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The use of horses in classical period Japan inferred from pathology and limb bone proportion

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Abstract

Pathology and limb bone proportions of horse remains from the classical period (latter half of 8th century CE) were investigated to discuss their use. Bit wear analysis (bevel and lower 2nd premolar anterior damage) and premaxillary remodeling confirmed that at least one of three horses was ridden. The evidence was limited for the other two, but one of them also exhibited bit-related damage indicative of riding. The limb bone proportion of the clearly ridden horse was distinct from any known native Japanese horses or archaeological specimens. The relatively elongated distal limb bones indicate its cursorial adaptation compared to the Japanese native horses, which survived in the steeper and more mountainous regions. The finding calls for a more cautious approach when applying native horse bone proportions to reconstruct the limb bone proportions of past horse populations. The combined methodology employed in this study has rarely been applied to Japanese horse remains. Although the sample was limited, the result presented here would serve as a valuable reference in exploring the use of horses from periods with little information related to their use, such as horse gears and historical documents.

Keywords

Bit wear, premaxillary remodeling, limb bone proportion, Japanese native horses, classical period

1. Introduction

At the latest, horses were introduced to the Japanese archipelago from the Asian continent within the early Kofun period (ca. 4th century CE). The gilt bronze harnesses commonly found as burial goods from tumuluses unequivocally indicate that riding was an essential part of their use, along with the role as a symbol of power and military purposes. *Ritsuryo* law codes were enacted with the establishment of the centralized government in the classical period (ca. late 7th century). According to these codes, it is evident that horses were also used as post-horses. Some scholars also insist on packhorses being used in constructing the imperial palace (Yoshikawa 1991). This view was supported by the recent discovery of young horses in concentration from a canal in the Fujiwara palace site presumed to have been used as pack horses at a construction site. One of them also bore spavin (Yamazaki 2011, Yamazaki et al. 2016). Harrows excavated from Kofun period sites also prove that their use as draft animals was present since the early stages of introduction (Kono 1994, Matsui 2004, Tanaka 2011). These archaeological and historical findings indicate that horses were already used for several purposes by the Kofun and the subsequent classical periods. However, reconstructing their use in detail at a regional and temporal scale is challenging, especially regarding local provinces in pre-medieval periods with limited documents. The horse remains from archaeological sites provide vital clues in resolving the issue.

An important piece of information gathered from horse remains regarding their use is pathological features which enable us to evaluate the degree of stresses or damages placed on certain parts of the body. Pathological studies of horse remains were limited for Japanese horse remains, and it was not until recently that methods from abroad were applied. The pioneering study by Gündem and Hongo (2013) was conducted on horse remains from several classical to medieval period sites from eastern Japan. The pathological changes to the crania, vertebrae, and metapodials were recorded according to the methods of Janeczek et al. (2012), Levine et al. (2005), and Bendrey (2007b, 2008). The horses from a medieval salt-production site, Muramatsu Shirane, which displayed considerable changes to the occipital bone (MSM) even in young individuals, was of particular relevance to this paper. Ossification of the metapodial ligaments and changes to the thoracic and lumbar vertebrae were also confirmed, leading them to estimate the relation with traction activities.

Another line of evidence which provided clues to horse use is their withers height and limb bone proportions. Nishinakagawa et al. (1991), in their nationwide compilation of measurements and withers height estimations from archaeological horse remains, revealed the coexistence of small and medium-sized horses in any given period, with the medium size dominating. This fact leads us to assume that horses were exploited for different uses according to their size. For example, the mean value of withers height at the above salt-production site was 120.9 cm (SD:7.6, Nishimoto 2003, Nishimoto and Namigata 2007), whereas, in the medieval site of Zaimokuza in Kamakura, presumed to be mostly military horses, it was 129.5 cm (SD:1.0, Hayashida 1957). If we consider the difference in site context, their height difference may be explained by their difference in use as pack horses at the former, and military horses in the latter site.

As for limb bone proportions, the medieval horse remains from the Yuigahama-minami site in Kamakura were analyzed by Uzawa and Hongo (2006). They reported an individual with limb bone proportions very different from the Japanese native horses and argued that the horse was more adapted to running since its lower limb, especially the radius, was longer than the native horses. They have also argued that because the Japanese native horses were preserved in the mountainous or steep island environments, their limb bone proportions may have drifted away from cursorial form and suggested the possibility that considerable variation in limb bone proportion may have existed in the medieval period.

The studies reviewed above mainly analyze relatively well-preserved medieval horses. Conversely, pathological studies on classical (ca. 7–12 century CE) horses are rare, largely owing to the generally poor preservation of this period's remains. This study aims to discuss the use of classical period horses by examining the pathological features, and limb bone proportions of a well-preserved horse remain excavated from the Suwada site, Chiba Prefecture.

2. Materials and methods

2.1. The horse remains

Suwada site is in Ichikawa City, in the northwestern part of Chiba Prefecture, eastern Japan (Figure 1A). The site is located on a plateau where the ancient provincial capital (*Kokufu*) was located (Yamaji 2019). The horse remains analyzed here were excavated from a large pit discovered in the 6th excavation of the site. The pit was round in plane figure, V-shaped in cross-section, 4.2 m in diameter, and 2.7 m deep. Although the pit is presumed to have been used originally for storage purposes, it was eventually used to discard/bury shells and animal carcasses. Four shell layers, primarily consisting of the clam *Meretrix lusoria* and oysters *Magallana gigas*, accumulated from the bottom to the upper layer. At least 11 dogs, mostly intact, were excavated from the bottom to the top shell layers (Kaneko et al. 1992, Yamazaki 2017). Horse and cattle were excavated from around the second shell layer from the top (Figure 1B and 1C, Matsuda 1992). A large number of pottery sherds were also excavated from the bottom and top layers, mainly belonging to the latter half of the 8th century CE, judging from pottery typology. Although the animal remains were not radiocarbon dated, this suggests the timing of their burial.

Zooarchaeological analysis of horses was already conducted in the original report by Matsumoto and Nishinakagawa (1992). The analysis revealed that the minimum number of individuals for the horse remains

