

Tooth replacement in a sauropod premaxilla from the Upper Cretaceous of Patagonia, Argentina

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Abstract. Anatomy and tooth replacement mechanism observed in a sauropod dinosaur left premaxilla from the Late Cretaceous of Patagonia are described. The specimen is assigned to Neosauropoda, and with doubts to Titanosauridae, due the presence of a stepped anterior margin, and long and cylindrical teeth with no denticles. The specimen presents a dental settlement pattern performed by intra-alveolar packages of four dental elements, one functional and three germinals, which compose a comb-like arrangement only recorded in diplodocid and titanosaurid sauropods.

Resumen. REEMPLAZO DENTAL EN UN PREMAXILAR DE SAURÓPODO DEL CRETÁCICO SUPERIOR DE PATAGONIA, ARGENTINA. Se describe la anatomía y el mecanismo de reemplazo dentario observado en un premaxilar izquierdo de un dinosaurio del Cretácico Superior de Patagonia. La presencia de un margen anterior escalonado, dientes largos y cilíndricos que no presentan denticulos en su corona, permiten la asignación del ejemplar a Neosauropoda, y con dudas a Titanosauridae. El ejemplar presenta un patrón de disposición de las piezas dentales conformando conjuntos intra-alveolares de cuatro elementos, uno funcional y tres germinales, configurando una estructura en peine sólo registrada en saurópodos diplodócidos y titanosáuridos.

Key words. Dinosauria. Sauropoda. Premaxilla. Tooth replacement.

Palabras clave. Dinosauria. Sauropoda. Premaxilar. Reemplazo dental.

Introduction

Cranial information of South American Cretaceous sauropods is scarce. Although skull remains have been described for several taxa including *Amargasaurus*, *Antarctosaurus* and *Saltasaurus*, rostral bones are virtually unknown or poorly described (see Bonaparte, 1996). The only rostral element so far described consists of an isolated premaxilla from the Upper Cretaceous of Argentina, assigned with doubts to Titanosaurinae (Powell, 1986). In this specimen (PVL-3670-12), Powell (1979) described the presence of one functional tooth and three replacement teeth in each of its four alveoli.

In contrast with other saurischians (theropods and prosauropods), some neosauropods developed a highly specialized dental morphology that could be related to distinct and specialized feeding behavior.

Among sauropods, two different dental morphologies have been recognized: the spoon-like teeth of camarasaurids, brachiosaurids and related forms;

and the peg-like teeth of diplodocids, dicraeosaurids and titanosaurs (Dodson, 1990). A more specific classification of sauropod dental morphology was subsequently proposed: peg-like teeth for diplodocids, spoon-like teeth for camarasaurids, cone-chisel-like teeth for *Brachiosaurus* and *Astrodon*, and chisel-like teeth for titanosaurs (Calvo, 1994; Salgado and Calvo, 1997). Nevertheless, dental replacement mechanisms in sauropod dinosaurs have never been described in detail.

A peculiar sauropod premaxilla (MPCA-79, Museo Provincial "Carlos Ameghino", Cipolletti, Río Negro Province, Argentina) (figure 1) from the Upper Cretaceous of Río Negro Province, Patagonia, Argentina, provides further information about the rostral anatomy of Cretaceous South America sauropods and in particular, their tooth replacement. **Abbreviations.** MB.R., Museum für Naturkunde der Humbolt-Universität, Berlin; MPCA, Museo Provincial Carlos Ameghino, Cipolletti, Río Negro, Argentina; PVL, Paleontología de Vertebrados, Instituto Lillo, Tucumán, Argentina.

Description

The surface of the specimen, a left premaxilla, is somewhat weathered, although the bone lacks only

