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Manuscript Draft

Manuscript Number: QUATINT-D-13-00254R1

Title: Blind test evaluation of accuracy in the identification and quantification of digestion corrosion damage on leporid bones

Article Type: ICAZ Taphonomy WG 2nd Meeting

Keywords: taphonomy, blind test, inter-observer error, digestion damage, leporids

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Manuscript Region of Origin: SPAIN

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Blind test evaluation of accuracy in the identification and quantification of digestion corrosion damage on leporid bones

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Abstract

The recording of digestion corrosion damage on the surface of archaeological skeletal remains is an important variable to take into account in taphonomic analyses. Different kinds of predators produce digestion damage of variable intensity; consequently, digestion is one of the most distinctive features used to identify the agents of accumulation, alongside anatomical representation profiles and bone breakage patterns. In order to quantify digestion corrosion on taphonomic studies of leporid (rabbits and hares) remains, different categories of digestion, distinguishing five grades of intensity, have been proposed. However, since they are based on morphological characters and represent the division of continuous variation into qualitative ordinal categories, their evaluation is subject to inter-observer error. With the aim of quantitatively evaluating the magnitude of ambiguity in the identification of digestion surface modification, a blind test was conducted with 25 volunteers. Results show that absent and slight digestion damage was the easiest to categorise. The accuracy of grading intermediate and more advanced cases of digestion damage proved harder to separate. It is concluded that this system remains a reliable method for identifying the agents of leporid accumulation in the archaeological record; however training in the identification of the effects of digestion damage is essential to obtain reliable scoring results.

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1. Introduction

Assessment of the origin of small prey assemblages has become an important research topic in taphonomic studies. On most prehistoric sites from the Iberian Peninsula and the Mediterranean region, leporid remains (rabbits and hares) and specifically European rabbit (*Oryctolagus cuniculus*) are especially abundant in small prey accumulations (Aura-Tortosa et al., 2002; Hockett and Haws, 2002). For this reason, and in order to confidently appraise the importance of these prey amongst prehistoric communities, it is essential to distinguish the agents of accumulation (Cochard, 2004; Sanchís, 2010; Lloveras et al., 2010, 2011a). In addition to humans, small mammal, and specifically, leporid predators include several species of mammalian carnivores, diurnal raptors and nocturnal owls (Delibes and Hiraldo, 1981). While the skeletal remains of ingested prey are concentrated in scat in mammalian carnivores, avian predators produce pellets (regurgitated masses of the undigested components). Many of these predators show high roost, den or latrine fidelity ranging, which can lead to a significant prey material accumulations affected by different intensities of damage caused by digestion (Andrews, 1990). Recording of digestion corrosion damage on the surface of fossil skeletal remains is, consequently, an important variable to take into account in taphonomic analyses.

Corrosion attrition due to digestion appears as pitting, cracking, polishing and rounding of fracture surfaces. This attrition is more conspicuous on the jagged ends of bones, which were broken during the chewing and ingestion process, and also on the intact articular ends (Andrews, 1990; Fernández-Jalvo and Andrews, 1992). The degree of damage to digested skeletal remains varies mainly due to the enzymes and acidity (pH) of the digestive tract of the predator. For this reason, different kinds of predators produce damage of variable intensity, and provide a character that can be used to distinguish between accumulating agents, alongside anatomical representation profiles and bone breakage patterns. Also intraspecific variability in the degree of corrosion may occur depending on the availability of prey, their age and the length of digestion (Lloveras et al., 2012). In recent years, results obtained from actualistic studies have shown the importance of digestion corrosion intensity as a distinctive feature when applied to the analysis of rabbit and hare remains (Schmitt and Juell, 1994; Schmitt, 1995; Hockett, 1995, 1996; Cochard, 2004; Sanchís, 2010; Lloveras et al., 2008a, 2008b, 2009, 2011b, 2012).