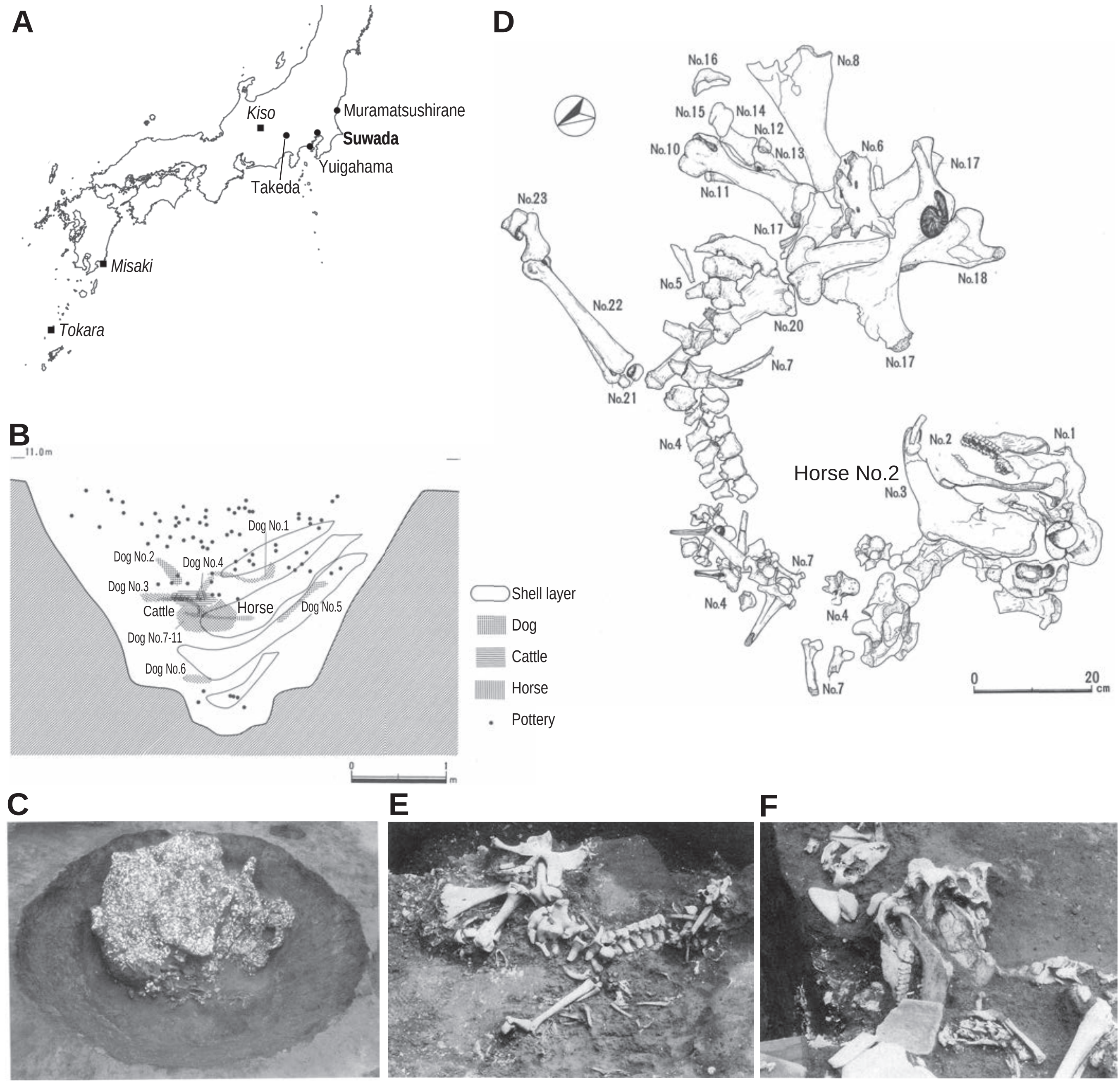

Figure 1. Suwada site and the pit which yielded horse remains.
(A) Location of the archaeological site and habitat of Japanese native horses (italics) mentioned in this paper. (B) Pit section. (C) Shell midden. (D) The horse remains. All belong to horse No.l, except for the mandible of No.2. (E) Vertebrae and limbs of horse No.l. (F) Skull of horse No.l. (B to F modified from Matsuda ed. 1992)

was three, but the elements found were limited. Horse No.1 was the most well preserved, with the skull, vertebrae, forelimbs, and hindlimbs mostly remaining. However, only the left side was found for the limbs, which was clearly not due to post-depositional processes, judging from its state of preservation (Figures 1D to 1F, 2). All bones were completely fused, and the estimated age from the wear stage of the incisors was approximately eight years of age. For horse No.2, only the mandibula was found. The estimated age was seven years of age. Both were male with large canine teeth. Several loose molars were also found, possibly from the same individual, since all are estimated to be three to four years old, and there is no overlapping. The estimated age and the overlapping with No.1 and No.2 indicated that the loose molars did not belong to the two individuals. These were referred to as No.3 provisionally.

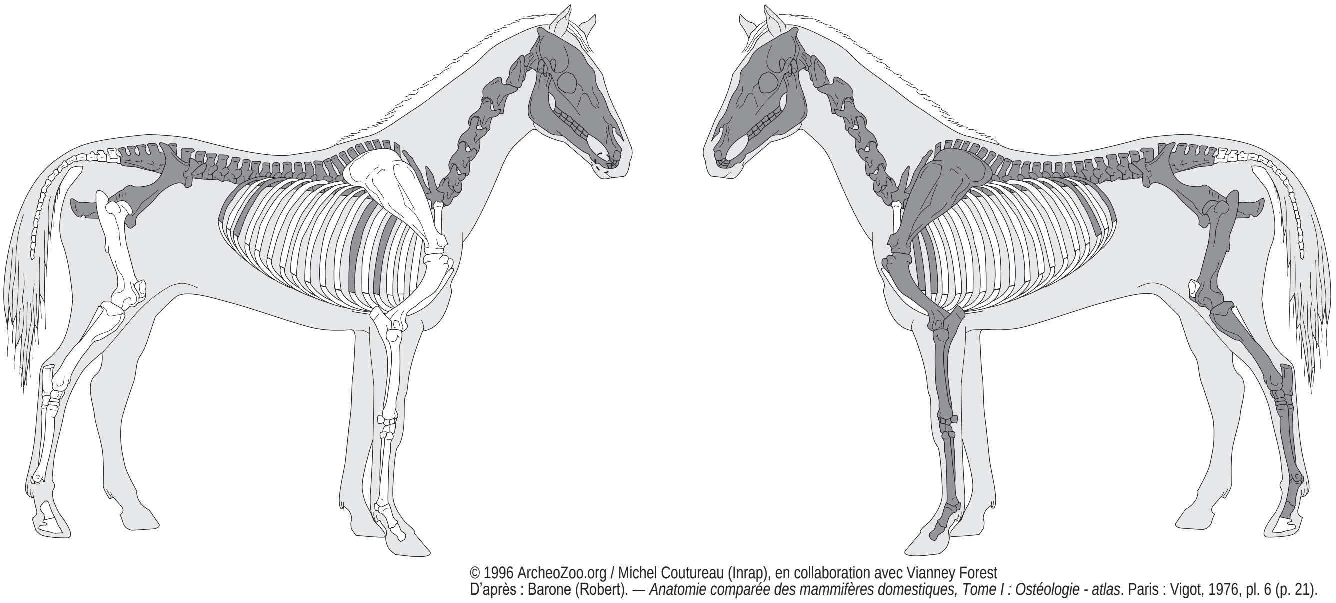

Figure 2. Body part distribution of horse No.1. Identified elements are shown in gray.

The withers height for horse No.1 was estimated from the greatest length of limb bones by regression equation in Hayashida and Yamauchi (1957). The estimated value varied between 118 to 129 cm depending on the element used for calculation. The mean value was 125 cm. The size is about the largest of the small-sized to the smallest of medium-sized native horses, roughly comparable to Misaki horses (medium-sized native Japanese horses). Additionally, the size difference between dimensions was also noted, with the length resembling that of the Misaki horses. In contrast, the breadth and diameter resemble that of the Tokara horses (small-sized Japanese native horses).

The recent examination of the remains by Uetsuki et al. (2022) of the butchering marks and taphonomic features revealed cracking of the braincase possibly for extracting the brain for use in skin tanning (Matsui 1987), and a cut mark on the humerus (Figure 3). Although butchering marks were scarce, the fact that the meaty upper limb bones were not found in anatomical position, whereas the extremities (carpals/tarsals and beyond) were found articulated, suggested the possibility of disarticulation for meat consumption. This was supported by the commonality in the lack of right forelimb bones with the cattle remains which showed clear signs of butchering marks and body part representation indicative of meat consumption.

2.2 Pathological investigations

The horse remains were first examined for their pathological features. As for oral pathologies, especially regarding the use of bits, the beveling of the upper and lower 2nd premolar (P2)s was observed and measured based on the methods described by Brown and Anthony (1998). Then, lower P2s were observed and measured for traces of bit wears on the anterior following the criteria of Bendrey (2007a). The diastema’s changes and damage were also recorded using Bendrey’s scoring system (Bendrey 2007a). For horse No.1, premaxillary remodeling suggestive of the pressure from nosebands or cheekpieces was observed and measured following Taylor et al. (2015) and Taylor and Tuvshinjargal (2018), which is a groove formed on the dorsal surface of the nasal process of the premaxillary bone. The measurement was casually performed by recording the profile of the groove using a bamboo profiling gauge and then tracing it on paper, and not with digital devices. Vertebral abnormalities caused by horseback riding, including hyperostosis, spinal fusion, horizontal fractures on epiphyses, and overriding/joining of dorsal spinal processes, were also examined following Levine et al. (1999) and Li et al. (2020).

For the limb bones, the ossification of the interosseous ligaments of metapodials, which indicates that the stress placed on legs were recorded following Bendrey’s scoring system (2007b).