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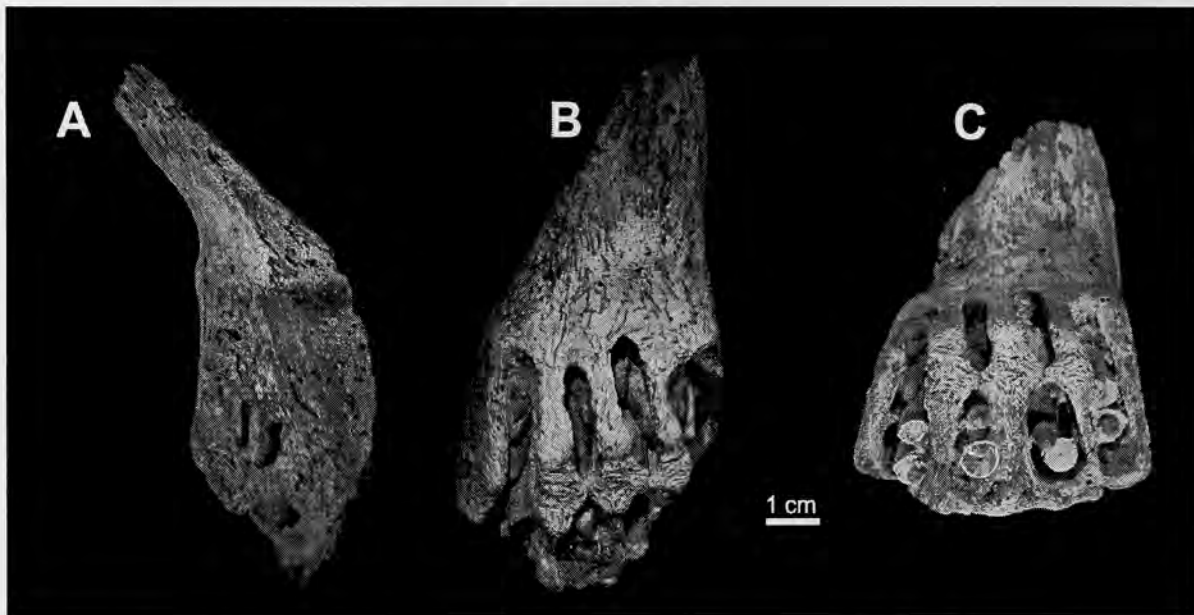


Figure 1. Premaxilla MPCA-79 in (A) medial, (B) lingual, and (C) oclusal views / Premaxilar MPCA-79 en vistas (A) medial, (B) lingual y (C) oclusal.

the dorsal end of the nasal process and the medial corner of the dentigerous margin (figures 1.A-B). It is a stout bone that is taller than wide, and which is thickest in its tooth-bearing portion (figure 1.C).

The premaxilla is convex anteriorly and concave posteriorly. Medially, it forms a flat and smooth surface for the interpremaxillary symphysis (figure 1.A). Laterally, the surface for its articulation with the maxilla is significantly smaller than that of the symphyseal area.

The nasal process is high and tapers dorsally (figure 1.B). In medial view, this process narrows toward its end (figure 1.A).

The premaxilla has four large alveoli, for which the labiolingual axis is roughly three times longer than the transverse axis (figures 1.C, 2.A). Alveoli 1 and 4 are slightly narrower and shorter than the other two; alveoli 2 and 3 appear to be the longest and widest, respectively (table 1).

The posterior side was likely pierced by one nutritional foramen for each alveolus. Nevertheless, weathering of the lingual alveolar wall resulted in large proximodistal openings that expose the alveolar cavities (figure 1.B).

Four teeth are housed in each alveolus (figures

2.B, 3). These are aligned in a row with the largest, more mature ones, located in the labialmost positions. These more mature teeth are broken in all alveoli, but most of the youngest, replacement teeth are complete and their tips are unworn. The teeth are subcircular in cross section (the diameter is 5.74 mm in the most mature one), and taper to a conical, pointed end. The labial and lingual sides of each tooth are convex; the labial convexity is more prominent. Distinct carinae separate labial from lingual sides (figure 2.B).

Systematic discussion

The presence of a stepped anterior margin, and long cylindrical teeth, and the absence of crown denticles support the identification of MPCA-79 as Neosauropoda (Wilson and Sereno, 1998). The cylindrical teeth of MPCA-79 suggest this specimen is either a diplodocoid or a titanosaurid. Because Calvo's (1994) discrimination between the teeth of these two groups is based on the morphology of their wear facets, which are not evident in MPCA-79, a more specific identification of the new premaxilla remains unresolved.

Table 1. Table of measurements. Measurements in mm, *: estimated / Tabla de medidas. Medidas en mm, *: estimado.

