Tyrannosaurs suffered from gout

Gout is a metabolic disorder in which urate crystals accumulate as space-occupying masses, producing monarticular spheroidal erosions in bone, often associated with new bone growth at their borders[1–3]. We now report the first identification of such lesions in dinosaurs. Caricatures of the agony and ill-temper of those afflicted with gout are magnified by its recognition in *Tyrannosaurus rex*.

In a cast of the right forearm of the *T. rex* from Hell Creek Formation, South Dakota, popularly known as 'Sue'[4] (specimen DMNH 30665; held at Denver Museum of Natural History), we observed that metacarpal I had a lesion of 11.5 × 9 mm with a slight rim (Fig. 1a). In addition, metacarpal II has a dorsal lesion of 7.1 × 5 mm, surrounded by an overhanging rim of bone (Fig. 1b), and a second medial surface erosion, 3 mm deep. This serendipitous observation led us to study other tyrannosaurids for erosive diseases.

Of 83 tyrannosaurid phalanges at the Royal Tyrrell Museum, only one specimen (TMP 92.36.328) has erosive lesions. The specimen is a partial tyrannosaurid pedal proximal phalanx (I-1) from Bonebed 149 (Upper Cretaceous), Dinosaur Provincial Park, Alberta, Canada. It has a defect (Fig. 1c) at the distal articular junction of subchondral and marginal bone. Slightly built-up bone forms an overhanging edge, overlying a smoothly excavated area of 4 × 9 mm, formed by the coalescence of two adjacent masses, as confirmed by radiological evaluation (Fig. 1d). There are no internal fronts or zones of bone resorption (Fig. 1) and there is no loss of perilesional bone density. Minimal filigree periosteal reaction is also present. Epi-illumination microscopy of the intact specimen, using polarizing optics, failed to reveal birefringent urate crystal preservation.

Gout is recognized clinically by documentation of urate crystal accumulation or by the recognition of characteristic radiological findings[1–3,5]. Identification of the alkali-soluble crystals is usually not possible in archaeological, let alone palaeontological, specimens[1–3], and was not possible in this case. Thus, macroscopic and radiological appearance must form the basis for recognition of gout in prehistory. The uniformly excavated nature of the erosions in these specimens is characteristic of gout. Spheroid lesions with overhanging edges, common in gout, are only rarely reported in other diseases, such as multicentric reticulohistiocytosis, amyloidosis and type IIA hyperlipoproteinaemia[1–3].

The *Tyrannosaurus* erosions are quite distinct from the 'bite-like' erosions characterized by the fronts of resorption seen in rheumatoid arthritis and spondyloarthropathy[2,6]; the ill-defined lesions of calcium pyrophosphate deposition disease[7]; osteoarthritis (which does not produce bone erosions)[1–3]; the draining sinuses and disorganized underlying osseous structure of infectious arthritis and osteomyelitis[1–3]; and from osteosarcoma (which does not afflict joints)[1–3]. A concurrent superficial bone infection in TMP 92.36.328 probably resulted from perforation of overlying skin by the gouty accumulation.

The apparent localization of erosion to the metacarpals and phalanges in tyrannosaurids may be the result of species variation. Only 15 per cent of human gout afflicts such joints, whereas first metatarsal phalangeal joints are more commonly affected (45 per cent of cases)[1–3,5].

Urate deposition in extant reptiles has been reported in both visceral and articular forms[8]. The latter has been reported in the monitor lizard (*Varanus*), turtles (*Testudo* and *Kinixys*), crocodilians (*Alligator* and *Crocodilus*) and in teguexin lizards (*Tupinambis*). These two occurrences in tyrannosaurids indicate that gout may have had a frequency similar to that observed in birds[9].

Although dehydration (reported in reptiles)[8] and renal failure (reported in birds)[9,10] could be contributing factors in *Tyrannosaurus rex*, a factor in humans is diet, by the ingestion of foods with a high purine content. One such dietary component is red meat, no stranger to this denizen from the Cretaceous. This tyrant king seems to have shared with subsequent tyrants the susceptibility to gout.

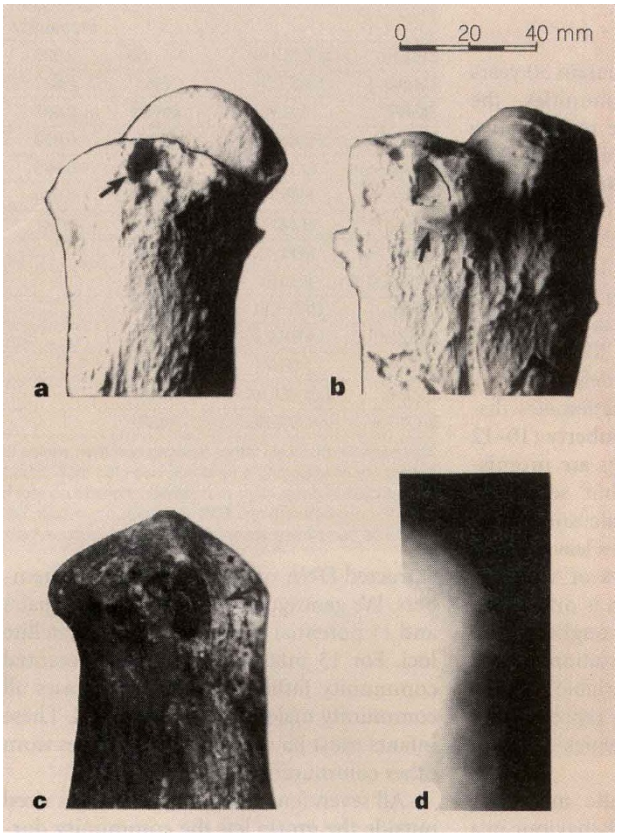

Figure 1 Dorsolateral views and X-ray of gouty lesions. **a,** DMNH 30665 metacarpal I. Erosion (arrow) with overhanging edge. **b,** DMNH 30665 metacarpal II. Spheroidal character of erosion is prominent at its base (delineated by a black line). Slightly overhanging edge (arrow) noted at lower margin of erosion. A second spheroidal erosion is present to the left and slightly above the first lesion. **c,** TMP 92.36.328 phalanx I-1. Oblong erosive process (arrow) consisting of two confluent spheroid erosions. Black area at the bottom of the erosion is an optical illusion. Arrow points to a slightly built-up adjacent bone. **d,** Oblique radiological view of TMP 92.36.328, illustrated in **c**. Two spheroidal erosions with overhanging edges.

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