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The anatomy of a troodontid tooth from the Late Cretaceous in Jiayin, Heilongjiang Province, China

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Abstract

The anatomical characteristics of troodontid teeth have remained largely unexplored. This study employs high-resolution computed tomography data to reconstruct and describe the morphology of a new troodontid tooth from the Upper Cretaceous Yuliangzi Formation, located in the Sunwu-Jiayin Basin of Jiayin, Heilongjiang, Northeast China. The reconstruction reveals previously unrecognized anatomical features and presents the first three-dimensional visualization of the pulp cavity of troodontid teeth. Notably, the ratio of enamel thickness at the base of the crown to the crown height is 1.9%. The enamel thickness on the labial side exceeds that on the lingual side in the distal denticles, a phenomenon observed in theropod teeth for the first time. The pulp cavity is distinctly narrow in the labiolingual dimension, tapering sharply towards the apex, and exhibiting a distal curvature, and displays nine distinct projections along basal half of its distal margin. Additionally, the presence of a wear facet supports the hypothesis of tooth-to-tooth occlusion in troodontids, similar to that observed in tyrannosaurids. Comparative morphological analysis identifies the specimen as a *Troodon*-morphotype tooth, thereby providing further evidence for faunal exchange between North America and Asia via Cretaceous Beringia. Moreover, the only theropods that have been definitively identified from the

Yuliangzi Formation are tyrannosaurids and troodontids. In addition, the comparison of various dinosaur faunal assemblages within Maastrichtian deposits in China indicates that all of them contain tyrannosaurids.

Keywords

Troodontidae, pulp cavity, enamel, Yuliangzi Formation, Tyrannosauridae

Introduction

Troodontids represent a clade of small theropod dinosaurs (Makovicky and Norell 2004) that display significant morphological similarities to birds (Xu et al. 2002). The teeth of later-diverging troodontids are unique in having proportionally large denticles that exhibit an apically hooked morphology as well as a distinct constriction between the crown and the root (Currie 1987; Makovicky and Norell 2004). Over the past 170 years, a considerable number of isolated troodontid teeth and troodontid bones associated with teeth have been documented (e.g., Leidy 1856; Osborn 1924; Russell 1948; Barsbold 1974; Currie 1987; Currie et al. 1990; Russell and Dong 1993; Norell et al. 2000, 2009; Currie and Dong 2001; Xu et al. 2002, 2011; Makovicky et al. 2003; Xu and Norell 2004; Xu and Wang 2004; Ji et al. 2005; Averianov and Sues 2007; Gao et al. 2012; Goswami et al. 2013; Tsuihiji et al. 2014; Pei et al. 2022; Wang et al. 2025). Despite the potential phylogenetic implications of certain dental traits and the prevalence of tooth fossils associated with troodontids, a comprehensive examination of the anatomical features of their teeth, particularly with respect to internal structure, remains to be conducted.

The Upper Cretaceous Yuliangzi Formation, situated within the Sunwu-Jiayin Basin in Jiayin, Heilongjiang, is characterized by a notable diversity of dinosaur fossils, including the first dinosaur remains identified in China (Riabinin 1925). This formation is particularly recognized for its extensive collection of hadrosaurid fossils (Riabinin 1930; Godefroit et al. 2000, 2008; Xing et al. 2022), in addition to a significant number of isolated theropod teeth (Riabinin 1930; Lü and Han 2012; Yu et al. 2022). However, many of these theropod remains have not yet been subjected to thorough examination. Recently, a new troodontid tooth was discovered in the Yuliangzi Formation at Longgushan, Jiayin of Heilongjiang, China. This study utilizes CT scanning technology to provide a comprehensive anatomical description of both the external and internal structures of this tooth, as well as to discuss its taxonomic classification.

Material and methods

Sc000900 is an isolated right maxillary tooth specimen. The specimen described in this study was collected from the lower member of the Upper Cretaceous Yuliangzi Formation at DMJY No. 4 (Yu et al. 2022; 48º51′26.0″N, 130º14′58.2″E), located in Longgushan, Jiayin County, Heilongjiang Province, China (Fig. 1). This member has been dated to the early

Maastrichtian age in detail (Markevich et al. 2011; Sun et al. 2011; Sun 2022). It is currently housed in the Shenzhou Dinosaur Museum of Jiayin, Jiayin Dinosaur National Geopark, China. In the description of Sc000900, we adhere to the terminology and measurement methodologies established by Hendrickx et al. (2015).

A steel needle was employed for the mechanical preparation of the specimen Sc000900 under a Leica S6 microscope. Subsequently, imaging of the specimen was conducted using a three-dimensional large depth-of-field microscopy system (Olympus DSX-1000) located at the Paleontological Museum of Liaoning. The specimen Sc000900 was subjected to computed tomography (CT) scanning at Yinghua NDT (Shanghai) Co., Ltd., utilizing the Phoenix V|tome|x M240, which produced a total of 2201 projections at 100 kV and 200 μA. The resultant voxel size was determined to be 3.54 × 3.54 × 3.54 μm. Segmentation, three-dimensional reconstruction, and measurements were executed using VG STUDIO MAX 3.4 (Volume Graphics, Heidelberg, Germany).

Systematic Palaeontology

Dinosauria Owen, 1842
Theropoda Marsh, 1881
Maniraptora Gauthier, 1986
Troodontidae Gilmore, 1924
Troodontidae indet.

Material. Sc000900, one isolated tooth (Figs 2-6).