In order to quantify digestion corrosion on leporid remains, different categories of digestion, distinguishing five grades of intensity, have been proposed (Lloveras et al. 2008b): null (0); light (1); moderate (2); heavy (3); and extreme (4). The variables described were based on high resolution actualistic and experimental models designed specifically to this end (Lloveras et al., 2008a, 2008b). Since these grades are based on morphological characters and represent the mapping of qualitative ordinal categories onto continuous variation, the potential for inter-observer error exists. This fact underscores the need for studies that quantitatively evaluate the magnitude of ambiguity in the identification of this type of surface modification.

With such an aim, we conducted a blind test with some volunteers in order to evaluate the degree of correspondence and accuracy in the identification and quantification of digestion corrosion damage on leporid bones. This is an unreported approach for studies of digestion bone surface modification, but is necessary to determine the impact of inter-observer error and assist in the refinement of the application of the method.

2. Materials and Methods

A total of ten leporid bone remains displaying different intensities of digestion corrosion damage were used in the blind test (Table 1, Figure 1). All bones came from actualistic experimental studies carried out with different kind of predators (terrestrial carnivores and raptors), with the exception of cases D and G, which were of archaeological origin (Table 1).

The number of participants in the blind test was 25. All of them were experienced researchers and students from the field of zooarchaeology, not necessarily habituated to analyse digestion damage on bone surfaces. They all were participants of the 2nd meeting of the ICAZ Taphonomy Working Group, entitled *Taphonomy and archaeozoological research: recent approaches*, held in Santander (Spain) in September 2012.

The morphological criteria employed to distinguish and quantify digestion damage during the blind test are described in Table 2. These criteria have been specified and employed in prior taphonomic actualistic studies involving leporid remains (Lloveras et al*.* 2008a, 2008b, 2009, 2011b, 2012).

Following the criteria established in Table 2, participants were asked to analyse the ten specimens in order to record digestion corrosion. A table to quantify different digestion categories was provided. As shown in Table 2, five grades of intensity were scored: null (0); light (1); moderate (2); heavy (3); and extreme (4). Participants did not receive any training, nor were they shown illustrations or specimens typical of each grade: they were only provided with the textual description. During the experiment, participants did not have the possibility to come back and eventually correct their first choice. The order of the bone sample was the same for all participants.

Leporid remains were analysed macroscopically and under a light microscope (x10 to x40). Participants were also asked to respond about their familiarity with the observation of digested bone remains and about the category they found most difficult to identify.

The evaluation of the results was made by comparing the scores provided by participants with the values previously scored by the authors. A score is described as correct if it matches the expected value and as error if it does not. The error is equal to one grade (within one grade) when the distance to the expected value is ±1. The error is larger than one grade when the distance to the expected value is higher than ±1.

3. Results

A total of 245 designations were registered, from which only 125 (51%) were correctly evaluated (Table 3). However, most errors were within one grade (29%), which means that the percentage of cases accurately scored or with a low error was 80%. The percentage of accuracy was variable among different participants, ranging from 80% to 10%. Of all participants, 12 (48%) stated to be familiar with the observation of digested bone remains. On the whole, accuracy was lower in participants that claimed to be unfamiliar with the observation of digested bone remains (40.8%) than in researchers experienced in digestion evaluation (59.2%).

Variability was also apparent in the accuracy of different grades of digestion. Most participants (95%) thought that degrees of digestion null (0) and extreme (4) were easier to evaluate, while the intermediate grades (1, 2 and 3) were more difficult: this is partly supported by the results.

The degree of accuracy in the identification of undigested bones can be evaluated through cases B and G (Table 3). Case B was correctly scored by 84% of participants; however only 20% correctly recorded Case G, making it the least accurately identified specimen in the test. This bone fragment is clearly altered but by diagenetic agents other than digestion corrosion (Figure 2). The problem was that most participants confused this alteration with digestion and scored it with a high degree of damage. The significance of this mistake is discussed below.

