

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

- | | |
|-------------------------------------|---|
| n/a | Confirmed |
| ☐ | ☒ The exact sample size (<i>n</i>) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☒ | ☐ The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ A description of all covariates tested |
| ☒ | ☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☒ | ☐ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☒ | ☐ For null hypothesis testing, the test statistic (e.g. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted
<i>Give P values as exact values whenever suitable.</i> |
| ☐ | ☒ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☒ | ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☒ | ☐ Estimates of effect sizes (e.g. Cohen's <i>d</i> , Pearson's <i>r</i>), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	115 tyrannosaur fossils were directly examined for this study and morphological data was captured in 3D for nearly all specimen. Specimens were digitized via photogrammetry (Abound v.3.0.1) and/or structured light scanning (Artec Spider 2; Artec Leo; software Artec Pro 19) CT data was acquired for NCSM 40000, BMRP 2006.4.1, and CMNH 7541 CGM measurements were taken in ImageJ (v.1.54f). Specimens were measured using Blender v3.0-4.4. CT data was reconstructed using Avizo 9 Lite. Osteohistological data was collected from images visualized with NIS-Elements D (v.5.41.01) software. Body mass was estimated with MASSTIMATE package (version 1.3) in R version 4.4.3.
Data analysis	Growth modeling was conducted in R (4.4.3), phylogenetic analyses were run in Mr Bayes (R (4.4.3) and TNT (1.6) and branch lengths estimated using STRAP (1.6.1).

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

Analytical input data and output results are available as Supplementary Information and Figshare with the identifier <https://doi.org/10.6084/m9.figshare.29124437>. μ CT datasets of the skulls of BMRP 2002.4.1 and CMNH 7541 are available by request to BMRP and CMNH. μ CT datasets of the skull of NCSM 40000 will be made available open access after the publication of an upcoming manuscript on skull anatomy.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender	Not applicable
Reporting on race, ethnicity, or other socially relevant groupings	Not applicable
Population characteristics	Not applicable
Recruitment	Not applicable
Ethics oversight	Not applicable

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	We describe an exceptionally well-preserved, near somatically mature tyrannosaur skeleton recovered from the Hell Creek Formation (NCSM 40000). We couple comparative gross and microstructural anatomy with longitudinal growth models, ontogenetic invariance in extant archosaurs and tyrannosauroid kin, and a novel phylogenetic dataset to test the validity of Nanotyrannus, demonstrating conclusively that this taxon is distinguishable from <i>T. rex</i> , sits outside the clade Tyrannosauridae, and unexpectedly contains two species - <i>N. lancensis</i> and <i>N. lethaeus</i> , sp. nov.
Research sample	120 tyrannosauroid specimens examined firsthand.
Sampling strategy	We examined nearly all tyrannosauroid specimens available at the time of the study. Phylogenetic analyses were conducted at the specimen level.
Data collection	Specimens were digitized to capture 3D surface data, several specimens were scanned with high-resolution computed tomography. Measurements were collected from digital models, and measured with hand-held instruments. Osteohistological data was collected following standard procedures for paleohistological samples. All data collection methods are detailed in the methods and supplementary information files.
Timing and spatial scale	Jurassic through Cretaceous tyrannosauroid taxa, spanning the Northern Hemisphere were examined.
Data exclusions	n/a
Reproducibility	Analytical input data including phylogenetic files, and output results are available as Supplementary Information and in Figshare. The analytic code for this study is available as Supplementary Information 2–6 and in Figshare.

Randomization

n/a

Blinding

n/a

Did the study involve field work?

☐

Yes

☒

No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance

NCSM 40000 was excavated by a team of private individuals for commercial sale. In 2021, NCSM 40000 was purchased by the Friends of the North Carolina Museum of Natural Sciences, a non-profit organization. NCSM 40000 has been in the care of the NCSM paleontology unit since February 2017; however, no preparation or research was conducted on the specimen until it was officially gifted to the NCSM in 2021. We provide a full ethics statement in the main text of the paper.

Specimen deposition

NCSM 4000 is repositied at the North Carolina Museum of Natural Sciences in the Paleontology Collections.

Dating methods

Reported age-dates are derived from a publication in review that is co-authored by Lindsay Zanno. Citation is provided.

☐ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.

Ethics oversight

No ethical approval was required for this study; however, the authors followed the code-of-conduct of the Society of Vertebrate Paleontology in withholding research activities and data collection until the specimen was gifted to the NC Museum of Natural Sciences.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks

Not applicable

Novel plant genotypes

Not applicable

Authentication

Not applicable