Formation and age. Lower member of Yuliangzi Formation; early Maastrichtian.

Description. Sc000900 consists of an almost complete tooth crown accompanied by the basal-most portion of the root (Fig. 2). The limited preservation of the root suggests that this specimen may represent a shed tooth. Additionally, the tooth is characterized by a relatively short crown, exhibiting a crown height ratio of 1.3 (Tab. 1), as documented by Hendrickx et al. (2015). The specimen is notably small, with a crown height of 9 mm (Tab. 1).

***Tooth anatomy*.** The crown exhibits a recurved shape and is compressed labiolingually. It is categorized as folidont, characterized by a distinct constriction at its base (Fig. 2A, B). The apex of the crown shows signs of wear. The basal cross-section of the crown is lenticular in shape, with a slightly concave on the lingual side (Fig. 2K, L). The labial apex of this cross-section is situated relatively mesially. The labial surface of the crown is convex. Both the mesial and distal carinae are characterized by denticulation along the crown (Fig. 2A, B). The mesial carina exhibits slight erosion. It is recurved distally (Fig. 2I, J), and is inclined slightly towards the lingual side when viewed mesially (Fig. 2G, H). The distal carina is only weakly concave, appearing nearly straight in both labial and lingual views, and is almost perpendicular to the crown's baseline. It is inclined slightly towards the labial side when viewed distally (Fig. 2C, D).

A lingual depression is observed (Fig. 2E, F), resembling the morphology observed in the previously reported troodontid tooth (see fig. 5b in Yu et al. 2022). This depression is centrally positioned and, in its preserved state, displays a sub-triangular shape, with its base spanning approximately one-half of the length of the lingual surface. The apicobasal extent of the lingual depression occupies one-third of the crown, which is in contrast to the condition typically seen in most theropods, where such depressions are generally restricted to the basal region of the crown (Hendrickx et al. 2015).

The enamel, dentine, and pulp cavity were segmented on the crown (Fig. 3). The respective total volumes for the enamel, dentine, and pulp cavity are 2.83 mm^3, 76.44 mm^3, and 0.99 mm^3. It is noteworthy that the pulp cavity is the smallest structure among the three components of the tooth.

The enamel exhibits a smooth texture (Fig. 3A, B). Its thickness remains relatively uniform around the circumference of the crown (Fig. 4E, F). However, it diminishes towards the base of the crown on both the labial and lingual surfaces (Fig. 4C). Specifically, the enamel thickness is measured as 31 μm, 29 μm, and 17 μm in the apical (Fig. 4D), middle (Fig. 4E), and basal (Fig. 4F) regions of the crown, respectively. Additionally, the enamel is consistently thicker on the labial surface of each distal denticle compared to the lingual surface (Fig. 4G, H). The enamel thickness exhibits a slight reduction on the labial side and an increase on the lingual side as it approaches the proximal base of a distal denticle. This pattern is observed across all distal denticles. For instance, in a middle distal denticle of the crown, the enamel thickness is measured as 36 μm, 35 μm, and 30 μm in the apical (Fig. 4G), middle (Fig. 4H), and basal (Fig. 4I) regions, respectively, on the labial side. Conversely, on the lingual side, the enamel thickness is recorded as 14 μm, 24 μm, and 28 μm in the apical (Fig. 4G), middle (Fig. 4H), and basal (Fig. 4I) regions, respectively. At the proximal base of the denticles, the enamel thickness is nearly uniform (Fig. 4I).

The dentine exhibits greater thickness on the labial side of the crown's base compared to the lingual side, and it is also thicker on the distal side of the crown's base in relation to the mesial side (Tab. 1). The morphology of the pulp cavity is characterized by a blade-like shape, demonstrating considerable labiolingual compression (Fig. 3D-G). It tapers sharply at the apex and exhibits a distal curvature, maintaining a central position in both mesial and distal views (Fig. 3F, G). Notably, the apex of the pulp cavity is situated significantly lower than that of the crown (Fig. 3D, E). The mesial margin of the pulp cavity is markedly apicobasally convex, while the distal margin is apicobasally concave. The central region of the mesial margin displays several projections, which may represent a natural anatomical feature, as indicated by the regular curvature of their distal margin. The basal half of the distal margin exhibits nine projections that gradually decrease in length as they extend towards the crown apex (Figs 3D, E, 4J). The spacing between each distal projection measures approximately 0.5 mm, while the proximal diameter of each projection is roughly 0.05 mm. Each projection extends toward the interdenticular diaphysis.

Denticle anatomy. The denticles are clearly visible at the base of the mesial carina and extend along the full length of the distal carina. They also appear to be present along the entire mesial carina, despite its slight erosion (Fig. 2H). It is noteworthy that the distal denticles protrude more in the proximodistal direction from the crown than their mesial counterparts (Fig. 2A, B). As a result, the distal denticles appear larger than the mesial denticles when viewed from both the lingual and labial views. The mesial denticles are relatively small, with a maximum length of 0.3 mm, and there are at least five mesial denticles clearly preserved.