Figure 3 supports the opinion of participants that grade 0 was one of the easiest to determine: grade 0 showed the highest level of accuracy in the study. However, grade 4 was only correctly scored in 46% of cases. Grade 1 was recorded with a reasonable degree of accuracy (68%). The most problematic grade to assess was grade 3.

The majority of errors occurred in the first bones observed, specifically cases J and I (only 20% and 12% accuracy). On the contrary, the last bones examined (H, F, E, D, C, B, A) displayed the highest percentages of accuracy of digestion corrosion damage quantification (Table 4). On the whole, most errors were a consequence of the tendency to underscore digestion damage (Table 5): 85% of incorrectly evaluated cases were underscored.

4. Discussion

The results of the blind test have highlighted a number of issues regarding the quantification of digestion damage in leporid bones. Firstly, it is possible to conclude that distinguishing digested from undigested remains is much easier than quantifying the degree of digestion damage. This is supported by the fact that in the blind test case B, the undigested leporid bone was correctly identified by the highest number of participants (84%). Test participants that scored it as a digested bone of grade 1, did so because they incorrectly mistook the slightly polished surface for low-grade digestion. However, the worse recorded specimen was another undigested bone (case G) that had been altered by other taphonomic agents, and was only correctly recorded by 20% of participants (Figure 2). This result highlights the potential for other diagenetic agents to be misidentified as digestion damage. Digestion damage is characterised by rounding and polishing, shiny surfaces, and dissolution, with the presence of porosities or holes, which enlarge when the effects of digestion increase (Figure 1). Digested bones are not usually affected equally on their entire surface; rather, articular ends and breakage surfaces are regularly more corroded than shafts. Bones with articular surfaces normally present holes with rounded edges, while fracture surfaces of the shaft are usually rounded and partly thinned (Andrews 1990; Fernández-Jalvo and Andrews, 1992; Bochenski and Tomek 1998). In case G, the entire diaphysis is affected by dissolution, probably a consequence of water damage. With respect to digestion quantification, it is clear from this study that some grades are harder to distinguish than others. In interpreting our results, it is necessary to take into account the fact that not all participants were familiar with digestion and leporid remains; so unfamiliarity with morphology and 'normal' anatomical variation. Nonetheless, it is clear that the separation of grades 2 and 3 and grades 3 and 4 posed particular difficulties for test participants.

The proportion of bones incorrectly assessed within one grade represents 71% of errors. It should be taken into account that the results obtained in the blind test must be considered as the *maximum difference* to be expected among researchers that are experienced in taphonomic analysis. When quantifying digestion damage it can be very difficult to distinguish between two consecutive grades in some specimens, because digestion corrosion damage is not a measurable variable. For this reason, it is normal that results obtained by different participants display a degree of variability. In fact, it is probable that if the same sample was analysed for digestion by the same researcher twice, the results would not be identical. Therefore, total accuracy is something that cannot be expected in this type of analysis. On the other hand, a low percentage of *low* errors is not necessarily a problem, because the assessment of the accumulating agent is based on the overall intensity of digestion within the assemblage. Thus, terrestrial carnivores inflict greater corrosion damage to bones than diurnal raptors, and these, in turn, are more destructive to skeletal material than nocturnal raptors (Andrews, 1990; Terry, 2007; Lloveras et al., 2008a, 2008b, 2009, 2011b, 2012). Despite the existence of this variability, therefore, when recording digestion damage on large bone samples, the ability to determine the overall direction of digestion damage intensity remains undiminished. Indeed, the application of this method to the analysis of archaeological remains shows that fossil assemblages yield very similar patterns of damage to that observed in modern assemblages, and the dominant predator type remained constant (Lloveras et al., 2010, 2011a).

The importance of training is also highlighted by this blind test. If we do not consider the first four cases observed, the results of the blind test change significantly (Table 6). Now, accuracy is of 70.3% and the percentage of assignments correctly assessed or within one grade of error is 96.5%. This shows that the more time participants spent recording digestion corrosion, the more they came to understand the morphological criteria described, and were better placed to correctly evaluate which grade a bone belonged to. The implication is that improved accuracy would result from prior training, and perhaps with additional illustrative examples.

