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TAIL FRACTURE PLANES OF AUTOTOMY IN GECKOS

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مستويات الكسر في الانفصال الذاتي لذيل البرص

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تم في هذا البحث دراسة التركيب المورفولوجي والهستولوجي لمستويات الكسر في الذيل لنوعين من الابراص التي تعيش في البيئة القطرية : سيرتودكتايلس سكابر ، بنوبس تيوبركيولاتس . يتكون مستوى الكسر من شق يمر خلال القرة الذيلية ، حاجز من نسيج ضام يقع في الطبقات الدهنية المحيطة بالفقرات ، والحاجز العضلي (مكون أيضاً من نسيج ضام) الذي يفصل بين القطع العضلية بعضها عن بعض . والشق الذي يمر خلال الفقرة يقع تقريباً في منتصفها . وتوجد مستويات الكسر هذه في جميع الفقرات الذيلية ماعدا الفقرات الخمس الأولى . ويمر الحبل الظهري من خلال جسم الفقرة ولكنه يستبدل بغضروف يسمى غضروف الحبل الظهري في موقع مستوى الكسر . ويوجد إلى جوار مستوى الكسر العديد من الروابط العضلية ، ويؤدي انقباض هذه العضلات إلى كسر الفقرة . تحمل جميع الفقرات الذيلية – ماعدا الفقرات الأربع الأولى – على الأسطح البطنية لأجسام الفقرات عظام ثيغرون وهي على شكل Y .

Key Words: Gecko, tail, autotomy planes, vertebrae.

ABSTRACT

The structure of the tail facture planes was morphologically and histologically studied in two species of geckoid lizards, living in Qatar, *Cyrtodactylus scaber* and *Bunopus tuberculatus.* The fracture plane is formed of a vertebral split, connective tissue septum in the fat zone surrounding the vertebrae and the myoseptum separting the adjacent muscle segments. The split passes through the middle of each vertebra. All the caudal vertebrae, except for the first five, possess such autotomy separations. The notochord which passes through the centrum is replaced by notobhordal cartilage or septum at the autotomy plane. The contraction of the numerous muscle attachments near the autotomy plane leads to the breaking of the vertebra. All the caudal vertebrae, except for the first four, have Y-shaped chevron bones.

INTRODUCTION

Many lacertilian reptiles possess the ability to cast off (autotomize) their tails. However, the tail regeneration which ensues has not been as extensively studied as has amphibian limb regeneration. The structure of the normal tail relative to its preformed autotomy planes has been described in several lizard species and in Sphenodon (Fraisse, 1885; Woodland, 1920; Byerly, 1925; Pratt, 1946; Hughes and New, 1959; Moffat and Bellairs, 1964; Werner, 1967; and Cox, 1969). The anatomy of the fracture planes in *Lacerta vivipara* has been described by Slotopolsky (1922), Pratt (1946) and Moffat and Bellairs (1964). The plane of fracture is made up of a split in the caudal vertebra, connective tissue in fat layer and the myoseptum. In *Anolis carolinensis* (Cox, 1969), the first autotomy plane occurs in caudal vertebra number eight or nine. The next eight or nine vertebrae exhibit true preformed vertebral autotomy separations, but distal to them no such seperation exist. In nearly all the caudal vertebrae in *Lacerta* (Parker and Haswell, 1974), the centrum is crossed by a narrow transverse unossified zone through which the vertebra readily breaks. In *Lacerta vivpara* (Moffat and Bellairs, 1964) each of the caudal vertebrae except for the first six or seven has an autotomy plane. In Scincus (Scincidae), the caudal autotomy begins at the 10th caudal vertebra (Mohammed, 1990). The amount of perivertebral fat in *Anolis carolinensis* is relatively small, and in each segement it is separated into an anterior and a posterior portion by muscle attachments and by a connective tissue septum which is continuous with myoseptum. In this species, Cox (1969) has stated that there is no cartilage, hyaline layer, mesenchyme-like tissue, or connective tissue forming the fracture planes, as has been reported for other lizards (Woodland, 1920; Quattrini, 1954; Moffat and Bellairs, 1964; Werner, 1967). In late embryos and new-born lizards of *Lacerta vivipara* (Maffat and Bellairs, 1964), the fracture planes are represented by small splits in the perichondral bone of the centra with connective tissue extending into them.

