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Note

Malocclusion in an Arctic Wolf (*Canis lupus arctos*) from northeast Greenland

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Abstract

I document the first case of malocclusion in an Arctic Wolf (*Canis lupus arctos*) from Greenland. All canine teeth of a wolf found dead on the tundra of northeast Greenland showed evidence of heavy anterior wear resulting from occlusion with the opposite teeth. Additional heavy wear on the incisors indicated a level bite. No cases of malocclusion were found in the largest museum collection of Arctic Wolf skulls (n = 11) from Greenland. However, the collection consisted exclusively of specimens from a northeast Greenland wolf population extirpated ca. 1939; thus, it provided no information on the incidence of malocclusion in more contemporary wolves. A finding of malocclusion in the more recent wolf population could be important because the condition is genetically based and the trait is expressed more frequently with increased inbreeding. The small, geographically isolated wolf population that this wolf was a part of disappeared for reasons unknown after 2002 and genetic conditions cannot be excluded as a contributing factor. Future study of the prevalence and severity of this abnormality in Arctic Wolves from Greenland will be problematic because of the difficulty of acquiring comparative material, but could be conducted on other populations of Arctic Wolves.

Key words: *Canis lupus arctos*; Arctic Wolf; malocclusion; Greenland; Canada; Ellesmere Island

Malocclusion occurs when opposing teeth contact each other in an abnormal way as the jaw is closed. The condition has been documented to various degrees in wolves and other canids. In Scandinavia, 13.7% of 131 Gray Wolf (*Canis lupus*) specimens in the Swedish Museum of Natural History with sufficient material to assess dental anomalies exhibited malocclusion, likely as a result of inbreeding or genetic deterioration (Räikkönen *et al.* 2013). In the Netherlands, a 16.7% incidence of malocclusion in Red Fox (*Vulpes vulpes*) was related to a founder effect (Bouwmeester *et al.* 1989). In other geographic areas, factors associated with the condition have been less certain. Wolves from the former Soviet Union exhibited malocclusion at a rate of at least 3%, but affected individuals did not originate from isolated segments of the population (Vilà *et al.* 1993). In Portugal, where inbreeding was considered low, 4.6% of wolves showed malocclusion (Pires *et al.* 2020). In the Middle East, 15% of wolves exhibited the condition, but the authors did not associate their finding with any factor (Janssens *et al.* 2016). In Alaskan wolves, 17.9% exhibited malocclusion, but less severely than in the sample from Sweden; again, no associated factors were identified (Döring *et al.* 2018).

Little is known about malocclusion in Arctic Wolf (*Canis lupus arctos*), a subspecies that inhabits parts of the Canadian Arctic Archipelago and north Greenland. Range-wide in Canada, Arctic Wolf has long been the least studied subspecies of Gray Wolf (Hayes and Gunson 1995) because of the inaccessibility of its habitat. Only a single case of malocclusion involving a wild Arctic Wolf has been reported: a skull collected in 1986 on Ellesmere Island, Nunavut, showed malocclusion so extreme that it may have caused the animal to starve to death (Clutton-Brock *et al.* 1994). A study on captive-bred Arctic Wolf suggested that malocclusion may be genetically based and that the trait is expressed more frequently with increasing levels of inbreeding (Federoff 1996).

Malocclusion has not been documented in Arctic Wolf in Greenland, where this subspecies has an interesting history. Arctic Wolf was present in northeast Greenland when Europeans arrived in 1899, but commercial hunters exterminated the population by

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1939 (Marquard-Petersen 2012). In 1979, wolves from north Greenland re-colonized their former range (Marquard-Petersen 2011). During the following decades, the new population grew but remained small and likely never exceeded about 23 individuals distributed in three packs (Marquard-Petersen 2009). Because of its small size, the population was at continual risk from stochastic variation and other detrimental factors; it eventually declined in the late 1990s and disappeared after 2002 (Marquard-Petersen 2021). The cause of the disappearance has not been investigated. Arctic Wolf can still be found in north Greenland, but that population is also small and likely does not exceed 30–40 individuals during favourable years (Marquard-Petersen 2022). This note reports the first case of malocclusion in the Greenland Arctic Wolf population, thereby adding to the scarce information on this condition in the wolves that inhabit the northern-most parts of the world.