The importance of training and experience is also evident when comparing results obtained by different participants. The variability is important and often, large errors were made by the same analyst. This is exemplified by participant number 24, who scored both leporid remains displaying extreme digestion corrosion (grade 4, cases A and J) as undigested (grade 0). The same volunteer also scored the undigested specimen - case G – with grade 4. This suggests that some participants had difficulties recognising the effects of digestion on bones. Further it emphasises the need for prior training and the availability of illustrative examples to help improve the accuracy of the results.

5. Conclusion

In taphonomic studies blind tests have proved to be an important tool to evaluate inter-analyst correspondence in identification of bone surface modifications (Blumenshine et al., 1996). The data presented in this study have allowed us to asses the degree of correspondence and accuracy in the identification and quantification of digestion corrosion damage on leporid bones. By analysing the results obtained in the blind test conducted it is evident that distinguishing digested from undigested remains is much easier than quantifying the degree of digestion damage. With respect to digestion quantification, it is clear from this study that some grades are harder to distinguish than others; grade 3 is the most likely to be incorrectly scored. Accuracy increases clearly as more time is spent recording digestion corrosion, which highlights the importance of training and familiarisation with the grading system before recording begins.

The results also underline the potential for other diagenetic agents to be misidentified as digestion damage. Some previous knowledge about what digestion is and what is not is important to accurately evaluate digestion scoring. From this standpoint it is essential to build reference collections of bones displaying different intensities of digestion corrosion, as well as other types of damage produced by other taphonomic agents that may be mistaken with digestion such as some diagenetic processes or particular pathological conditions.

This is a previously unreported caveat in studies of digestion bone surface modification. It is evident that interpretation of digestion damage on leporid accumulations from archaeological sites deserves further research of the kind presented in this study as well as a better understanding of the modifications produced by digestion. Larger samples comparing trained and untrained participants and also comparing intra-observer error before and after training may provide a better understanding of the differences produced by analysts when studying digestion on bones.

It is concluded that this system, remains a reliable method for identifying the agents of leporid accumulation in the archaeological record, however some experience on the evaluation of digestion bone surface modification is essential to obtain reliable results.

Acknowledgements

We are very grateful to all volunteers that participated in the blind test. We would like to thank A. B. Marín Arroyo and M. Moreno-García as organizers of the 2nd ICAZ Taphonomy Working Group for hosting a workshop on a part of this paper at the University of Santander in September 2012. Ll. Lloveras was funded by a postdoctoral grant (BP-A 00334 2011) from the Secretaria d'Universitats i Recerca del Departament d'Economia i Coneixement de la Generalitat de Catalunya. Financial support from research projects HAR2011-26193 from the Ministerio de Ciencia e Innovación (MICINN) and SGR2009-1145 from the Generalitat de Catalunya are gratefully acknowledged. M. Moreno-García received financial support from the network programme CONSOLIDER (TCP) CSD2007-0058, funded by the Spanish Science and Innovation Ministry (MiCInn).

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FIGURE 3. Accuracy of corrosion digestion assessment by grade (case G has been removed because it did not represent digestion damage).