A total of 19 distal denticles have been preserved, although it is possible that one distal denticle is not preserved at the crown base. Four distal denticles located at the mid-crown exhibit incompleteness. The counts of distal denticles per 5 mm along the basal, middle, and apical crown regions are 12, 10.5, and 11, respectively. The average number of denticles per 5 mm along the distal carina is calculated to be 11.2. The distal denticles exhibit an apically inclined orientation and are relatively large (Fig. 5), with a maximum apicobasal length of 0.6 mm recorded at approximately the mid-length of the mesial carina. This length exhibits a gradual reduction towards both the tooth apex and base of the tooth as one moves away from the mid-crown. Furthermore, the distal denticles are elongated in the proximodistal direction compared to in the apicobasal direction (Fig. 5A, B). The external margin of the denticles displays an apically hooked morphology (Fig. 5A, B). The interdenticular slit is subtriangular in shape, while the interdenticular space is both deep and large (Fig. 5A, B). Additionally, the interdenticular diaphysis is shallow in nature (Fig. 5A, B).

Wear facet. The wear facet is situated on the lingual surface (Fig. 2 E, F) and presents an elliptical shape with smooth margins (Fig. 6A, B). The longest axis measures 4.3 mm, while the shortest axis measures 1.0 mm, resulting in a consistently flat surface. Fine scratches have been identified on the polished surface, in addition to several coarse scratches that are likely indicative of dental microwear. However, it remains challenging to entirely rule out the possibility that these coarse scratches may have resulted from the fossilization process (Fig. 6A, B). The majority of these fine scratches exhibit a parallel orientation and are typically positioned slightly offset from the longest axis of the wear facet. Specifically, they are generally located more apically on the mesial side of the facet and more basally on the distal side (Fig. 6A, B).

Discussion

Relationships of Sc000900

Sc000900 is distinguished by labiolingual compression, distal recurvature, and denticulation. These morphological features substantiate its classification as a theropod (Hendrickx and Mateus 2014; Yu et al. 2023). The specimen is identified as a lateral tooth based on its moderately compressed crown base, which exhibits a crown base ratio of 0.42, as documented by Hendrickx et al. (2015). Within theropod clades, Sc000900 can be confidently assigned to the family Troodontidae, based on the presence of a pronounced constriction between the crown and root, and the presence of exceptionally large, hook-like denticles (Makovicky and Norell 2004; Hendrickx et al. 2019).

Among troodontids, Sc000900 exhibits distal denticles, distinguishing it from taxa such as

Byronosaurus (Makovicky et al. 2003), *Mei* (Xu and Norell 2004), *Jinfengopteryx* (Ji et al. 2005), *Urbacodon* (Averianov and Sues 2007; Wang et al. 2025), *Xixiasaurus* (Lü et al. 2010), *Gobivenator* (Tsuihiji et al. 2014), *Almas* (Pei et al. 2017), and *Papiliovenator* (Pei et al. 2022), all of which lack denticles on their teeth. Furthermore, Sc000900 possesses large denticles that are apically hooked, with a density of 2.2 per millimeter distally. This characteristic differs from that observed in *Sinovenator* (Xu et al. 2002), *Sinusonasus* (Xu and Wang 2004), *Daliansaurus* (see fig. 5b in Shen et al. 2017), and *Hesperornithoides* (Hartman et al. 2019), all of which possess relatively small denticles and lack apically hooked denticles. Morphologically, Sc000900 shares morphological similarities with the lateral teeth of *Zanabazar* (Barsbold 1974), *Sinornithoides* (Currie and Dong 2001), *Saurornithoides* (Norell et al. 2009), *Linhevenator* (Xu et al. 2011), *Troodon* (Currie 1987), and some troodontid teeth (Goswami et al. 2013), particularly in the presence of large denticles along the distal carina that are apically hooked. Among these taxa, Sc000900 is particularly comparable to the maxillary teeth of *Troodon*, as indicated by the presence of denticles along the entire length of both carinae and a similar crown base length of ≥ 6 mm (Currie 1987). In contrast, *Zanabazar*, *Sinornithoides*, *Saurornithoides*, and *Linhevenator* either lack denticles along the mesial carina or have denticles restricted to the base of the mesial carina in lateral dentition (Barsbold 1974; Currie and Dong 2001; Norell et al. 2009; Xu et al. 2011). Taken together, Sc000900 is conservatively classified as a *Troodon*-morphotype tooth, given that it is represented solely by a tooth specimen.

Paleoecology of the Upper Cretaceous Yuliangzi Formation

The occurrence of theropod fossils within the Yuliangzi Formation is significantly lower when compared to that of ornithischian hadrosaurids (Yu et al. 2022). Over the past century, seven theropod taxa have been documented from isolated dental remains within this Formation (Riabinin 1930; Lü and Han 2012; Yu et al. 2022). Specifically, Riabinin (1930) and Yu et al. (2022) reported the presence of tyrannosaurids and troodontids, respectively, whereas Lü and Han (2012) identified tyrannosaurids, dromaeosaurids, carcharodontosaurids, *Fukuiraptor*, and two potential new theropod taxa. However, Bolotsky (2013) posited that all of the theropod teeth described by Lü and Han (2012) may be attributable to tyrannosaurids, as they exhibit similar tyrannosaurid measurements. It is noteworthy that the majority of theropod teeth recovered from the Yuliangzi Formation have not undergone detailed description or comprehensive analyses, such as cladistic and cluster analyses, despite the critical importance of employing multiple lines of evidence to accurately identify theropod teeth and to avoid misidentifications caused by convergent evolution (Yu et al. 2023). To date, the only theropods definitively identified from the Yuliangzi Formation are tyrannosaurids and troodontids. The *Troodon*-morphotype tooth analyzed in the present study adds new information to the limited theropod fossil record and confirms the presence of troodontids within the Yuliangzi Formation. Moreover, the previous identification of a fragmentary *Troodon*-like tooth from the Yuliangzi Formation has been interpreted as evidence supporting faunal exchange between East Asia and western North America during the Cretaceous (Yu et al. 2022). The discovery of a relatively complete *Troodon*-like tooth in the present study provides additional support for this biogeographic hypothesis.