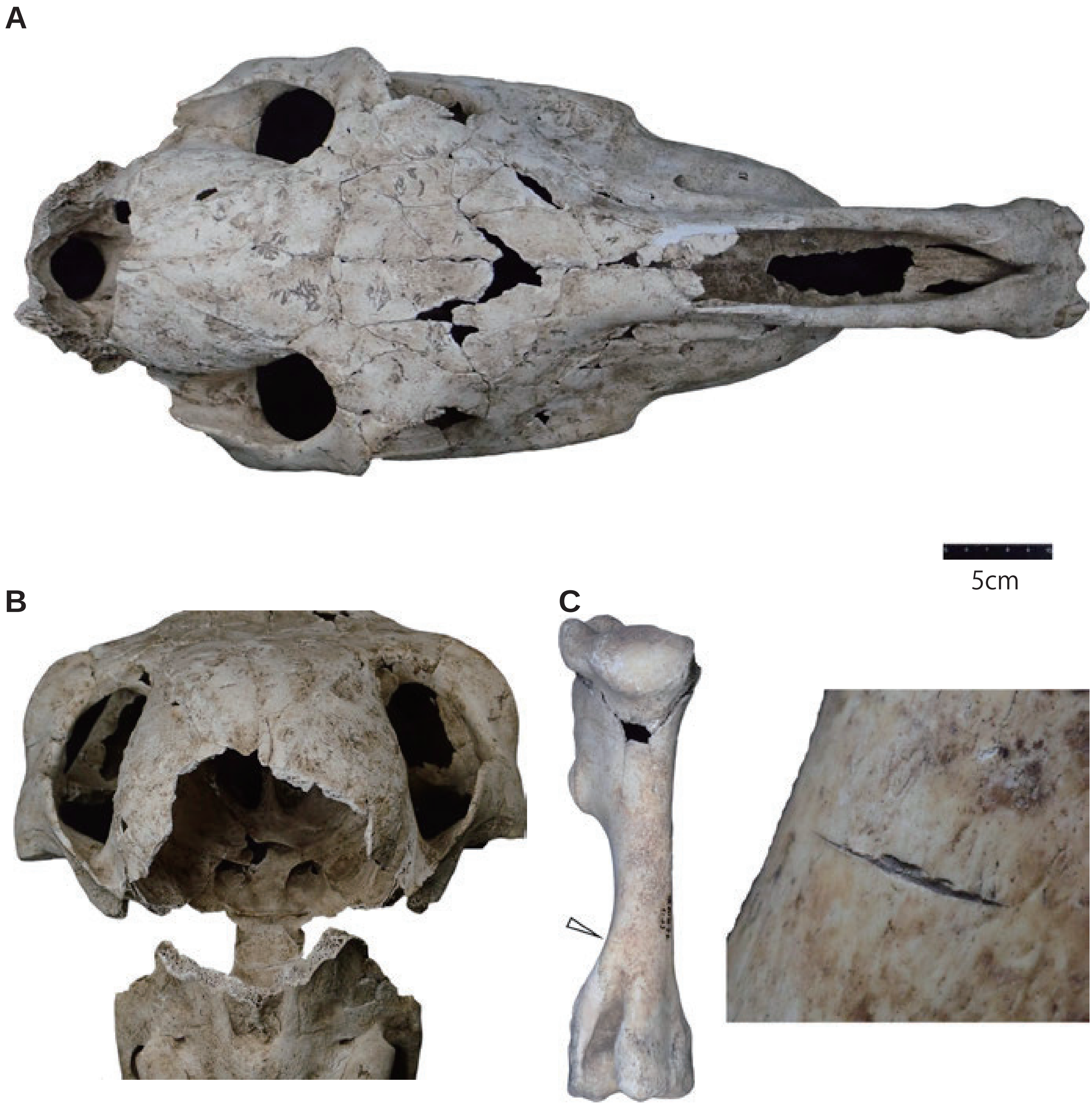

Figure 3. Butchering traces of horse No.l.
(A) Cranium. (B) Damage to the parietal and occipital bone. (C) Cut mark on the humerus lateral epicondylar crest (arrow).

2.3. Limb bone proportion

The limb bone proportion of horse No.1 was examined by comparing their relative length to the modern Japanese native horse specimens. The native Misaki horse population was used as the standard. The measurements were standardized by dividing the deviation of the mean value by the standard deviation of the standard Misaki horse population.

3. Results

3.1. Dental and oral pathologies

Beveling, bit wears, and changes in diastema were examined for evidence of bitting. Clear beveling was found only on horse No.1. In No.1, the measurement for the left and right was approximately 8.0 mm and 7.0 mm, respectively, both exceeding the 3.0 mm threshold for the bit-induced bevel proposed by Brown and Anthony (1998). In addition to the bevel, the so-called

Table 1. Changes to lower P2s and diastema.

No.	Age	Sex	Left/ right	L (mm)	W (mm)	Anterior enamel/dentine exposure*a							Diastema changes*b	Bevel measurements*c		
						EDH (mm)			EDW (mm)	Material exposed	Form: suggestive of bitting	notes	New bone formation/ bone loss score	Bevel (mm)	UP2+LP2 profile:suggestive of bit chewing/rasping	notes
						ant.	bucc.	ling.								
1	8	m	L	31.8	12.8	17.0	5.3	14.4	x	Enamel	Yes	Exposure not parallel-sided but extends to the buccal side. Anterior enamel grooved/roughened near the alveolus.	1-2/0	8.0*d	Yes	Anterior half of the occlusal surface bevelled and smoothened (loss of Greaves' effect). Gap between corresponding upper P2 which is also beveled.
			R			11.4	2.8	12.5	x	Enamel	Yes?	Exposure not parallel-sided but extends to the buccal side. Anterior EDH smaller than lingual, but isolated. Anterior enamel grooved near the alveolus (more prominent than left).	1-2/0	7.0*d	Yes	Same as above
2	6/7.8	m	R	30.7	12.3	10.4	4.8	11.4	x	Enamel	No	Exposure not parallel-sided but extends to the buccal and lingual side.	2/0	2.9	-	Greaves' effect present
3	3-4	?	L	33.5	14.0	7.0	2.6	5.6	2.2	Enamel	Yes	EDH indistinct due to anterior cementum loss (after excavation?). Measurement is from stained portion estimated to be the original exposed area. The white portion below is estimated to be recent exposure.	-	1.3	-	Greaves' effect present

*a,b Following Bendrey (2007a). *c Following Brown and Anthony (1998). *d Difficulty in measurement and not accurate.
L: length of the biting surface. W: width of the biting surface. EDH: height of enamel/dentine exposure. EDW: enamel/dentine exposure at widest point.

Greaves' effect (Greaves 1973) was lost for the anterior half of the occlusal surfaces on both sides, meaning that the enamel ridge was worn out and in level with the dentine. Such traces were not observed for No.2 and No.3. For No.1, the bevel and loss of Greaves' effect on the anterior half was also observed on the anterior half of the upper P2s on both sides. When the maxilla and mandible were occluded, a clear gap between the upper and lower P2 was present, especially in the left side (Figure 4). The gap measurement was 9.4 mm for the left and 5.4 mm for the right.

Enamel exposure on the anterior of lower P2s was observed on all three individuals, and they all exceeded the 5 mm criteria, as evidence of bitting in terms of height measurements proposed in Bendrey (2007a) (Table 1). As for the form of the exposure, only No.3 exhibited a parallel-sided band suggestive of bit wear (Figure 5). The anterior exposure in No.1 (both left and right) and No.2 extended to the buccal side. Lingual enamel exposures were prominent in all of them. In No.2, the lingual height was slightly larger than the anterior. In No.1, there was a shallow groove/roughening of the anterior enamel near the alveolus, and the cementum was lost. When this part was included in the exposure measurement, they clearly exceeded lingual measurements. Such trace was not seen in No.2 and No.3.