Figure 1
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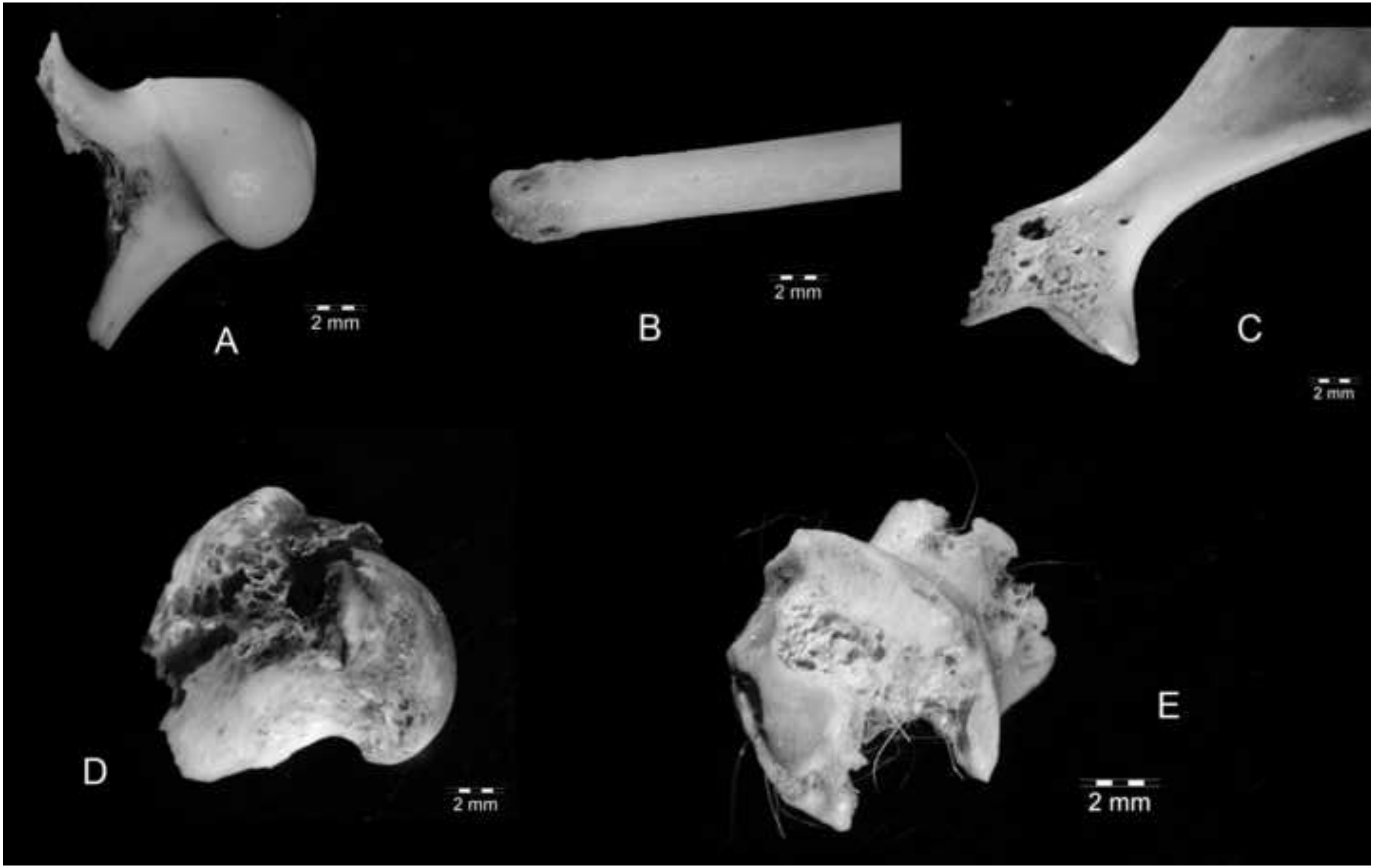