	A1	A2	A3	A4
Alveolar maximum length (labiolingual axis) / Largo alveolar máximo (eje labiolingual)	4.9	25.01*	22.6*	21.4*
Alveolar maximum width (transverse axis) / Ancho alveolar máximo (eje transversal)	7.3	8.9	9.5	8.8

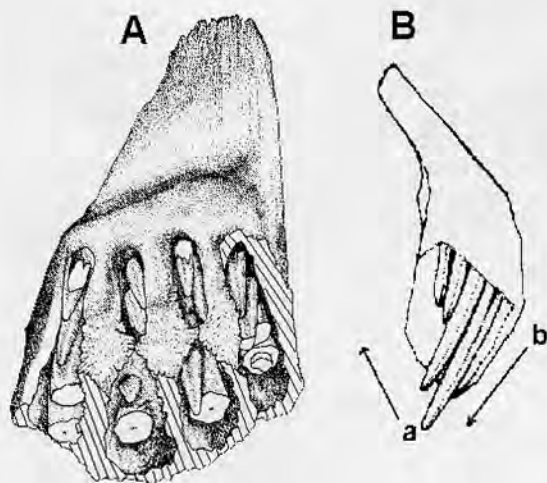


Figure 2. A, MPCA-79 in occlusal view / *en vista oclusal*; B, reconstruction of the tooth battery of alveolus 2 of MPCA-79 in lateral view depicting: a, replacement direction and b, growing direction of teeth / *reconstrucción de la batería dental del alvéolo 2 de MPCA-79 en vista lateral detallando: a, dirección del reemplazo y b, dirección de crecimiento del diente.*

It is important to notice, however, that the dental morphology and other anatomical characteristics of MPCA-79 compare well with those of an Upper Cretaceous premaxilla (PVL-3670-12) that Powell (1979, 1986) tentatively assigned to Titanosaurinae. It seems that the only differences between these specimens are the flatter lingual sides of the teeth of PVL-3670-12.



Figure 3. Longitudinal computer tomographic scan image of MPCA-79 at level of alveolus 2 / *Imagen tomográfica en sección longitudinal de MPCA-79 a nivel del alvéolo 2.*

Sauropod tooth replacement

Each alveolus of MPCA-79 contains a labialmost functional tooth and three other replacement teeth that are parallel and labiolingually aligned, and whose crowns show no indication of wear (figure 3). The most posterior dental element is the youngest in the replacement sequence.

The fact that the largest tooth corresponds to the labialmost position in the alveolus suggests backwards growth during tooth development, a condition typical of reptilian upper jaws (Osborn, 1977) (figure 2.B). In addition, the labiolingually decreasing size of the four teeth of an alveolus indicates an inward direction of replacement (figure 2.B). The comb-like pattern of the premaxillary teeth of MPCA-79 is different than those observed in most dinosaurs. This condition is shared by the sauropods *Diplodocus* (Marsh, 1896) and *Dicraeosaurus* (MB.R.2337) as well as the Upper Cretaceous titanosaurine premaxilla described by Powell (1979).

The morphology and pattern of the teeth of MPCA suggest that the method of tooth replacement of these sauropods differs greatly from those of other saurischians (Edmund, 1960). In MPCA and other sauropods with comb-like dentition, each functional tooth was replaced as the growing tooth put pressure on the lingual flange of the more mature tooth.

Once the functional tooth fell out, its place was occupied by the tooth behind it. Such a method of replacement appears to have been more comparable to other sauropodomorphs with no comb-like dentition such as prosauropods (Edmund, 1960). In contrast, theropod teeth were replaced as germ teeth resorbed the insides and bases of the roots of the old teeth (Edmund, 1960).

The fact that comb-like pattern of dentition is present in the maxilla of *Diplodocus* (Marsh, 1896; Edmund, 1960), suggests that such a condition may also characterize the maxilla of pencil-like toothed sauropods. In light of current hypothesis about phylogenetic relationships of sauropods (Salgado *et al.*, 1997; Wilson and Sereno, 1998), this comb-like pattern of dentition appears to have evolved at least twice in the evolution of this group: in the low premaxilla bearing diplodocids and in the high premaxilla bearing titanosaurs.

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