In China, Maastrichtian dinosaur faunal assemblages are mainly distributed in three provinces: Heilongjiang, Jiangxi, and Guangdong, with the latter two being adjacent. These assemblages come from specific geological formations or groups: the Yuliangzi Formation of the Sunwu-Jiayin Basin of Heilongjiang, northeastern China (Sun 2022); the Nanxiong Group (Guifeng Group) in the Ganzhou Basin of Jiangxi and the Nanxiong Basin of Guangdong (BGMRGP 1984; Zhao et al. 1991); and the Dalangshan Formation of the Sanshui basin of Guangdong, southern China (Xing et al. 2024). The dinosaur fauna of the Yuliangzi Formation include tyrannosaurids (Riabinin 1930; Lü and Han 2012), hadrosaurids (Godefroit et al. 2000, 2008; Xing et al. 2022), and troodontids. In the Nanxiong Group, the dinosaur assemblages differ slightly between the two basins: the Ganzhou Basin yields tyrannosaurids (Lü et al. 2014; Zheng et al. 2024), oviraptorids (Xu and Han 2010; Wang et al. 2013; Wei et al. 2013; Lü et al. 2013a, 2015, 2016, 2017), sauropods (Lü et al. 2013b), and hadrosaurids (Xing et al. 2021, 2022; Yao et al. 2026), whereas the Nanxiong Basin contains tyrannosaurids (Dong 1979), oviraptorosaurians (Lü and Zhang 2005), therizinosaurids (Dong 1979), sauropods (Young 1965), nodosaurids (Young 1965), and hadrosaurids (Dong 1979). The Dalangshan Formation, by contrast, has only yielded tyrannosaurids so far (Xing et al. 2024). Notably, tyrannosaurids are present in all of these Maastrichtian formations, suggesting that faunal exchange may have occurred among them. The observed differences in dinosaur composition across these formations may be explained by paleoenvironmental factors and/or sampling biases.

New dental features of troodontids

Despite the identification and description of troodontid teeth as early as 1856 (Leidy 1856), as far as we known, a comprehensive understanding of their detailed dental characteristics, particularly the internal structures, remains limited. The CT scan data of specimen Sc000900 offers valuable insights into these internal features, including the pulp cavity and enamel.

To date, the three-dimensional geometry of the pulp cavity in troodontids has not been described. This study reveals the internal structure for the first time. Notably, the pulp cavity exhibits a blade-like morphology, curving distally and tapering sharply towards the apex, which is situated lower than the apex of the crown. The transverse section of the pulp cavity at the crown exhibits a slit-like shape. Additionally, the basal half of the distal margin of the pulp cavity displays nine distinct projections.

The enamel thickness in troodontids is notably reduced (Wang et al. 2023). This trait was previously identified in a single troodontid tooth (Li et al. 2020); however, comprehensive investigations into the enamel thickness throughout the entire crown and the ratio of enamel thickness at the base of the crown to the crown height (ET/CH) in troodontids remain largely unexamined. In the present study, the enamel thickness of specimen Sc000900 was analyzed utilizing computed tomography (CT) scan technology, yielding measurements of 31 μm, 29 μm, and 17 μm at the apical, middle, and basal regions of the crown, respectively. The calculated ET/CH ratio was found to be 1.9%, which is markedly greater than the ratio of less than 1.3% observed in the non-ornithothoracine species *Sapeornis* and *Jeholornis* (Li et al. 2020). However, this ratio falls within the range of 1.8% to 4% reported for certain enantiornithines (Li et al. 2020).

These results further substantiate the hypothesis that enamel thickness is reduced in troodontids.

The enamel thickness of the denticles in troodontids has not been studied. Through the application of computed tomography (CT) scanning on specimen Sc000900, it has been determined that the enamel thickness of the distal denticles is greater on the labial side than on the lingual side. This finding constitutes a novel contribution to the understanding of the troodontid clade. Moreover, to the best of our knowledge, this specific characteristic has not been documented in other theropod subgroups. While asymmetrical enamel has been observed in the crowns of sauropods (Sereno and Wilson 2005; D'Emic et al. 2013; Zhang et al. 2024; Sui et al. 2026) and ornithischians (Norman 2004; You and Dodson 2004), our research indicates that this phenomenon is also present in theropods, albeit localized to the distal denticles rather than the entire crown.

In addition, while an elliptical lingual wear facet has also been reported in *Troodon* (Leidy 1856, 1860) and certain isolated troodontid teeth (Fiorillo 2008; Torices et al. 2014), there is a lack of sufficient evidence supporting the presence of parallel wear scratches in those instances. A wear surface has been identified on the lingual aspect of specimen Sc000900, characterized by an elliptical morphology and parallel wear striations. These features strongly suggest that this surface serves as a wear facet (Schubert and Ungar 2005; Hendrickx et al. 2019). Our findings provide further support for the hypothesis that tooth-to-tooth occlusion occurs in troodontids, similar to that observed in tyrannosaurids (Schubert and Ungar 2005).