Figure 2
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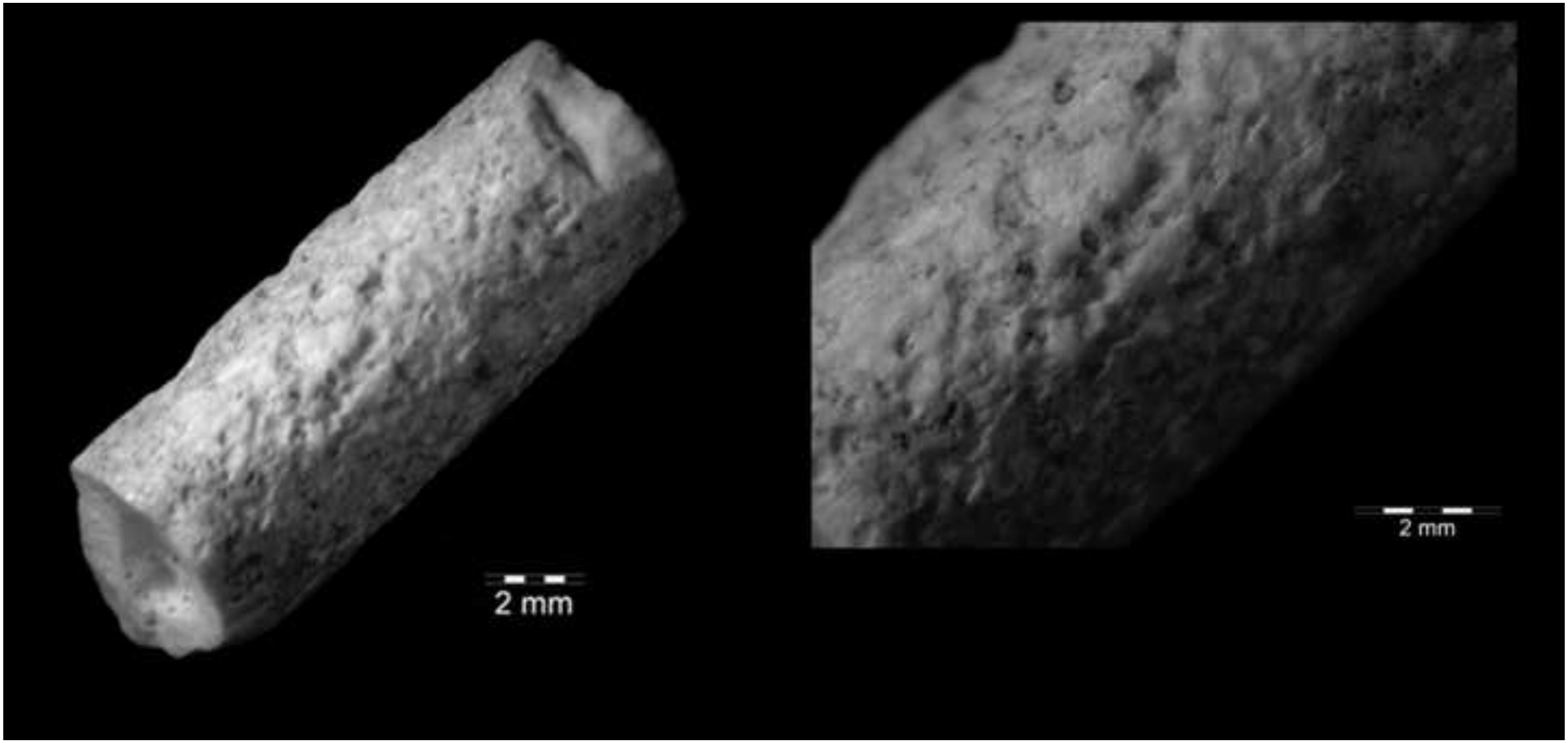