No.1. and No.2 were available for examining the change in diastema. Small to moderate bone formation

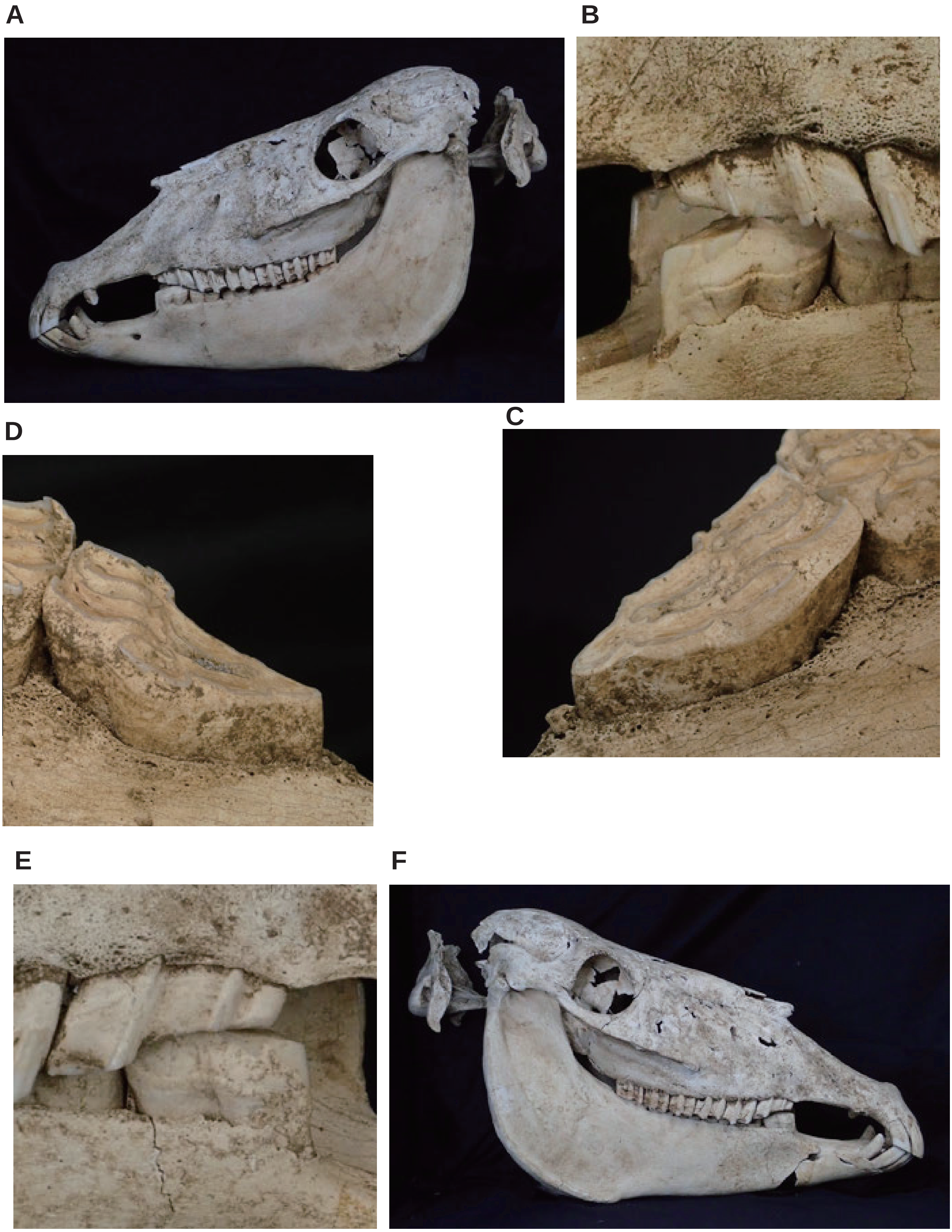

Figure 4. Horse No.l beveling of the upper and lower P2.
(A) and (B) Left upper and lower jaw in occlusion; (C) Left P2 occlusal surface. (D) Right P2 occlusal surface. (E) and (F) Right upper and lower jaw in occlusion.

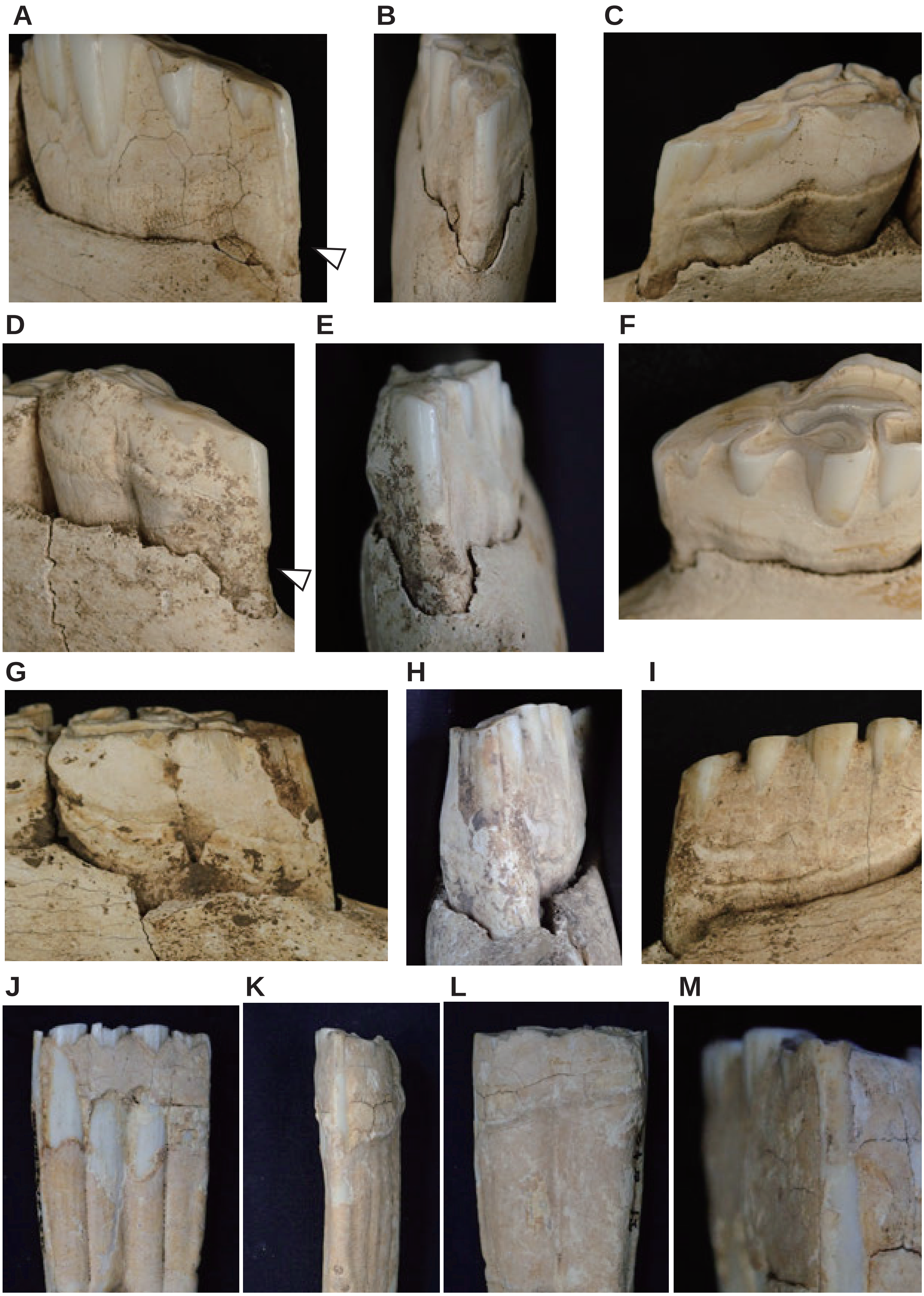

Figure 5. Lower P2 enamel exposure and beveling.
(A) to (C) No.1 left lingual, anterior, and buccal/occlusal aspects. Arrowheads indicate groove/roughening of enamel. (D) to (F) No.l right buccal, anterior, and lingual/occlusal aspects. (G) to (I) No.2 right buccal, anterior, and lingual aspects. (J) to (M) No.3 left lingual, anterior, buccal aspects, and anterior close-up.

Figure 6. Changes to the diastema.
(A) Horse No.1; score 1-2. (B) Horse No.2; score 2.