Conclusions

A *Troodon*-morphotype tooth has been documented from the Yuliangzi Formation situated at Longgushan, Jiayin, Heilongjiang, China. This specimen offers novel insights into the internal morphology of troodontid teeth, particularly regarding the enamel thickness on the crown and distal denticles, as well as the features of the pulp cavity. The identification of this specimen, alongside other theropod teeth, implies that the Yuliangzi Formation may also contain theropod body fossils in addition to isolated teeth, thereby suggesting the potential for future paleontological discoveries. Furthermore, the reported diversity of theropods from the Yuliangzi Formation might be exaggerated owing to the absence of comprehensive studies. Additionally, analysis of dinosaur faunal assemblages within Maastrichtian strata in China reveals the consistent presence of tyrannosaurids.

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Figure captions

Figure 1. Map showing four major dinosaur sites of the Upper Cretaceous in the northern Sunwu-Jiayin Basin (modified from Godefroit et al. 2008).

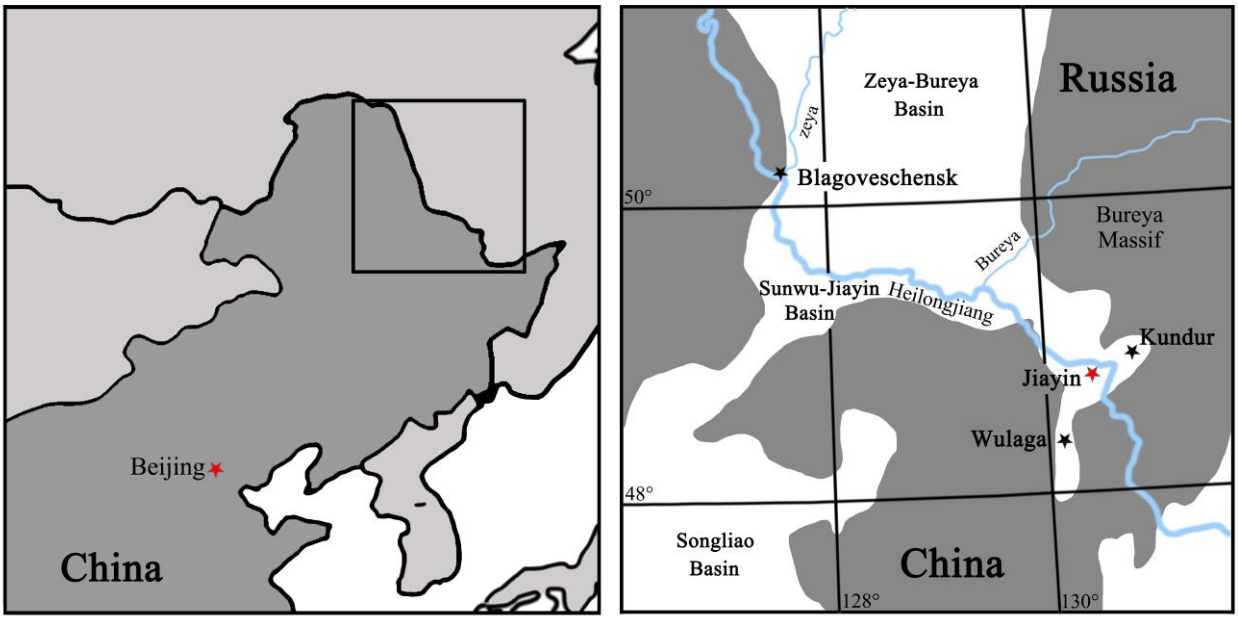

Figure 2. The right maxillary tooth (Sc000900) of a troodontid in labial (**A, B**), distal (**C, D**), lingual (**E, F**), mesial (**G, H**), apical (**I, J**) and basal (**K, L**) views. Abbreviations: dca, distal carina; dde, distal denticles; lid, lingual depression; mca, mesial carina; mde, mesial denticles; wfa, wear facet.

