies conducted on this subject concern animals living in the north of the Peninsula (Mariezkurrena 1983). Furthermore, permanent teeth eruption follows an ordered sequence and takes place in chronological periods which are relatively independent from the physiological state of the animal (Bourlière & Spitz 1975). However, eruption time can be affected by genetic and environmental factors (Attwell 1980). The use of dental eruption patterns established for deer living in distant geographical locations can lead to errors in age estimation. The aim of this study is to describe the teeth eruption pattern of Sierra Morena deer (*Cervus elaphus hispanicus)* in Andalusia (southern Spain).

Material and Methods

The deer specimens studied came from hunting and management culls that had taken place in the eastern area of Sierra Morena (province of Jaén) between 1993 and 1997. A total of 158 jawbones with incomplete dentition were examined (56 from stags, 87 from hinds, and 15 from deer of unknown sex). Their ages ranged between 4 and 44 months. Determination of their age was possible for the exact dates of their death and period of births were known to us, in a manner similar to that reported by Attwell (1980), Mariezkurrena (1983), Vigal & Machordom (1985), Genov et al. (1992) or Pérez Barbería & Mutuberría (1996). In eastern Sierra Morena, most births took place in June and July during the study period (Azorit 1999). The age was recorded every two months, starting at 6 months of age and assuming a possible maximum error of one month in the estimation. Table 1 shows the number of animals, according to age ranges. Apart from the above group, the jaws of 14 living deer (10 hinds and 4 stags) and 1 dead hind were also analyzed. Their ages ranged from almost 2 months to 4 months. All of them had been born in captivity between June and August at the University of Castilla-La Mancha. Examination of their jawbones proved useful for confirming the eruption time of the first lower molar (M_1), which is the first permanent tooth to grow. A comparison was made between eruption time and sequence of all the teeth of both the mandible and the maxillar, and the similarity of the dental patterns for each age class. The comparison method followed is similar to that reported by Aitken (1975). The methodological variations described by Attwell (1980), Vigal & Machordom (1985) and Moore et al. (1995) have also been used. A tooth was considered erupted when it protruded through the gum in at least one jaw side (Vigal & Machordom 1985, Simpson 1986). We use asterisks for the entire tooth and other symbols for the third cusp of the third molar. The meaning of the symbols is as follows:

***: the tooth is still inside the gingiva but there is an open hole in the mandible that allows the vision of the dental crown.

**: the tooth is emerging through the gingiva but only half, or less, of the crown is visible.

*: the tooth has almost emerged but not in full. The absence of asterisk represents that the teeth is completely erupted.

And for the third cuspid of the M_3:

$M_{3\square}$: the third cuspid has not emerged.

M_{3v}: the third cuspid has emerged almost in full.

$M_{3\bigcirc}$: the third cuspid has fully emerged, with occlusal zone in a circle but without colour.

$M_{3\omega}$: moderately coloured.

$M_{3\lambda}$: third cuspid coloured. In none of those cases appears still erosion of the occlusal surface.

Results and Discussion

Table 2 shows the stage of dental eruption and indicates the percentage and the number of cases in which the same tooth pattern coincides in stags and hinds. The results of the observations carried out on the calves born in captivity are shown in Table 3. The sequence of tooth eruption of deer is shown in table 4. The first permanent tooth to erupt is the first molar, visible above gum line from the age of three months. At the age of four months, one third of the cusp of the crown is visible. At the age of five months, the molar has not fully erupted. At the age of six months, the molar has erupted fully

Age in months	Males	Females	Total
4	-	-	5
5	-	-	1
6	-	-	4
6-7	-	-	2
7-8	-	-	3
13-14	1	0	1
14-15	5	9	14
15-16	6	16	22
16-17	3	2	5
17-18	0	7	7
18-19	1	8	9
19-20	3	1	4
25-26	0	2	2
26-27	0	7	7
27-28	1	3	4
29-30	1	2	3
31-32	0	1	1
37-38	0	7	7
38-39	1	4	5
39-40	7	6	13
40-41	12	6	18
41-42	13	2	15
42-43	2	3	5
43-44	0	1	1
total	56	87	158