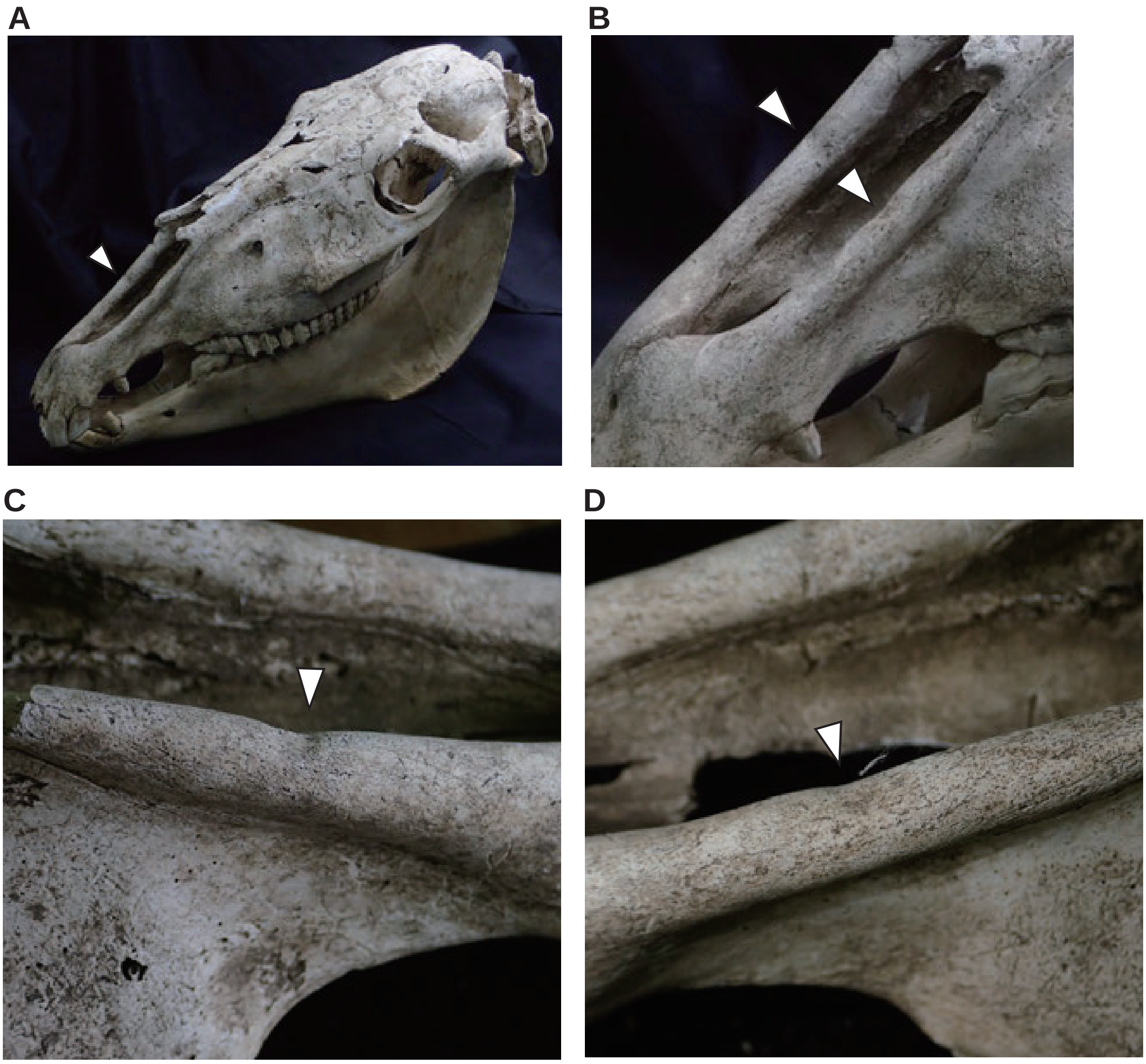

Figure 7. Horse No.l premaxillary remodeling. (C) Right side. (D) Left side. Arrowheads indicate grooves.

Figure 8. Horse No.l ossification of metapodial interosseous ligaments. (A) Metacarpus; score = 0:2. (B) Metatarsus; score = 0:0. (C) Metatarsus close up.

was observed in both specimens, with the formation in No.2 slightly more prominent (Table 1, Figure 6). Bone losses were not observed in either specimen.

3.2. Cranial changes

No.1 was available for premaxillary remodeling observation. Grooves were observed on both the left and the right premaxilla on the medial side, both at approximately 115 mm from the prosthion (Figure 7). The depth of the grooves was 0.7 mm and 1.2 mm for the left and right, respectively. The diameter of the premaxillary bone was 10.6 mm and 10.7 mm. When the data were normalized for size difference through dividing by premaxillary bone width, the value for right (1.12) exceeded the range of feral horses and was included in the quartile range of ridden horses, while the value for the left (0.66) was close to the upper quartile range of feral horses presented in Taylor et al. (2015, Figure 7B). The asymmetry in depth and the larger value for the right side is consistent with the tendency reported by Taylor et al. (2015) for contemporary, historical, and archaeological Mongolian specimens.

3.3 Vertebral abnormalities

Vertebrae of No.1 was examined for abnormalities, but no clear signs were observed. However, the result was obscure since the dorsal end of the spinal processes were lost in most specimens due to poor preservation and dog gnawing.

3.4. Ossification of the metapodial ligaments

Only horse No.1 was available for study. The interosseous ligaments between the second and the third metacarpus were ossified and attached to the two bones. The lateral side of the third metacarpus and both sides of the third metatarsus did not show any clear signs of change (Figure 8). The score assigned to the former was 2, and 0 for the latter according to Bendrey's scoring system (2007b).

Table 2. Limb bone measurements (mm)

	Humerus GL			Femur GL			Radius GL			Tibia GL			Metacarpus GL			Metatarsus GL		
	N	mean	SD	N	mean	SD	N	mean	SD	N	mean	SD	N	mean	SD	N	mean	SD
Suwada	1	252.2	-	1	344.8	-	1	302.0	-	1	321.2	-	1	212.0	-	1	255.4	-
Yuigahama 1110	1	287.0	-	1	385.0	-	1	351.0	-	1	-	-	1	231.0	-	1	-	-
Yuigahama total	3	278.5	-	11	379.1	-	14	330.1	-	14	340.4	-	12	220.4	-	4	262.0	-
Takeda	1	257.5	-	1	360.0	-	1	315.5	-	1	327.0	-	1	201.5	-	1	242.5	-
Misaki (m)	11	284.2	10.1	11	381.8	11.4	11	325.9	8.1	12	340.2	9.1	10	215.1	5.8	11	254.6	8.2
Kiso (f)	10	293.3	10.1	10	401.5	13.4	7	336.0	13.2	8	358.3	13.3	8	224.6	9.8	8	269.6	10.7
Tokara (f)	8	258.7	11.4	8	348.9	12	8	296.5	7.7	8	315.2	12.3	8	199.0	5.2	8	238.7	5.6
Arab	5	300.6		5	406.0	-	5	349.6	-	5	366.6	-	5	244.8	-	5	290.9	-

Upright: archaeological specimens. Suwada (Matsumoto & Nishinakagawa 1992), Yuigahama (Uzawa & Hongo 2006), Takeda (Imoo & Suzuki 2000). Italic: Japanese native horses. m=male, f=female (Nisinakagawa et al. 1991). Arab (Eisenmann 2017).

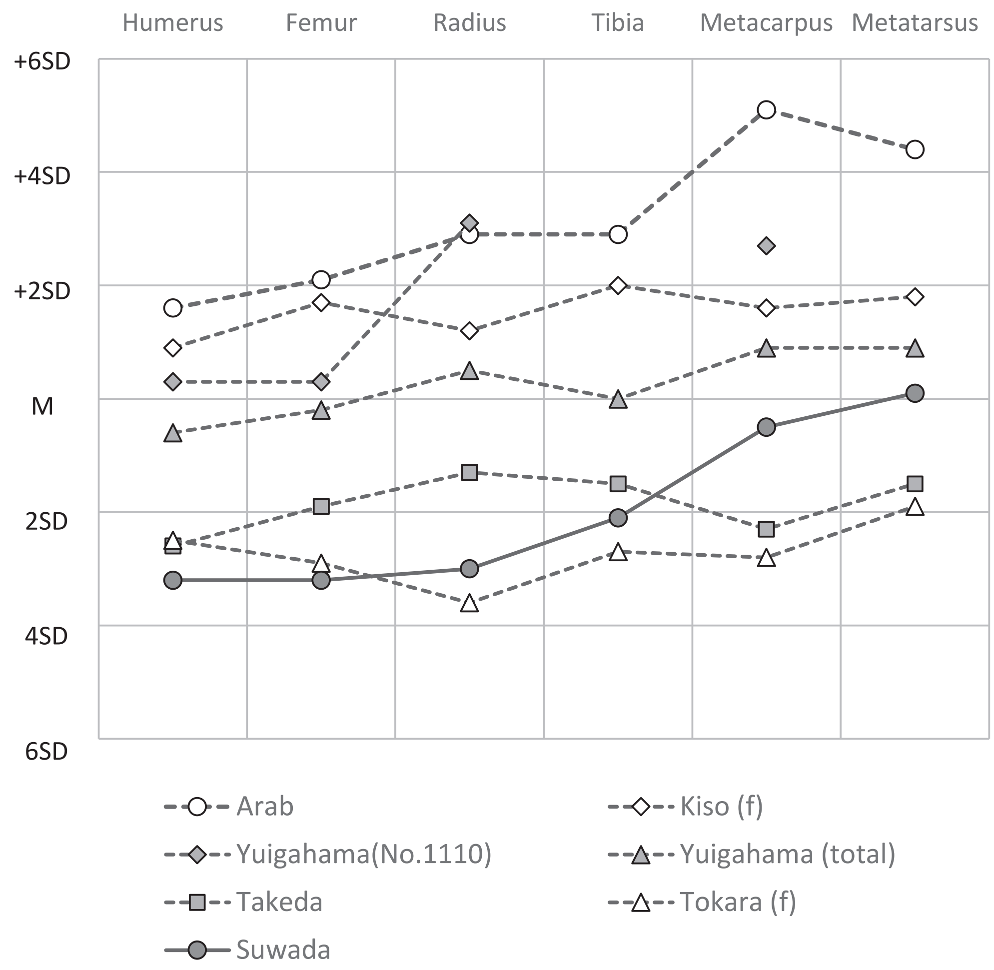

Figure 9. Graph showing deviation of limb bone greatest length. M= mean of male Misaki native horses.