In August 1995, the carcass of an Arctic Wolf was found on the tundra of northeast Greenland in Ole Rømer Land near the lake Krumme Langsø (74.079°N, 23.873°W). Only the skull was collected and then deposited in the Natural History Museum of Denmark (catalogue number M10575); additional details on its genomics have been published (Sinding *et al.* 2018). I also examined all wolf skulls (n = 11) from Greenland in the Zoological Museum in Copenhagen, the principal repository of Greenland wolf hides and skeletal material since 1869, to see if any showed malocclusion similar to that of the Krumme Langsø wolf.

The Krumme Langsø skull represented a young wolf of undetermined sex and age. The cranium had not been cleaned, and remaining tissue was desiccated and hardened, giving the skull a mummified appearance (Figure 1a), probably as a result of freeze-drying in the polar, semi-desert environment. That

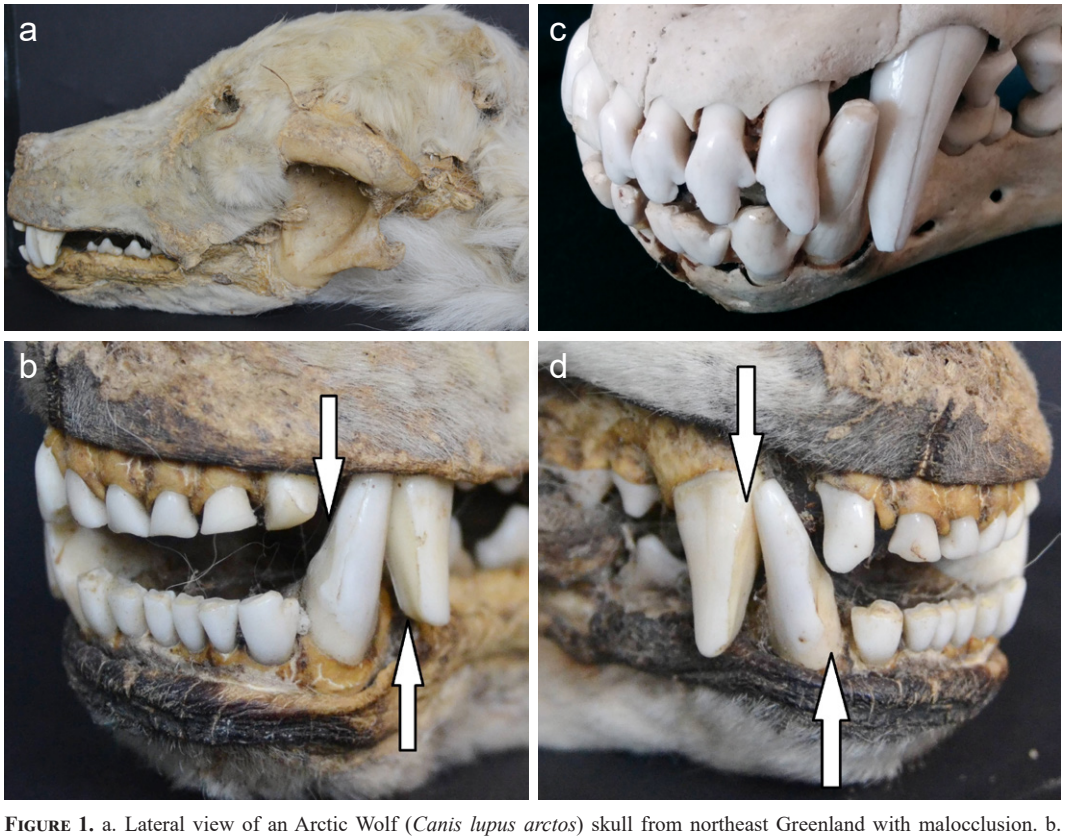

Figure 1. a. Lateral view of an Arctic Wolf (*Canis lupus arctos*) skull from northeast Greenland with malocclusion. b. Close-up view of the left anterior side showing broken third maxillary incisor, broken maxillary canine, and heavy occlusal wear on both canines (arrows). Notice also that the maxillary incisors show evidence of premature wear from excessive attrition indicative of a level bite. c. Normal bite in a Gray Wolf (*Canis lupus occidentalis*) legally harvested in interior Alaska. Notice the absence of wear on the incisors compared with the condition of the teeth of the Arctic Wolf from Greenland. d. Close-up view of the right anterior side of the Arctic Wolf skull, showing occlusal wear on both canines (arrows). Photos: U. Marquard-Petersen.