Figure 3
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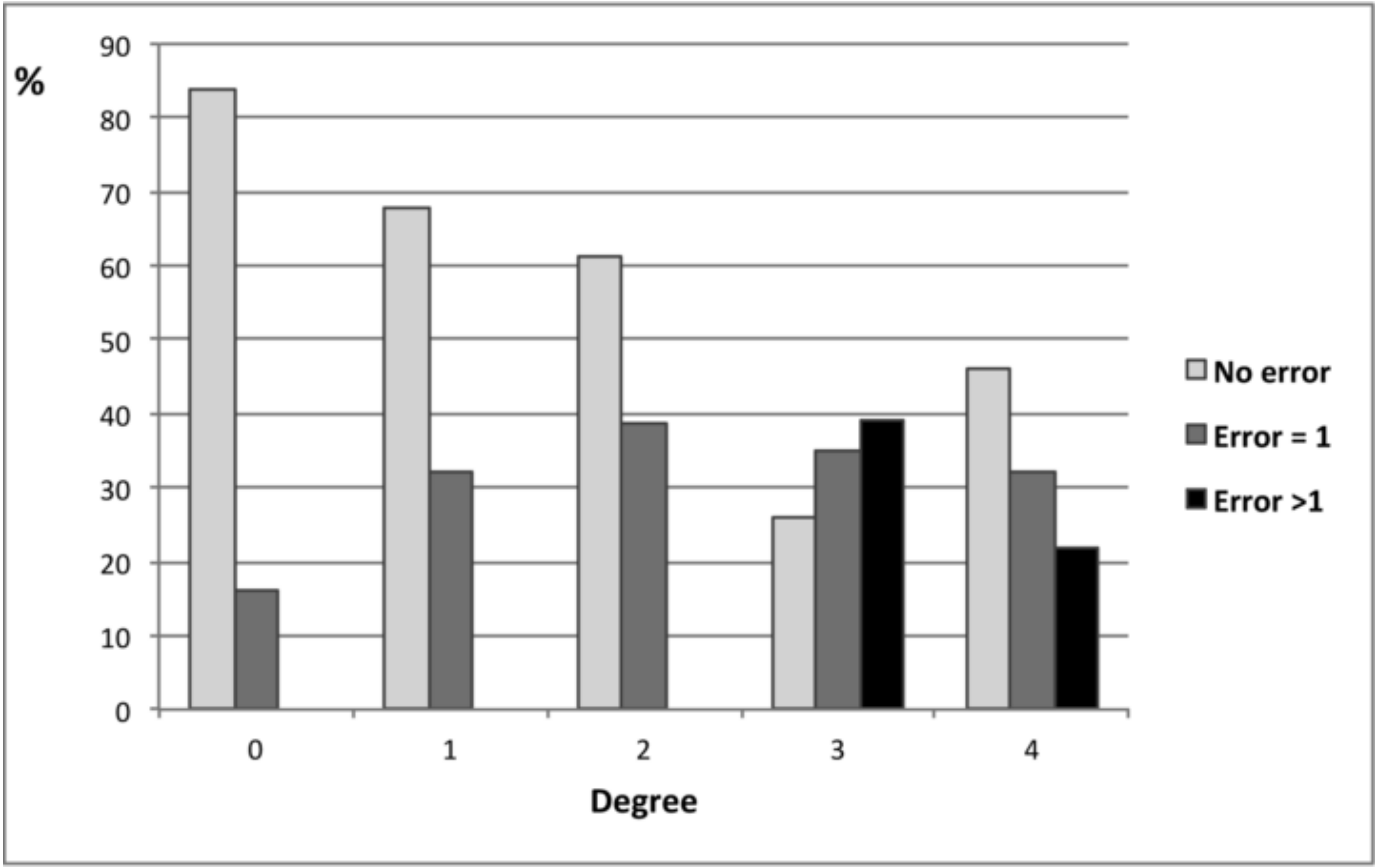

Table 1

CASE	DIGESTION GRADE	ORIGIN
A	4	Terrestrial carnivore
B	0	Diurnal raptor
C	2	Diurnal raptor
D	1	Archaeological
E	3	Terrestrial carnivore
F	1	Diurnal raptor
G	0	Archaeological
H	2	Diurnal raptor
I	3	Diurnal raptor
J	4	Terrestrial carnivore

TABLE 1. Leporid bone remains used in the blind test, intensities of digestion corrosion damage displayed and specimen origin.

