Ecology & Evolution | Jan 26, 2026 | 9 min read | By Bryan White

Not Just Archaic Remnants: How Southern Ceratosaurs Matched the Tyrannosaur Bite

Biology * Evolution * Paleontology

The Bifurcation of the Mesozoic World

The evolutionary history of theropod dinosaurs has long been framed through the lens of the Northern Hemisphere's tyrannosaurids, whose massive, bone-crushing skulls represent a benchmark of predatory adaptation. In contrast, the ceratosaurs of the Southern Hemisphere -- specifically the Abelisauridae and Noasauridae -- were historically characterized as "archaic" or functionally inferior remnants. However, the 2026 study Southern hemisphere ceratosaurs evolved feeding mechanics paralleling those of Northern hemisphere tyrannosaurids, published in Scientific Reports by Rowe, Cerroni, and Rayfield, fundamentally dismantles this Laurasian-biased perspective.[1] By employing high-fidelity Finite Element Analysis (FEA) on four key taxa -- Ceratosaurus, Carnotaurus, Majungasaurus, and Masiakasaurus -- the researchers demonstrated that these southern predators evolved feeding mechanics that rivaled the performance of tyrannosaurids, despite utilizing radically different anatomical strategies.[1]

Contextualizing these findings requires examining the biogeographical stage of the Late Cretaceous. Driven by plate tectonics and the fragmentation of Pangea, the dinosaurian world split into two realms: northern Laurasia, dominated by coelurosaurs including tyrannosaurids, and southern Gondwana, an isolated evolutionary laboratory dominated by the Ceratosauria.

For decades, the scientific narrative favored the north. Tyrannosaurus rex, with its robust teeth and fused nasal bones, was championed as the ultimate terrestrial predator, capable of bone-pulverizing "puncture-pull" feeding.[1] By contrast, southern abelisaurids -- with their short, tall skulls, vestigial arms, and prominent horns -- were often viewed as biomechanically weak oddities suited only for soft prey or neck-driven "hatchet" strikes.[2]

Rowe et al. (2026) challenged this paradigm using quantitative engineering physics. By subjecting the skulls of southern ceratosaurs to the same digital stress-tests used on tyrannosaurs, they revealed a striking example of convergent evolution within broader theropod evolution. Structural constraints forced both lineages -- tyrannosaurs and abelisaurids -- along parallel mechanical paths despite vastly different ancestral anatomies.[1] To trace this trajectory from generalized Jurassic origins to specialized Cretaceous forms, the study examined four genera spanning the adaptive radiation of the Ceratosauria: Ceratosaurus (Late Jurassic ancestral baseline), Carnotaurus (the horned cursorial giant of Late Cretaceous Argentina), Majungasaurus (the robust apex predator of Late Cretaceous Madagascar), and Masiakasaurus (the small-bodied, procumbent-toothed specialist from Madagascar).[1]

Methodology: Finite Element Analysis and Digital Reconstruction

The conclusions drawn by Rowe et al. are grounded in Finite Element Analysis (FEA), a computational method borrowed from civil and aerospace engineering that calculates structural stress and strain in Newtons and Pascals. The skulls of Ceratosaurus, Carnotaurus, Majungasaurus, and Masiakasaurus were digitized via Computed Tomography (CT) scanning and high-resolution surface scanning.[1]

CT scanning is particularly vital for abelisaurids like Majungasaurus because their skulls are permeated by complex air-filled sinuses (pneumaticity). A surface scan would treat the cranium as a solid block, vastly overestimating its rigidity; internal CT slices capture the precise trabecular struts and sinus cavities needed for an accurate structural model.[3] The researchers digitally retro-deformed the fossil scans to correct for taphonomic compression and converted the restored 3D geometries into meshes composed of millions of tetrahedrons assigned the elastic material properties of bone.