Table 1. Age and sex of deer studied, harvested in hunting parties and/or management culls in Sierra Morena.
Tabla 1. Edad y sexo de los ciervos estudiados, procedentes de monterías o/y caza selectiva en Sierra Morena.

and is functional, both in stags and hinds. At this age either there are still no visible signs of wear or they are insignificant, so that the underlying dentine in the chewing surface is not yet visible. At the age of 7 or 8 months, some degree of wear is observable, with very little dentine exposed on the chewing surface.

None of the captivity-born deer showed full eruption of the first molar. Only one third of the cusp was visible in the most advanced eruption cases. This entire group presented fully erupted milk incisors, canines and premolars, including the youngest calf, a female which died at the age of one month and 24 days. After cleaning the skull, examination revealed an empty tooth socket in the jaw, but the first molar was still completed inserted in the gum. At the age of two months, the deer dentition showed fully erupted milk teeth.

At about the age of 15 months, the first permanent incisor has erupted, while the second molar has not yet emerged completely. Full eruption of both the second incisor and the permanent canine takes place at the age of 17-18 months. The third incisor erupts before the fourth one, but it we have been unable to determine the exact moment of eruption, due to the lack of animals aged between 19 and 25 months. However, we can state that both incisors are functional by the age of 26 months. About 50% of the deer presented a fully erupted third incisor at the age of 20 months, and in 25% of them, the fourth incisor also fully erupted. Premolars are fully erupted at the age of 27-30 months and their cusps are visible on the jaw at the age of 25-26 months.

The third molar (M_3) is the last permanent tooth that deer grow. Its first two cusps are fully erupted at 31-32 months of

	No	%	MONTHS	DENTAL SEQUENCE	OBSERVATIONS
In calves (n=20)	1/1	100	2	M_{1***}	
	5/5	100	4	M_{1**}	
	1/1	100	5	M_{1*}	
	6/6	100	6	M_1	
In hinds (n=89)	7/9	77.78	14-15	$M_1M_{2*}\ I_1$	
	13/16	81.25	15-16	$M_1M_2\ I_1$	Delay in I_1 (2/16)
	1/2	50	16-17	$M_1M_2\ I_1I_{2*}$	
	6/7	85.71	17-18	$M_1M_2\ I_1I_2C$	Delay in I_2 (1/7)
	5/8	62.5	18-19	$M_1M_2\ M_{3***}\ I_1I_2$	Delay in I_2(1/8)
	1/1	100	19-20	$M_1M_2\ M_{3***}\ I_1I_2I_3I_4$	
	2/2	100	25-26	$M_1M_2\ M_{3**}\ I_1I_2I_3I_4\ PM_{1**}\ PM_2\ {}_{***}PM_{3**}$	
	2/12	16.67	26-30	$M_1M_2\ M_{3**}\ I_1I_2I_3I_4\ PM_1\ PM_2\ PM_3$	
	1/12	8.33	26-30	$M_1M_2\ M_{3*}\ I_1I_2I_3I_4\ PM_{1***}\ PM_{2**}\ PM_3$	Delay in premolars
	8/12	66.67	26-30	$M_1M_2\ M_{3*}\ I_1I_2I_3I_4\ PM_1\ PM_2\ PM_3$	
	1/12	8.33	26-30	$M_1M_2\ M_3\ I_1I_2I_3I_4\ PM_1\ PM_2\ PM_3$	
	1/1	100	31-32	$M_1M_2\ M_3\ I_1I_2I_3I_4\ PM_1\ PM_2\ PM_3$	
	8/9	88.89	37-38	$M_1M_2M_{3\square}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	4/10	40	38-40	$M_1M_2M_{3\square}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	3/10	30	38-40	$M_1M_2M_{3\nu}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	3/10	30	38-40	$M_1M_2M_{3\mu}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	8/8	100	40-42	$M_1M_2M_{3\omega}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	2/4	50	42-44	$M_1M_2M_{3\lambda}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
In stags (n=55)	5/5	100	14-15	$M_1M_{2*}\ I_1$	
	3/6	50	15-16	$M_1M_2\ I_1C_*$	Delay in I_1 (1/6)
	1/3	33.33	16-17	$M_1M_2\ M_{3***}\ I_1I_{2*}$	
	1/3	33.33	16-17	$M_1M_2\ I_1I_{2**}$	The same as in hinds but with a delay in I_2
	1/1	100	18-19	$M_1M_2\ M_{3***}\ I_1I_2\ C$	
	2/3	66.66	19-20	$M_1M_2\ M_{3**}\ I_1I_2I_{3*}I_{4**}$	
	1/3	33.33	19-20	$M_1M_2\ M_{3**}\ I_1I_2I_3I_{4*}$	
	2/2	100	27-30	$M_1M_2\ M_{3*}\ I_1I_2I_3I_4\ PM_1\ PM_2\ PM_3$	
	8/8	100	38-40	$M_1M_2M_{3\square}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	10/12	83.33	40-41	$M_1M_2M_{3\nu}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	(1/12) with $M_{3\square}$ and (1/12) $M_{3\mu}$
	2/15	13.33	41-43	$M_1M_2M_{3\nu}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	2/15	13.33	41-43	$M_1M_2M_{3\mu}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	8/15	53.33	41-43	$M_1M_2M_{3\omega}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	
	3/15	20	41-43	$M_1M_2M_{3\lambda}\ I_1I_2I_3I_4\ PM_1PM_2PM_3$	