Table 2

0 / Null	No traces observed
1 / Light	The surface of the bone is slightly altered. Digestion is concentrated in a particular area of the bone with presence of pitting caused by digestion enzymes. Less than 25% of the surface of the bone has been affected by alteration. Edges may be slightly rounded.
2 / Moderate	Between 25% and 75% of the surface of the bone is affected and the digestion is more advanced than in the previous category. Effects of pitting increase. Bone destruction may have occurred, but it is very localized. Possible splitting and rounding of edges.
3 / Heavy	The entire surface of the bone is affected. Extensive pitting with presence of small holes that become visible in the bone surface. Advanced bone destruction affecting more than 50% of the bone. Extensive rounding of edges. Possible splitting and cracking.
4 / Extreme	Important bone destruction has affected the entire surface of the bone. The bone structure has been destroyed by corrosion. Strong rounding of edges. Identification of the bone element is difficult.

TABLE 2. Description of the grades of digestion damage on leporid bones.

Table 3

		PARTICIPANTS																										
CASES	**GRADE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**		
A	4	4	4	4	4	4	4	4	3	4	4	4	3	3	3	4	3	4	4	4	4	4	0	4	3	4		
B	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
C	2	2	1	2	NR	2	2	1	1	2	2	2	2	1	2	2	1	2	2	1	1	2	2	2	2	1		
D	1	2	1	0	0	1	1	1	2	2	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	2		
E	3	3	2	3	NR	4	3	NR	2	2	4	3	2	1	3	3	3	0	2	NR	NR	4	0	3	1	3		
F	1	1	1	1	2	1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1		
G	0	0	0	0	0	3	3	4	4	3	3	2	3	2	3	3	3	0	4	3	3	3	4	3	3	3		
H	2	1	3	2	3	2	2	1	1	2	2	2	2	2	1	2	1	2	2	2	2	1	3	1	2	1		
I	3	3	1	1	3	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2	2	1	3	2	2	2	**TOTAL**	
J	4	3	4	2	3	3	4	3	3	4	2	3	2	3	2	4	2	3	3	2	2	3	0	2	0	4	N	%
NO ERROR		6	6	6	4	6	7	4	1	6	5	7	5	3	4	8	4	7	6	4	5	4	3	5	4	5	125	51
ERROR = 1		4	3	2	4	2	1	3	7	2	2	1	2	5	3	1	3	2	2	3	2	4	3	3	3	4	71	29
ERRORS >1		0	1	2	0	2	2	2	2	2	3	2	3	2	3	1	3	1	2	2	2	2	4	2	3	1	49	20
																											245	

TABLE 3. Results obtained in blind test conducted with 25 volunteers in order to evaluate the degree of correspondence and accuracy in the identification and quantification of digestion corrosion damage on leporid bones. White: correct, Green: error = 1 degree, Red: error = >1 degree, NR: no result recorded.

Table 4

CASES	GRADE	Error = 0	Error = 1	Error > 1	% error = 0	% error = 1	% error > 1
A	4	16	6	1	72	24	4
B	0	21	4	0	84	16	0
C	2	16	8	0	66.7	33.3	0
D	1	15	10	0	60	40	0
E	3	9	8	4	42.9	38.1	19
F	1	19	6	0	76	24	0
G	0	5	0	20	20	0	80
H	2	14	11	0	56	44	0
I	3	3	8	14	12	32	56
J	4	5	10	10	20	40	40

TABLE 4. Numbers and percentages of accuracy of digestion corrosion damage quantification in each case analysed in the blind test.

Table 5

	N Scored				
Grade	**0**	**1**	**2**	**3**	**4**
0	21	4	0	0	0
1	11	34	5	0	0
2	0	16	30	3	0
3	2	16	13	12	3
4	3	0	8	16	23

TABLE 5. Number of designations correctly (in grey) and incorrectly scored (Case G has been excluded).

Table 6

	N	%
NO ERROR	102	70,3
ERROR = 1	38	26,2
ERROR > 1	5	3,4
	145	

TABLE 6. Numbers and percentages of accuracy of digestion corrosion damage quantification in the last six cases analysed (F,E,D,C,B,A) in the blind test.