3.5. Limb bone proportion

The limb bone proportion of the Suwada horse in terms of length was unlike any native or archaeological horse specimens compared (Table 2, Figure 9). A marked difference existed because while its proximal limbs (humerus and femur) were the shortest among the specimens, its metapodials were much longer and close to the medium-sized Misaki horses. The bones in between (radius and tibia) were intermediate. Such proportion is most similar to the Arab data from Eisenmann (2017).

Table 3. Comparison of bit wear analysis results.

Site	Area/ prefecture	Context	Period	Bit wear		%Yes	source
				Yes	No		
Hayashinomae	Aomori (Japan)	Settlement site	Classic (10-11th cen. CE)	3	1	75.0%	Uetsuki et al. (2020)
Nejou	Aomori (Japan)	Castle site	Medieval (14-17th cen. CE)	2	3	40.0%	Uetsuki et al. (2021)
Yuigahama	Kanagawa (Japan)	Mass burial at city margin	Medieval (13-14th cen. CE)	19	4	82.6%	Uetsuki (unpublished data)
Iron Age Bury Hill	England		Iron age	13	8	61.9%	Bendrey (2007a)
Worked	Europe		Modern	10	7	58.8%	Bendrey (2007a)

4. Discussion

4.1. Bitting

Beveling, bit wear, and changes to the diastema were examined for bitting signs. The use of bevel as a bitting indicator, proposed by Anthony and Brown (1991, 2003), Anthony et al. (2006), has been questioned by some scholars (Bendrey 2007a, Cross 2018, Levine 1999, 2002). One strong supporting evidence for this argument is the existence of beveling in evidently natural Pleistocene specimens reported by Olsen (2006). In Olsen's case and in similar cases reported by others (Cross 2018, Levine 2002), malocclusion with the upper jaw causes the beveling of the lower P2. Therefore, the state of the corresponding upper P2 needs consideration when interpreting lower P2 bevels. Of the three Suwada horses, beveling was observed only in No.1. The opposing upper P2 was also beveled with a considerable gap between them, ruling out the possibility of bevel caused by malocclusion. The loss of Greaves' effect in all four P2s (upper and lower, both sides) also differs from the natural cases reported by Olsen, suggesting human-induced change. Similar cases of such gap between the upper and lower P2s have been associated with intentional rasping or bit chewing (Cross 2018, Taylor and Tuvshinjargal 2018). However, in Suwada, rasping is unlikely since the gap is too large to be the result of removing hook or point for malocclusion treatment. This leaves bit chewing as the most likely cause.

Three horses showed mixed results in the analysis of enamel exposure. The most concrete evidence was from No.1 (both left and right). Their form did not meet the criteria set by Bendrey (2007a), but shallow groove/roughening near the alveolus seemed to be related to the use of bits. It was clearly different from anterior exposure near the occlusal surface, or lingual and buccal exposure, so they were not caused by normal dietary abrasions. Although this feature is not present in the original criteria, the only plausible explanation for the damage seemed to be the contact with metal bits. This is significant because it is less likely to occur from cribbing and is a more direct evidence of bitting than beveling. Only No.3 exhibited enamel exposure in the parallel-sided band and met the criteria in its form. However, the height of the anterior exposure was similar to the lingual height, making it difficult to distinguish from exposure owing to dietary abrasion. No.2 did not meet the criteria in its form nor relative height compared to the lingual side.

Another evidence to show that horse No.1 was ridden is the asymmetry of premaxillary grooves. According to Taylor and Tuvshinjargal (2018), such asymmetry is present in Mongolian horses, but not in feral or Przewalski horses. Also, notably, the groove depth of the right side was larger. As previously mentioned, this is also consistent with the observation on Mongolian horses by Taylor et al. (2015). The result was estimated to relate to left-handed control (rein tension) prevalence in riding. The premaxillary groove itself is merely an evidence for using bridles or headgears. Considering the existence of bitless bridles in Japanese ethnography (Kojima 2013), and a possible medieval artifact related to it (Matsui 2010), caution is needed to link grooves to the use of bits directly. However, No.1 was clearly bitted, as discussed above. The asymmetry of the Suwada horse crania may also be the result of horse-riding customs. Interestingly, the magnitude of the gap between the upper and lower P2 was also asymmetrical, and in this case, larger on the left side. This is also consistent with the observation of Mongolian horses by Taylor and Tuvshinjargal (2018) that the bevels were more invasive on the left side.

To summarize the bit wear analysis, No.1 was clearly bitted, judging from the combined evidence of bit-chewing and bitting damage. No.3 may have been bitted, but No.2 showed no clear sign of bitting.

Analysis of bit wears in Japanese archaeological specimens remain rare, but limited studies have produced various results (Table 3). At the Yuigahama site, the ratio of specimens with evidence of bitting was the highest, and even higher than the modern ridden horses reported by Bendrey (2007a). This may reflect the presence of many ridden horses used by the samurai warriors in the capital city of the Kamakura Shogunate. Contrarily, relatively fewer bitted specimens found at the Nejou castle site, also related to the warrior class, seemed to contradict the above view. The horses at the site were smaller than the Kamakura horses, and it was assumed that the horses were not just war horses but included horses for various purposes, such as pack or draft horses (Uetsuki et al. 2021b).

The mixed results of three individuals at Suwada may also indicate wide array of uses of horses at the site. The oxygen and carbon isotope analysis of horse remains excavated from the Kitashita site nearby revealed a highly variate behavior among the individuals and was estimated to be caused by importing horses from different locales for use at the provincial capital (Uetsuki et al. 2021a). Both sites are a part of the large provincial capital area. The variation in use inferred from bit wear analysis at Suwada may imply that horses of various origins were imported to the provincial capital and put to diverse uses. However, the sample in Suwada is clearly too small to discuss their use as a population, and further study is necessary.

Only one individual was available to observe the ossification of the metapodial ligaments. The result matched the general tendency suggested by Bendrey (2007b) that ossification is more severe on the forelimbs and on the medial side. At Yuigahama, where the age distribution is similar to or older than Suwada (8 yrs <), score 2 consisted less than 20% of the metacarpal specimens (medial side. Uetsuki 2018). It could be concluded that Suwada horse No.1 was put under relatively heavy stress.

4.2. Limb bone proportion

Suwada No.1 had elongated metapodials, unlike any population or individuals compared. Firstly, it should be discussed whether they truly belong to the same animal. The limb bones were excavated from a restricted area. All elements of the forelimb and hindlimb were present, and there was no overlapping of the elements. Only the left side was present for all elements with sides. Additionally, both the forelimb and hindlimb displayed similar changes in a relative length in the proximal-distal direction (upper < middle < lower limb). The chances of these phenomena occurring coincidentally, are scarce if they are derived from different individuals. Thus, it could be concluded that they belong to the same individual.

The question then, is why the Suwada horse had such a unique proportion. One possible explanation would be the difference in use. As already mentioned, Uzawa and Hongo (2006), in their analysis of the horses from the Yuigahama-minami site in Kamakura, reported a tall individual with a unique proportion whose radius and metacarpus were relatively longer compared to modern Japanese native horses (Figure 9 No.1110). They proposed the possibility that the individual was more cursory adapted than the native horses, which were more adapted and/or bred to fit the mountainous and steep lands they have endured. Although not as extreme, the average of other specimens at the site also tends to have longer lower limbs.