Table 2. Percentage and number of cases coinciding in the stage of teeth eruption indicated for each age class.
Tabla 2. Porcentage y número de casos en los que coincide el mismo estado de erupción dental indicado para cada edad.
***: the tooth is still inside the gum but there is a hole in the mandible through which the tooth crown is visible.
**: the tooth is emerging through the gum but only half, or less, of the crown is visible.
*: the tooth has almost emerged but not fully. The absence of asterisk means that a teeth has completely erupted.
And for the third cusp of the M_3:
$M_{3\square}$: the third cusp has not emerged.
$M_{3\blacksquare}$: the third cusp has emerged almost fully.
$M_{3\bigcirc}$: the third cusp has fully emerged, with chewing surface in a circle but without color.
$M_{3\blacktriangleright}$: moderately colored.
$M_{3\bullet}$: third cusp colored. No signs of wear of the chewing surface yet in any of those cases.

Sex	Date of birth	Age in months and days	Eruption stage of M_1
		Living animals	
F	4-jun	4 months and 9 days	Cusp crests of the first molar are visible above gum line in M_{1**}
F	7-jun	4 months and 6 days	Cusp crests are visible only a few millimeters in M_{1**}
F	10-jun	4 months and 3 days	Without M_1
F	19-jun	3 months and 24 days	Cusp crests are visible only a few millimeters in M_{1**}
M	22-jun	3 months and 21 days	No observation taken
F	23-jun	3 months and 20 days	No observation taken
M	23-jun	3 months and 20 days	Without M_1
F	6-jul	3 months and 7 days	Only cusp crests of the first molar are visible above gum line in M_{1**}
F	8-jul	3 months and 5 days	No observation taken
F	11-jul	3 months and 2 days	No observation taken
M	12-jul	3 months and 1 day	Without M_1
F	12-jul	3 months and 1 day	Without M_1
M	3-aug	2 months and 10 days	Without M_1
F	12-aug	2 months and 1 days	No observation taken
		Dead female	
F	16-aug	1 month and 24 days	Without M1 (empty socket in the jaw) M_{1***}
		All these animals show fully erupted milk incisors and premolars	

Table 3. Observations of the eruption stage of the first molar of captivity-born deer. (Observation date: 13 October, 1998).
Tabla 3. Resultados de la observación del estado de erupción del primer molar en ciervos nacidos en cautividad. (Observación realizada el 13 de octubre de 1998).