Jaw adductor muscles were reconstructed from osteological correlates -- muscle attachment scars on the fossilized bone -- and virtual bite forces were simulated across anterior, middle, and posterior tooth positions.[1] The resulting simulations generated maps of von Mises stress, a scalar metric combining tension, compression, and shear that predicts material failure. High von Mises stress indicates regions under maximum mechanical load, whereas low stress denotes structural safety margins or unloaded ornamentation.

Biomechanics of the Abelisaurid Giants: Stress, Clamping, and Ornamentation

The central finding of the study concerns the large-bodied abelisaurids, Carnotaurus and Majungasaurus. Previous hypotheses suggested that the extremely short, deep skulls of these animals were adaptations to minimize stress, turning the skull into a low-stress rigid block. Contrary to this "stress-minimization" hypothesis, the FEA models revealed that the skulls of large abelisaurids experienced high magnitudes of stress during biting, comparable to or exceeding those of generalized tetanurans when scaled to equivalent size.[1]

This result directly parallels findings in Tyrannosaurus rex and reflects the Square-Cube Law under natural selection: as theropods evolved into multi-ton giants, the force generated by their jaw musculature scaled cubically with volume, while the cross-sectional strength of their cranial bones scaled only quadratically. Carnotaurus and Majungasaurus did not evolve shortened rostra to make biting effortless; rather, shortening the snout reduced the out-lever arm of the bite to maximize mechanical advantage while the bone itself operated near its structural limit.[1]

Majungasaurus vs. Carnotaurus Feeding Mechanics

Within Abelisauridae, the two giants diverged into distinct mechanical profiles:

* Majungasaurus crenatissimus (The Clamp): FEA results strongly support a "bite-and-hold" feeding strategy.[1] During biting, stress accumulated heavily along the dorsal snout. Unlike most theropods, the nasal bones of Majungasaurus are fused

and thickened, preventing inter-nasal shearing and converting the rostrum into a rigid clamp capable of restraining struggling sauropod prey.[3] Internal pneumatic sinuses supported by bony struts -- analogous to giraffe ossicones -- maximized the strength-to-weight ratio of the skull.[3]

* Carnotaurus sastrei (Strike and Shock Absorption): While its upper cranium was rigid, the Carnotaurus mandible exhibited stress distribution patterns indicative of kinetic flexibility.[1] Combined with an unusually mobile intramandibular joint, a rigid upper skull and shock-absorbing lower jaw support a "slash-and-bite" or hatchet-strike model, in which powerful neck musculature drove the upper dentition into prey while mandibular compliance prevented fractures if the prey wrenched away.[2][5]

Refuting the Mechanical Role of Cranial Ornamentation

A hallmark of ceratosaurs is their extravagant cranial ornamentation: the blade-like nasal horn of Ceratosaurus, the bull-like brow horns of Carnotaurus, and the rugose frontal boss of Majungasaurus.[4] Paleontologists long debated whether these structures served as mechanical buttresses to dissipate bite stress. Rowe et al. (2026) definitively refuted this hypothesis: stress trajectories bypassed the horns and bosses entirely during simulated biting, leaving these structures mechanically unloaded.[1] Their absence of feeding utility confirms that ceratosaurian horns and domes evolved primarily through sexual selection as visual signals for species recognition, courtship display, or intraspecific flank- and head-butting combat.

Precision Mechanics and Niche Partitioning in Masiakasaurus

While the giants illustrate raw clamping and striking power, the small-bodied noasaurid Masiakasaurus knopfleri demonstrates the mechanical versatility of the ceratosaurian Bauplan. Coexisting with Majungasaurus in the Late Cretaceous Maevarano Formation of Madagascar, the wolf-sized Masiakasaurus possessed a highly specialized heterodont dentition in which the anterior teeth projected forward (procumbency).[1][6]

In the FEA simulations, Masiakasaurus exhibited the lowest overall peak cranial stresses of all modeled taxa.[1] When bite loads were applied to the tips of the procumbent anterior teeth -- simulating the grasping of small prey -- stress was channeled axially down the tooth root directly into the reinforced mandibular symphysis. Had those anterior teeth been oriented vertically, seizing struggling prey at the jaw tips would have generated large bending moments (torque) capable of snapping the slender mandible. Angling the dentition forward converted dangerous bending torque into manageable axial compression, isolating the posterior jaw from structural strain.[1]