Not all medieval horses displayed limb bone proportion like Yuigahama-minami. The Takeda horse also shown in Figure 9, was found buried in a late medieval castle site in Yamanashi, a mountainous area in central Japan. This horse had shorter metapodials and a more even proportion, similar to the native horses. This seems to support the influence of the geographic factor proposed by Uzawa and Hongo.

The above findings demonstrated that the proportion of Suwada horses was better suited for running, coinciding with the fact that the site is in the lower and level land of Kanto Plains. However, it is noteworthy that the proportion of Suwada horses is somewhat different from Yuighama-minami No.1110 in that the metapodials are relatively longer than the radius or tibia. Interestingly, the Suwada horse was most similar in proportion to the Arab horses (Eisenmann 2017), which is another supporting evidence that it was fit to run. Further comparison with other intact remains is necessary to understand the degree of variability in limb proportion in past Japanese horse populations and discuss the causes.

5. Conclusion

This study clarified that at least one horse (No.1) was used for riding at the Suwada site. The other two horses lacked sufficient evidence to determine if they were ridden with bits but did not leave bit damage or were used for other purposes without bitting.

In the Japanese archipelago, horses were introduced from the continent, so they were basically domesticated. Since the initial stage of introduction, horse harnesses commonly buried in the Kofun tumuluses indicate that riding was their important role. Therefore, the result obtained in our study is not surprising. However, after the disappearance of the Kofun tombs, excavation of bits and other horse gears becomes extremely rare in the following Classic period. Simultaneously, historic documents or paintings that provide detailed information on horse use are not as abundant as in the subsequent medieval or pre-modern period. The pathological study of horse remains can be a useful tool in filling the gap between the two periods. Methods employed here remain rarely applied to Japanese specimens, and clearly, more data is needed to unravel various horse uses in the past.

As for the limb proportions, archaeological specimens compared in this paper, although limited in numbers, have shown considerable variations. It can be concluded that horses with limb proportion very distant from the native Japanese horses existed in the classical to medieval periods. Whether this is related to usage, geographical factors, or both need to be explored in detail by incorporating more specimens and combining pathological features. The horses used by the warrior class, like the ones analyzed by Uzawa and Hongo (2006), were preferentially crossbred with western breeds to increase size in the early 20th century for military purposes, and their line of descent no longer exists. Archaeological horse remains are the most direct evidence for reconstructing the proportions of past horses, especially those used for riding and warfare in the plains and level grounds.

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References

Anthony D., Brown D. (1991) The origin of horseback riding. *Antiquity*, 65: 22–38.

Anthony D., Brown D. (2003) Eneolithic horse rituals and riding in the steppes: new evidence. In M. Levine, C. Renfrew, and K. Boyle (eds) *Prehistoric Steppe Adaptation and the Horse*, 55–68. Oxford, McDonald Institute for Archaeological Research.

Anthony D., Brown D., George C. (2006) Early horseback riding and warfare: the importance of the magpie around the neck. In S. Olsen, S. Grant, A. Choyke and L. Bartosiewicz (eds) *Horses and Humans: The Evolution of Human-Equine Relationships*, 137-156. Archaeological Reports International Series 1560. Oxford, Archaeopress.

Bendrey R. (2007a) New methods for the identification of evidence for bitting on horse remains from archaeological sites. *Journal of Archaeological Science*, 34: 1036–1050.

Bendrey R. (2007b) Ossification of the interosseous ligaments between the metapodials in horses: a new recording methodology and preliminary study. *International Journal of Osteoarchaeology*, 17: 207-213.

Brown D., Anthony, D. (1998) Bit wear, horseback riding and the Botai Site in Kazakstan. *Journal of Archaeological Science*, 25, 331e347.

Cross P.J. (2018) Where have all the mares gone? Sex and "gender" related pathology in archaeological horses: clues to horse husbandry and use practices. In L. Bartosiewicz and E. Gal (eds). *Care or Neglect? Evidence of Animal Disease in Archaeology*, 155-175. Oxford, Oxbow Books.

Eisenmann V. (2017). The Arab Horse, Prehistoric Horses, and How to Study them. Vera Eisenmann. https://vera-eisenmann.com/the-arab-horse-prehistoric-horses-and-how-to-study-them? lang=en, (accessed 2022-2-10).

Greaves W. S. (1973) The Inference of Jaw Motion from Tooth Wear Facets. *Journal of Paleontology*, 47(5): 1000-1001.

Gündem J. Y., Hongo H. (2013) Observation on the pathology of ancient horse bone remains from Japan. *Zoo-archaeology*, 30: 249-259.

Hayashida S. (1957) Studies on the medieval Japanese horses. *Nihon chikusan gakkaihou (Animal Science Journal)*, 28(5): 301-306 (in Japanese with English summary). 林田重幸「中世日本の馬について」『日畜会報』

Hayashida S., Yamauchi T. (1957) Deduction of Withers Height from the Length of the Bone in Horses. *Bulletin of the Faculty of Agriculture, Kagoshima University*, 6: 146-156 (in Japanese with English summary). 林田重幸・山内忠平「馬における骨長より体高の推定法」『鹿児島大學農學部學術報告』

Imoo T., Suzuki T. (2000) Horse remains excavated at 31st excavation. *National historic site, mansion of the Takeda clan VII*, 78-99. Kofu City Archaeological Report Series 11 (in Japanese). 妹尾俊彦・鈴木健夫「第 31 次調査出土の馬骨について」『史跡武田氏館跡 VII』甲府市文化財調査報告 11

Janeczek M. A., Chroszcz A., Onar V., Henklewski R., Piekalski J., Duma P., Czerski A., Całkosiński I. (2012) Anatomical and biomechanical aspects of the horse spine: the interpretation of vertebral fusion in a medieval horse from Wroclaw (Poland). *International Journal of Osteoarchaeology*, 24(5): 623-633.

Kaneko H., Matsumoto M., Nishinakagawa H. (1992) Animal remains from pit No.3. *Suwada Site 6th Excavation*, 34-65. Ichikawa City Board of Education (in Japanese). 金子浩昌・松元光春・西中川駿「３号土坑出土の動物遺体」『須和田遺跡第６地点』市川市教育委員会

Kojima M. (2013) Names of horse tack: standard names of horse tack for database. *Annual Report*, 5: 57-81 International Center for Folk Culture Studies, Kanagawa University (in Japanese). 小島摩文「馬具の種類と名称について―データベース化のための標準名を考える―」神奈川大学国際常民文化研究機構年報

Kono M. (1994) *Fundamental Study of the History of Agricultural Tools in Japan*. Izumi shoten (in Japanese). 河野通明『日本農耕具史の基礎的研究』和泉書店

Levine M. (1999) The origins of horse husbandry on the Eurasian steppe. In M. Levine, Y. Rassamakin, A. Kislenko and N. Tatarintseva (eds) *Late Prehistoric Exploitation of the Eurasian Steppe*, 5–58. Cambridge, McDonald Institute for Archaeological Research.

Levine M. A., Whitwell K. E., Jeffcott L. B. (2002) A Romano-British horse burial from Icklingham, Suffolk. *Archaeofauna*, 11: 63–102.

Levine M. A., Whitwell K. E., Jeffcott L.B. (2005) Abnormal thoracic vertebrae and the evolution of horse husbandry. *Archaeofauna*, 14: 93-109.