N	months	%	I_1	I_2	I_3	I_4	C	PM_1	PM_2	PM_3	M_1	M_2	M_3	3rd cusp
1	2	100	-	-	-	-	-	-	-	-	***	-	-	-
5	4	100	-	-	-	-	-	-	-	-	**	-	-	-
6	6	100	-	-	-	-	-	-	-	-	X	-	-	-
14	14-15	85.71	X	-	-	-	-	-	-	-	x	*	-	-
22	15-16	72.73	x	-	-	-	*	-	-	-	x	X	-	-
5	16-17	40	x	*	-	-	¿	-	-	-	x	x	-	-
7	17-18	85.71	x	X	-	-	X	-	-	-	x	x	-	-
9	18-19	66.67	x	x	-	-	x	-	-	-	x	x	***	-
4	19-20	50	x	x	*	**	x	-	-	-	x	x	**	-
2	25-26	100	x	x	X	X	x	**	***	**	x	x	*	-
14	27-30	71.43	x	x	x	x	x	X	X	X	x	x	*	-
1	31-32	100	x	x	x	x	x	x	x	x	x	x	X	-
27	37-40	74.07	x	x	x	x	x	x	x	x	x	x	x	I
39	40-44	58.97	x	x	x	x	x	x	x	x	x	x	x	II

Table 4. Eruption sequence of permanent teeth.
Tabla 4. Secuencia de erupción de la dentición permanente.
***, **, *: indicate different stages of eruption; **X**: moment of full eruption; **I**: the third cusp of the molar has not fully erupted and is not colored; and **II**: has fully erupted.
***, **, *, indican diferentes grados de erupción de menor a mayor; **X**: momento de erupción completa; **I**: la tercera cúspide del tercer molar no está totalmente erupcionada ni coloreada; y **II**: está totalmente erupcionada.

PRESENT STUDY											
M_1		I_1		M_2	I_2		C	I_3 I_4	Premolar	M_3	3rd cusp
6		14-15		15-16	17-18		17-18	Before 25-26	27-30	31-32	37-44
OTHER AUTHORS											
M_1	M_2	I_1	I_2	C	I_3	I_4	M_3	P_2	P_3	P_1	References
5-12	12-14	15	15-17	15-18	18-20	21-23	24-27	27-30	27-30	27-30	ONC, 1984
4	12	14	16	17	19	19	21	25	25	25	Wagenknecht, 1980
4	12	14	15	16	19	19	21	25	25	25	Muller-Using, 1971
5	13						26				Brown & Chapman, 1991
4-6	12-15	12-15	19	21		21-28	33	21-28	21-28	21-28	Mitchell, 1967
after 12		16					30				Godawa, 1989
		15							24		Grue & Jensen, 1979
before 8							32				Mariezkurrena, 1983

Table 5. Eruption sequence and age (in months) of permanent teeth according to different authors.
Tabla 5. Secuencia y edad (en meses)de aparición de los dientes permanentes por diferentes autores.

age, while the third cusp completes its eruption between 37 and 44 months of age. The latter cusp becomes visible at the age of 37-39 months and it has completely emerged by the age of 40-41 months. It finishes its eruption and shows dark coloration in the crown at 42-44 months of age, but does not show any signs of wear in the chewing surface.