These biomechanical distinctions explain how two ceratosaurs coexisted within a semi-arid ecosystem subject to severe seasonal droughts. By partitioning the food web, Majungasaurus functioned as the macro-predatory clamp specialist targeting sauropods and large carcasses, whereas Masiakasaurus operated as a low-stress precision grasper feeding on fish, invertebrates, lizards, and small vertebrates.[1]

Comparative Evolution: Gondwana vs. Laurasia

Comparing the southern ceratosaurs with northern tyrannosaurids reveals how physical laws constrain apex predator design.[7][8] Both clades evolved multi-ton body masses and reinforced, high-stress crania with fused nasals to subdue megaherbivores, yet their anatomical toolkits diverged in key respects. Tyrannosaurs retained functional two-fingered forelimbs and relied on deep-snouted, bone-crushing "puncture-pull" mechanics driven by an S-curved neck. Abelisaurids reduced their forelimbs to vestigial nubs, placing the entire burden of prey capture on a drastically shortened, broad skull paired with rigid neck musculature suited for grappling and prolonged clamping.[1] Meanwhile, the Late Jurassic Ceratosaurus occupied an intermediate mechanical baseline -- a generalized predator with moderate cranial stress and blade-like dentition whose ancestral flexibility later diverged into the extreme Cretaceous specializations of Abelisauridae and Noasauridae.[1]

| Feature | | Masiakasaurus | | Ceratosaurus | | Carnotaurus | | Majungasaurus |

| Family | | Noasauridae | | Ceratosauridae | | Abelisauridae | | Abelisauridae |

| Skull Morphology | | Long, low, heterodont | | Moderate length, blade-like | | Short, deep, horned | | Short, broad, fused nasals |

| Primary Stress Profile | | Low Stress (Optimized) | | Intermediate | | High Stress (Flexible mandible) | | High Stress (Rigid clamp) |

| Anterior Dentition | | Procumbent (Forward) | | Vertical, blade-like | | Vertical, slender | | Vertical, conical/robust |

| Key Biomechanical Adaptation | | Stress Isolation: Procumbent teeth direct force axially, protecting the slender jaw. | | Baseline: Generalized theropod mechanics without extreme specialization. | | Speed/Shock: Mandibular compliance aids rapid closure and shock absorption. | | Clamp/Rigidity: Fused pneumatic nasals resist shear loads during prolonged grip. |

| Ecological Niche | | Small-prey specialist (fish, invertebrates) | | Generalist hunter | | Cursorial pursuit predator | | Ambush / bite-and-hold apex predator |

| Ornament Function | | None prominent | | Display (nasal horn) | | Display (brow horns) | | Display (frontal boss) |

Rehabilitating the Southern Apex Predators

The 2026 finite element analysis by Rowe, Cerroni, and Rayfield overturns the view of Gondwanan ceratosaurs as archaic evolutionary holdovers.[1] Rather than indicating structural weakness, the high cranial stresses documented in Majungasaurus and Carnotaurus reflect high-performance biological engineering operating at the limits of bone strength -- matching the mechanical intensity of Laurasian tyrannosaurids through shortened rostra and fused pneumatic nasals. Simultaneously, the axial stress-isolation mechanics of Masiakasaurus and the purely socio-sexual role of cranial horns demonstrate the remarkable functional plasticity of the ceratosaurian skull across the Mesozoic Southern Hemisphere.

Updates... (Nov 21, 2026): Replaced Wikipedia reference with Delcourt (2018) on ceratosaur paleobiology in Scientific Reports; added specific publication dates and

verified journal volume/issue/page metadata across all eight CrossRef DOIs; split grouped inline citations; and corrected minor spacing typography.

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