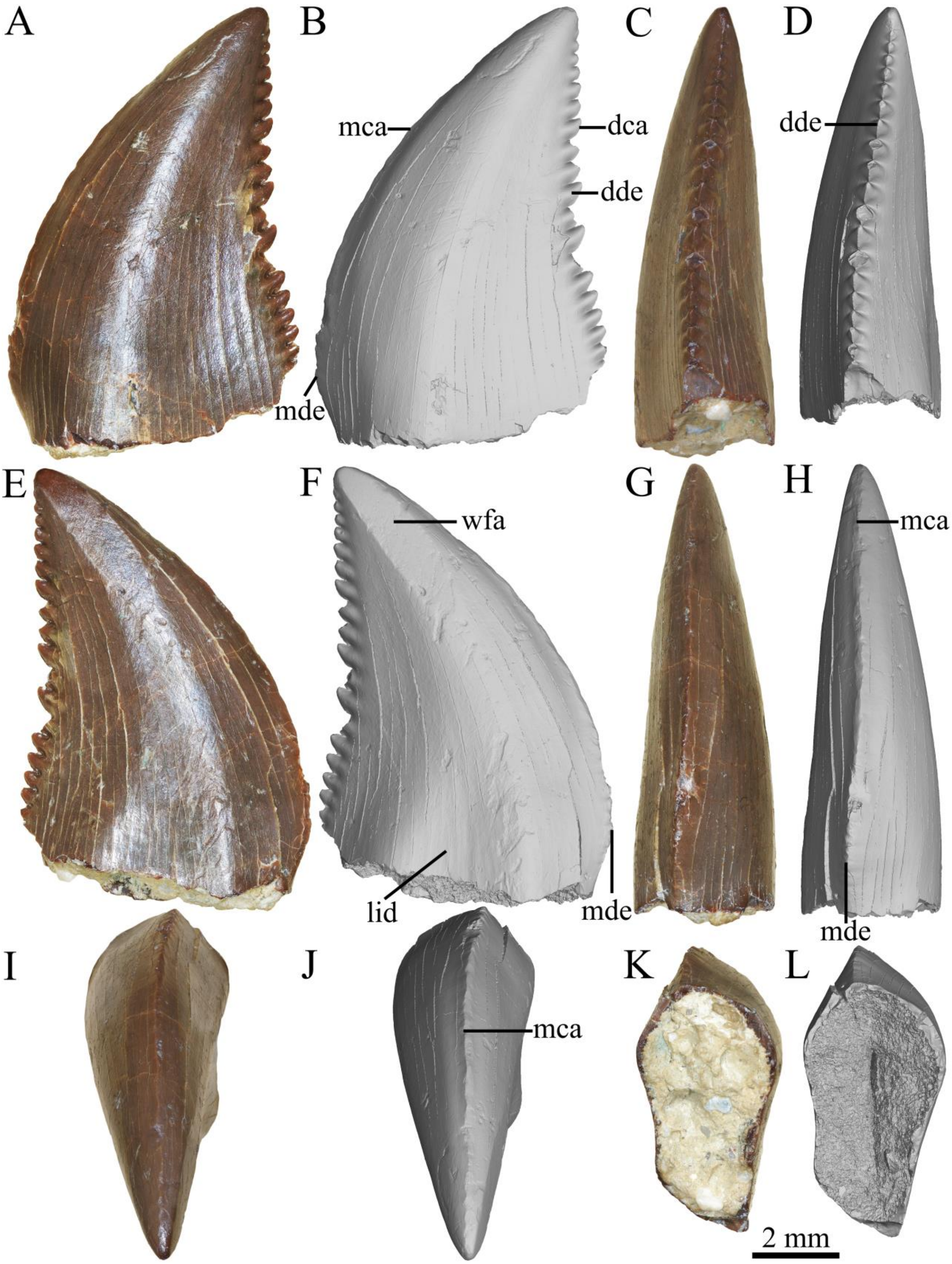

Figure 3. CT rendered images of the enamel, dentine, and pulp cavity of the right maxillary tooth (Sc000900) of a troodontid. **A.** Enamel and dentine in lingual view; **B.** Enamel in lingual view; **C.** Dentine in lingual view; Semi-transparent tooth with the high light of the pulp cavity in lingual (**D**), labial (**E**), distal (**F**), and mesial (**G**) views. Abbreviations: del, dentine layer; enl, enamel layer; puc, pulp cavity; wfa, wear facet.