condition made a closer inspection of several relevant features unrealistic, including the extent of closure of the canine apical foramen and possible misalignment of the maxillary third premolars (see Clutton-Brock *et al.* 1994; Federoff 1996). Premolars that were readily observable showed little normal wear, indicating young age. On the left side of the maxilla, however, tips of the third incisor and the canine were broken. The latter exhibited abnormal, heavy lateral wear, resulting from occlusion with the mandibular canine that indicated contact with the maxillary third incisor (Figure 1b; Figure 1c shows normal wolf occlusion and tooth wear). Similar abnormal wear was observed on both right canines, but those teeth and the maxillary third incisor were intact (Figure 1d). Both mandibular canines appeared to have grown into a tilted position, thereby producing the abnormal wear on the maxillary canines. Additional heavy wear on the incisors was suggestive of a specific type of dental malocclusion termed a "level bite" (see Figure 3b in Döring *et al.* 2018), where the tips of the upper and lower incisors contact each other in contrast to a normal incisor scissor bite, where the upper incisors precisely overlap the lower ones.

The Zoological Museum in Copenhagen has 11 Arctic Wolf skulls from northeast Greenland collected during 1908–1935, thus representing the early 20th century wolf population extirpated ca. 1939. I found no evidence of malocclusion similar to that observed in the Krumme Langsø wolf, but several skulls showed tooth damage consistent with each animal's documented history of being trapped in steel, foot-hold traps. The collection did not contain specimens from the late 20th century population and little insight could be gained into the incidence of malocclusion in that population.

This is the first case of malocclusion in the Greenland Arctic Wolf population. Based on the amount of tissue left on the skull and its general condition, showing limited evidence of scavenging, it is likely that the carcass had been on the tundra for weeks or a few months and that the wolf probably died the year it was found. The degree of malocclusion was much less severe than that of the skull from Ellesmere Island reported in Clutton-Brock *et al.* (1994), but the mummified condition of the Greenland skull did not permit a complete study, and interpreting overall differences between the two skulls was difficult.

A level bite has also been reported in other wolf populations and was the most commonly reported form of malocclusion in Alaskan wolves (Janssens *et al.* 2016; Döring *et al.* 2018). The condition causes premature attrition of the incisors from tooth-to-tooth contact and might have made it more difficult for the Krumme Langsø wolf to grasp and hold prey. Wolves commonly break at least one tooth during their lifetime, with higher rates of breakage in populations that rely more heavily on scavenging, when large ungulate prey is scarce (Van Valkenburgh *et al.* 2019). Canines are the most frequently broken teeth in large predatory mammals (Van Valkenburgh 1988). The overall effect of the minor malocclusion might have been a decrease in fitness.

It is particularly relevant that founder effect and inbreeding have been implicated in malocclusion in canids, because the wolf population in northeast Greenland was likely founded by three or four wolves and was geographically isolated (Marquard-Petersen 2011). The much larger Scandinavian wolf population, consisting of hundreds of wolves, was also founded by a few individuals; it has become highly inbred and has shown an increase in the incidence of congenital vertebral and dental anomalies (Räikkönen *et al.* 2013). Therefore, the potential involvement of inbreeding and founder effect in the malocclusion in northeast Greenland wolves, and in the disappearance of the late 20th century population, warrants future consideration.

Another potentially important factor in producing the observed malocclusion, where both incisors and canines were affected, could involve nutritional deficiency in a severe habitat. Food stress resulting in undernutrition during early life could have resulted in a rostrum that did not reach full length, thereby producing the heavy, abnormal wear observed on the lower canines from contact with the maxillary third incisors. Evidence to support nutritional deficiency as a cause is largely from laboratory studies (e.g., Tonge and McCance 1973; Pucciarelli *et al.* 1990; Miller and German 1999), but should be considered because wolf range in Greenland may constitute the most impoverished wolf habitat in North America (Marquard-Petersen 2009).

There was little comparative material other than the skull from Ellesmere Island, and that constraint is not likely to change in the near future. In northeast Greenland, finding the carcass of a wolf with a skull suitable for examination is an exceptionally rare occurrence because of the extremely low wolf density. Skulls of wolves killed nowadays in Greenland have traditionally been destroyed after testing for rabies as part of a surveillance program. Additional insight into the prevalence and severity of dental anomalies in this subspecies is, therefore, likely to come from the Canadian part of Arctic Wolf's range.

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