Matsuda R. (ed) (1992) *Suwada Site 6th Excavation*. Ichikawa City Board of Education (in Japanese). 松田礼子（編）『須和田遺跡第６地点』市川市教育委員会

Matsui A. (1987) Archaeological consideration of the Yoro-Kumoku Code: on the treatment of slaughtered horses and cattle. *Shinano*, 39(4): 231-256 (in Japanese). 松井章「養老厩牧令の考古学的考察－斃れ馬牛の処理をめぐって－」『信濃』

Matsui A. (2010) Omoge excavated from the Bungo Funai ruins and its problems). *Papers in Honor of Kiyotari Tsuboi's 90th Birthday: between Administration of Buried Cultural Properties and Research*, 1276-1284 (in Japanese). 松井章「豊後府内遺跡出土のオモゲーとその問題点」『坪井清足先生卒寿記念論文集－埋文行政と研究のはざまで－』

Matsui K. (2004) Transformative process of harrow in Japan. *Kokogaku Kenkyu (Quarterly of Archaeological Studies)*, 51(1), 76-93 (in Japanese with English summary). 松井和幸「馬鍬の起源と変遷」『考古学研究』

Matshumoto M., Nishinakagawa H. (1992) Cattle and horse remains. *Suwada Site 6th Excavation*, 54-63. Ichikawa City Board of Education (in Japanese). 松元光春・西中川駿「ウシとウマについて」『須和田遺跡第６地点』市川市教育委員会

Nishimoto T. (2003) Animal remains from Muramatsu shirane in 2003. *Muramatsu shirane site 1 vol.2*, 567-575. Educational Foundation of Ibaraki Prefecture Archaeological Report Series 250 (in Japanese). 西本豊弘「村松白根遺跡の動物遺体（2003 年度）」『村松白根遺跡 1 下巻』（茨城県教育財団文化財調査報告第 250 集）

Nishimoto T., Namigata S. (2007) Animal remains from Muramatsu shirane in 2004. *Muramatsu shirane site 2 vol.2*, 561-617. Educational Foundation of Ibaraki Prefecture Archaeological Report Series 284 (in Japanese). 西本豊弘・浪形早季子「村松白根遺跡の動物遺体（2004 年度）」『村松白根遺跡 2 下巻』（茨城県教育財団文化財調査報告第 284 集）

Nishinakagawa H., Honda M., Matumoto M. (1991) *A Study on the Time and Route of the Introduction of Cattle and Horses into Japan, as Examined from Skeletal Remains of Archaeological Sites*. Grant-in-Aid for General Scientific Research (B) Fiscal Year 1990 Report (in Japanese with English summary). 西中川駿・本田道輝・松元光春「古代遺跡出土骨からみたわが国の牛,馬の渡来時期とその経路に関する研究」『平成 2 年度文部科学省研究費（一般研究 B），研究成果報告書』

Li Y., Zhang C., Taylor W. T. T., Chen L., Flad R. K., Boivin N., Liu H., You Y., Wang J., Ren M., Xi T., Han Y., Wen R., Ma J. (2020) Early evidence for mounted horseback riding in northwest China. *Proceedings of the National Academy of Sciences*, 117 (47): 29569-29576.

Olsen S. (2006) Early horse domestication: weighing the evidence. In S. Olsen, S. Grant, A. Choyke and L. Bartosiewicz (eds) *Horses and Humans: The Evolution of Human-Equine Relationships*, 81–113. British Archaeological Reports International Series 1560. Oxford, Archaeopress.

Tanaka Y. (2011) On ancient harrows. *Study of Yayoi Period Settlements*. Shinsensha (in Japanese). 田中義昭「古代馬杷一試考」『弥生時代集落址の研究』新泉社

Taylor W. T. T., Bayarsaikhan J., Tuvshinjargal T. (2015)

Equine cranial morphology and the archaeological identification of riding and chariotry in late Bronze Age Mongolia. *Antiquity*, 89: 854–871.

Taylor W., Tuvshinjargal T. (2018). Horseback riding, asymmetry, and anthropogenic changes to the equine skull: evidence for mounted riding in Mongolia's late Bronze Age. In L. Bartosiewicz and E. Gal (eds) *Care or Neglect? Evidence of Animal Disease in Archaeology*, 135-154. Oxford, Oxbow Books.

Uetsuki M. (2018) The role of cattle and horses in eastern Japan. *Kikan Kokogaku (Archaeology Quarterly)*, 144: 47-50 (in Japanese). 植月学「東国における牛馬の利用」『季刊考古学』

Uetsuki M., Gakuhari T., Kanai T., Kobayashi S. (2021a) Investigating the life history of horses from the Shimosa provincial capital area: carbon and oxygen isotope analysis of horses excavated at Kitashita site. *Kenkyu Renraku-shi*, 85: 30-40. Chiba Prefectural Education Foundation Cultural Properties Center (in Japanese). 植月学・覚張隆史・金井拓人・小林信一「下総国府域出土馬の履歴をさぐる－北下遺跡出土馬の炭素・酸素同位体比分析による検討－」『研究連絡誌』千葉県教育振興財団文化財センター

Uetsuki M., Gakuhari T., Sakuraba R., Funaba M. (2021b) Horse production and use by the Nanbu Clan in the Medieval period: zooarchaeological and isotopic investigation of horse remains excavated from Nejo castle site. *Bulletin of Research Institute of Cultural Properties*, Teikyo University, 20:233-246 (in Japanese). 植月学・覚張隆史・櫻庭陸央・船場昌子「中世南部氏の馬利用―根城跡出土馬の動物考古学・同位体化学的研究―」『帝京大学文化財研究所研究報告第』20

Uetsuki M., Kaneko H., Yamaji N. (2022) Cattle and horse meat consumption and ritual use in the classical period: formation process of the remains from the Suwada site. *Shishi Kenkyu Ichikawa*, 13: 49-67 (in Japanese). 植月学・金子浩昌・山路直充「古代の牛馬肉食と祭祀利用－須和田遺跡大型土坑出土牛馬遺体の形成過程による検討－」『市史研究いちかわ』

Uzawa K., Hongo H. (2006) A morphological study of the horses from Yuigahama-minami site, Kamakura. *Kokogaku to Shizen Kagaku (Archaeology and Natural Science)*, 53: 57-67 (in Japanese with English summary). 鵜澤和宏・本郷一美「由比ヶ浜南遺跡出土ウマ（Equus caballus）の形態」『考古学と自然科学』

Yamazaki T. (2011) Bone disease of a horse: an example in the construction period of the Fujiwara Palace site. *Bulletin of National Research Institute for Cultural Properties, Nara 2011*, 74-75 (in Japanese). 山崎健「藤原宮造営期の馬の骨に認められる骨病変」『奈良文化財研究所紀要 2011』

Yamazaki T., Gakuhari T., Furihata J., Ishibashi S. (2016) Breeding practice and origin of horses excavated from the Fujiwara Palace Ruins. *Investigation of Horses Excavated from Fujiwara Palace Ruins*, Nara National Research Institute for Cultural Properties Report Series 17, 76-87. Independent Administrative Institution National Institute for Cultural Heritage Nara National Research Institute for Cultural Properties (in Japanese). 山崎健・覚張隆史・降幡順子・石橋茂登「藤原宮跡から出土した馬の飼育形態と産地推定」『藤原宮跡出土馬の研究 . 奈良文化財研究所報告書 17』独立行政法人国立文化財機構奈良文化財研究所

Yamazaki K. (2017) A preliminary analysis of the paleopathological features of the ancient dog (no.1) from Suwada area No.6 site, Chiba Prefecture in Japan. *Asian J Paleopathol*, 1: 40-54 (in Japanese with English summary). 山崎京美「千葉県須和田遺跡第 6 地点から出土した古代犬の病変について (予察)」

Yamaji N. (2019) Provincial capital and county governmental office compound. *History of Ichikawa City: Historic Period vol.3*, 66-75. Ichikawa City (in Japanese). 山路直充「国府と郡家」『市川市史　歴史編 III　まつりごとの展開』市川市

Yoshikawa T. (1991) Use of horses and transition of the Maki system in the ancient state. *Shirin (The Journal of History)*, 74(4): 24-61 (in Japanese with English summary) 吉川敏子「古代国家における馬の利用と牧の変遷」『史林』

和文抄録

古病理と四肢骨プロポーションからみた日本古代馬の用途

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本研究では古代（8 世紀後半）のウマ遺体の古病理と四肢骨プロポーションの分析を通じて，その用途について検討した．銜痕の分析（下顎第 2 前臼歯の斜角 bevel と近心の磨耗）および切歯骨の変形により，3 個体のウマのうち少なくとも 1 個体が乗用とされたことが確認された．他の 2 個体については証拠が限定的であったが，うち 1 個体は乗用を示す銜痕が確認された．乗用とされたことが明確な個体の四肢骨長の比率は，既知の日本在来馬や出土標本とは異なり，遠位部ほど長いことが明らかになった．この特徴は急峻な山地に適応してきた日本在来馬に比べてより走行に適応していたことを示唆する．この分析結果は，過去の馬の体形に関して在来馬のプロポーションを参照する際には，より慎重なアプローチが必要であることも示している．本研究で採用した複合的なアプローチが国内の出土ウマ遺体に適用された例はまだほとんどない．標本数は限られていたが，本研究の成果は，文献史料や馬具など馬の用途に関する史資料に乏しい古代馬の用途を考察する際の基準になると期待される．