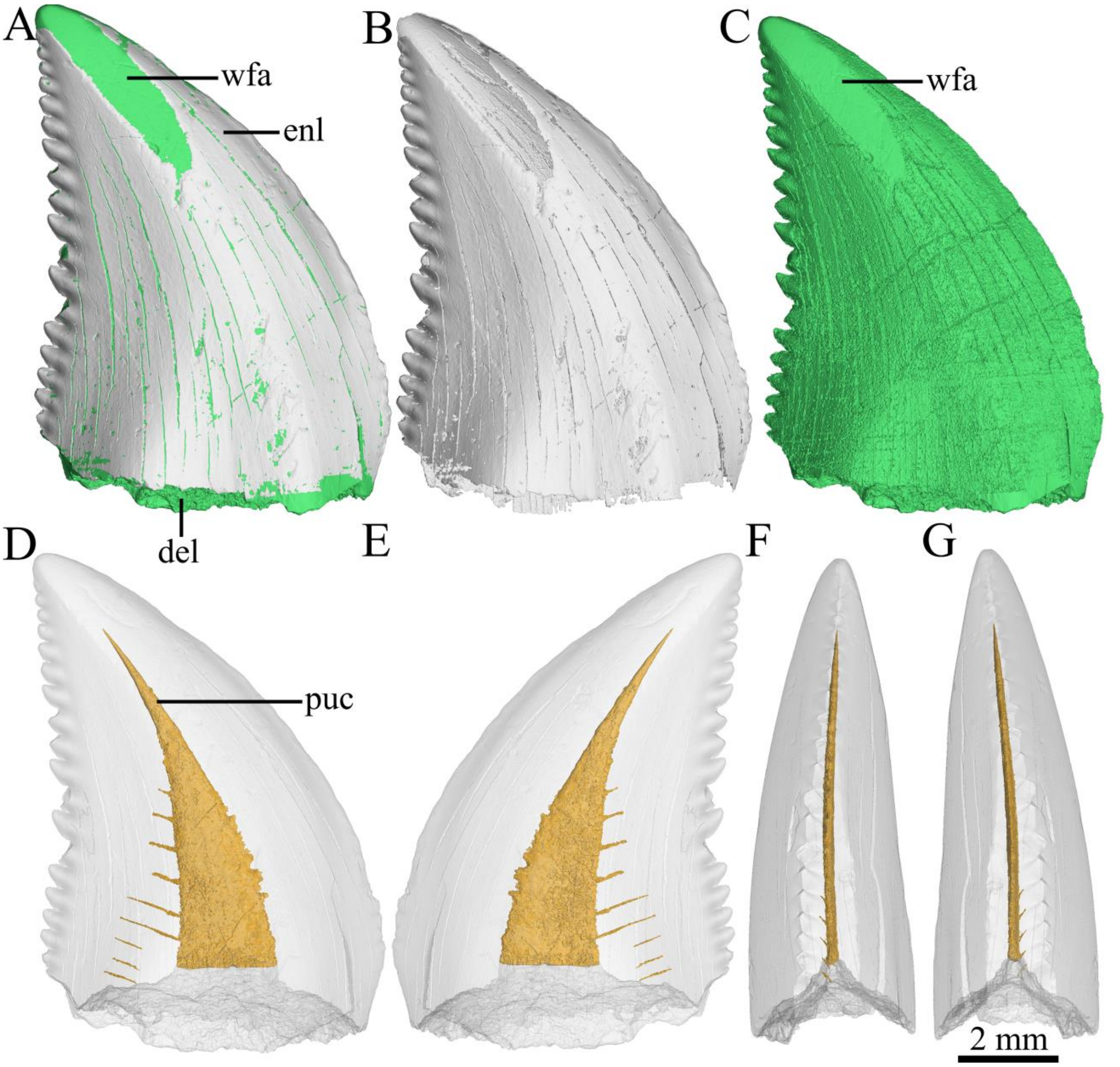

Figure 4. CT rendered images of the right maxillary tooth (Sc000900) of a troodontid. **A.** tooth in lingual view with its selected sections; **B.** A central distal denticle in lingual view with its selected apicobasal sections; **C.** Longitudinal section; **D.** Apical cross-section; **E.** Central cross-section; **F.** Basal cross-section; **G-I.** Apicobasal sections of a distocentral denticle; **J.** Saggital section. Abbreviations: del, dentine layer; enl, enamel layer; lab, labial; lin, lingual; proj, projections; puc, pulp cavity.

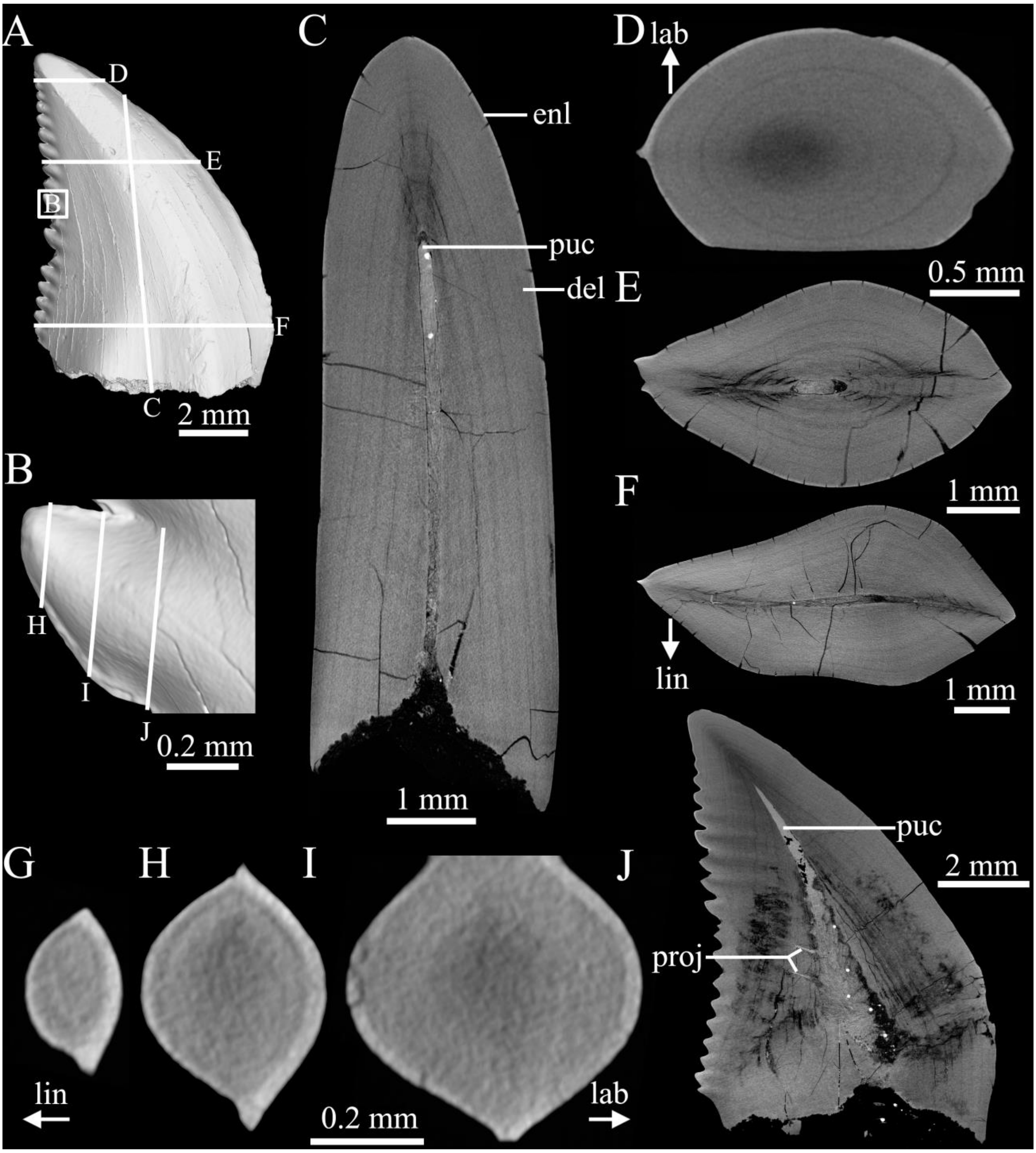

Figure 5. Distal denticles of the right maxillary tooth (Sc000900) of a troodontid in labial (**A, B**), distal (**C, D**), and lingual (**E, F**) views. Abbreviations: ema, external margin; idd, interdenticular diaphysis; idsl, interdenticular slit; idsp, interdenticular space.