The eruption sequence of the permanent teeth was as follows: **M_1, I_1, M_2, I_2, C, I_3, I_4,** the **premolars** and finally the **M_3.** The eruption order in the premolars is different from their linear position in the mandible. In general, the second premolar (PM_2) is the last premolar to erupt (Table 4). Some cases of delay in the replacement of permanent teeth were observed. Almost 20% of the animals studied showed a delay in the replacement of all the incisors, while 18.75% showed a delay in the replacement of the first incisor (I_1), which erupted after the second molar. Furthermore, there are cases of animals under 18 months of age whose first and second molars are functional, but which have not yet shed any incisors. These animals belong to the group of those that died in 1994 and 1995 and which had been born very late (in September) in years of severe drought. Animals of the same age that died in 1997 showed two fully erupted first incisors. The reason for these differences in the general development of the animals may lie in nutritional deficiencies or in environmental and population variables, as commented by Mitchell (1967) in his study on Scottish deer. This author reported that some two-and-a-half-year-old individuals suffering from severe malnutrition showed three permanent molars but at the same time still kept all their milk premolars. This was the case of about 8% of all hinds in Sierra Morena.

Table 5 shows the sequence and age of permanent teeth eruption in *Cervus elaphus* according to several authors. Our results do not agree with Müller-Using (1981) and Wagenknecht (1980), who set the eruption of M_1 at four months of age. At this age none of the deer harvested in Sierra Morena nor those born in captivity had completed the eruption of this molar. Mariezkurrena (1983) studying deer living in the mountains of Cantabria (northern Spain) was unable to fix the eruption time for the M_1 because there were no animals under the age of 8 months at his disposal. However, his conclusions for 8-month-old deer coincide with those reached for the Sierra Morena deer. It has not been possible to compare the eruption time of the incisors with other information from deer in the rest of the Peninsula, since these teeth are not included in any study. Most of the authors studying other subspecies estimated the eruption of the first incisor (I_1) at one year of age, which is earlier than that observed in our study. The results obtained also agree with Mitchell (1967) and Grue & Jensen (1979), who suggested that I_1 erupts approximately at the age of 15 months and the last premolar at the age of 24 months. Mitchell (1963) observed that almost the entire third cusp of the third molar is visible on the mandible at 31-32 months of age. However, in our study this occurs after the age of 37 months. Some authors like Müller-Using (1981), Gottschlich (1979) and Wagenknecht (1980) have stated that the eruption of the third molar in German deer takes place at the age of 21 months, much earlier than in our study. Others, like Eidmann (1932, in Müller-Using, 1981), placed this eruption at the age of 29-31 months. Mariezkurrena (1983) does not establish the exact time of the eruption of the M_3 as he conducted his research on animals of 8, 20 and 32 months of age only. However, we do not agree with what is described for the age of 32 months. For this age we have observed an erupted third molar, though only with just two cusps emerged, while only

one-third of the third cusp is visible, in agreement with Mariezkurrena (1983), at least for ages over 44 months.

Differences are also observable in the eruption sequence, which is usually considered to be constant (Mitchell 1967, Attwell 1980). In this sense, while most authors consider the eruption of the second molar (M_2) to take place prior to the eruption of the first incisor (I_1), our data prove that this is incorrect. For Sierra Morena deer, 85.71% of the animals aged between 14 and 15 months follow the next dental pattern: **M_1, I_1, M_2**. This means that, for 85.71% of animals of the same age and of either sex, the second molar is still completing its eruption when the incisor is already functional. Variations in the time of eruption and replacement between deer populations in far apart geographical locations is the result of differences in nutritional conditions. Attwell (1980) and Steenkamp (1970) showed that sheep and goats undergo eruption at an earlier age when nutritional conditions are better. Furthermore, differences in teeth eruption may have some functional or adaptive meaning. Nevertheless, the differences observed between authors, especially those referring to eruption sequence, could be explained by the lack of agreement in the definition of concepts such as *dental development*, *dental eruption* or *the age at which a tooth is fully functional*.

As stated above, complete eruption of the permanent teeth (including the third cusp of the third molar) of the deer from the eastern area of Sierra Morena takes place at 42-44 months of age. We can therefore determine the individual age for this species, up to the age of three years and a half, by studying the gradual changes in dentition. After that, other criteria such as teeth wear and skeletochronology, can be applied to determine age.

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