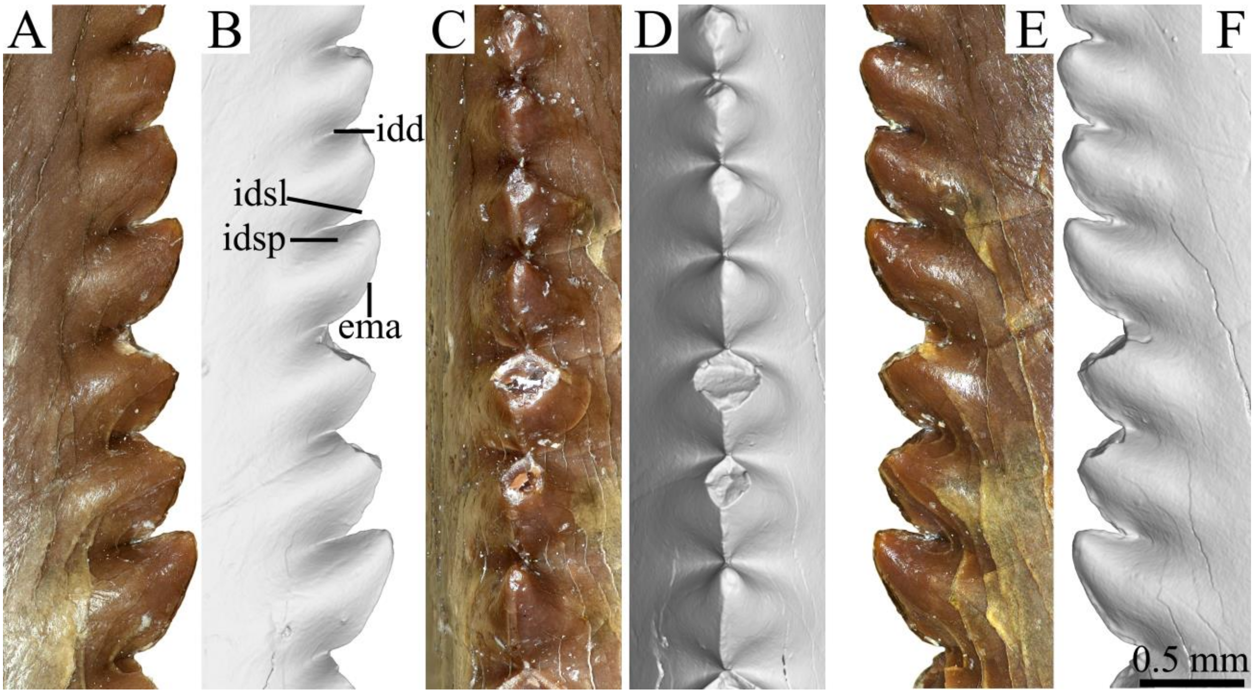

Figure 6. Wear facet of the right maxillary tooth (Sc000900) of a troodontid.

Table 1. Measurements of Sc000900.

Right maxillary tooth Sc000900							
CBL	CBW	CH	AL	CA	CBR	CHR	MCL
6.9 mm	2.9 mm	9.0 mm	11.3 mm	53°	0.42	1.3	5.1 mm
MCW	MCR	DSL	DCAL	DDH	DDL	DDW	DHR
2.4 mm	0.47	7.9 mm	8.3 mm	0.5 mm	0.5 mm	0.5 mm	1
DBR	DA	DC	DB	DAVG	EHA	EHM	EHB
1	11	10.5	12	11.2	31μm	29 μm	17 μm
DMT	DDT	DLIT	DLAT	PCL	PCW	PCH	
2.2 mm	2.7 mm	1.3 mm	1.5 mm	2 mm	0.16 mm	6.8 mm	

Abbreviations: AL, apical length; CA, crown apical angle; CBL, crown basal length; CBR, crown base ratio; CBW, crown basal width; CH, crown height; CHR, crown height ratio; DA, distoapical denticle density; DAVG, average denticle density on distal carina of tooth crown; DB, distobasal denticle density; DBR, distal denticle base ratio; DC, distocentral denticle density; DCAL, distal carina length; DDH, distal denticle height; DDL, distal denticle length; DDT, dentine thickness distally; DDW, distal denticle width; DHR, distal denticle height ratio; DLAT, dentine thickness labially; DLIT, dentine thickness lingually; DMT, dentine thickness mesially; DSL, distal serrated carina Length; EHA, enamel thickness at the apical region of the crown; EHM, enamel thickness at the middle region of the crown; EHB, enamel thickness at the basal region of the crown; MCL, mid-crown length; MCR, mid-crown ratio; MCW, mid-crown width; PCH, pulp cavity height; PCL, pulp cavity length; PCW, pulp cavity width.