MATERIAL AND METHODS

Individuals of adult geckos, without previously regenerated tails, were collected at various places in Doha, Qatar. The study comprised two species, *Cyrtodactylus scaber* and *Bunopus tuberculatus*. The tail length in *Cyrtodactylus* ranged from 4.5 to 7 cm and in *Bunopus* from 3.5 to 6 cm. The animals were anaesthesized with ether, and then the tail with the most posterior part of the trunk was cut from the body. The tails of each species were divided into three groups: The tails of the first group were dissected using binocular microscope. The second group was fixed in FAA (formalin, acetic acid and 70% alcohol) and then subjected to macroscopic examination of the caudal vertebrae after preparing transparancies using toluidine blue-Alizarin red-S double staining technique (modified from Dingerkus and Uhler, 1977, and Kimmel and Trammel, 1981) for staining cartilage blue and bone red. The tails of the third groups were fixed in Bouin's fluid for 24 hours, decalcified in 2% acid alcohold, and then followed by dehydration and infiltation with wax. Cross and logitudinal sections of 8 µm thick were cut in an air-conditioned room at 22° C. The sections were stained with borax carmine and counterstained with modified Azan. Ten to twelve tails from each concerned species were used in the study.

RESULTS

Cyrtodactylus scaber:

The scales covering the tail are aligned in such a way that they form rings around the tail and give it a segmented appearance. Each ring is occupied by about 3-4 rows of scales, the posterior row shows posterior sharp projections with tapering borders. The tail has a considerable number of vertebrae, the first five of which have long centra with long neural spines and long slender transverse processes (Fig. 1). Posterior to the fifth vertebra, the caudal vertebrae become gradually musch smaller and the various processes reduced in prominence. The vertebrae from number six to number fifteen have greatly reduced, or sometimes lack transverse processes. At the end of the tail, behind the 15th vertebra, the whole vertebra is represented merely by the centrum without any processes so that the vertebrae are represented by a rod-like bone. Attached to the ventral faces of the centra of the caudal vertebrae from number five to fifteen are Y-shaped chevron bones, the upper limbs of the Y articulating with the vertebra, while the lower limb extends downwards and backwards.

Each of the caudal vertebrae, except for the first five, has a split passing through it about halfway along its length or a little further forward (Fig. 2). The connective tissue around the margins of the split is continuous with a septum which passes outwards through the large zone of fatty tissue surrounding the caudal vertebrae, and joins the transverse myoseptum between adjacent muscle segements (Fig. 3). The vertebral split, the connective tissue septum in the fat zone and the myoseptum together make up a single plane of fracture, which traverses most of the tail tissues. It does not pass across the spinal canal (see Figs. 2, 3 & 4), however, and contains a gap in the ventral mid-line which transmits the caudal artery and vein. The centrum is about the same size throughout the vertebra. It is divided transversely by two layers of bone giving a complete autotomy separation planes (see Figs. 2, 3 & 4). The centrum of each autotomizing vertebra is amphicoelous (its anterior and posterior sides are concave). The notochord passes through the centrum, it is formed of vacuolated cells, and is chondrified at the autotomy plane to form the notochodral cartilage or septum (see Figs. 2 & 6).

Between each two successive caudal vertebrae there is a massive intervertebral cartilage (Figs. 1, 2, 5, 6 & 7). Numerous muscle attachments are to be found near the autotomy plane. Apparently, it is the contraction of these muscles which leads to a breaking of the vertebra. In a cross section of a caudal vertebra, the myotomes, formed of striated muscle fibres, are separated by horizontal septum of connective tissue into epaxial or dorsal and hypaxial or ventral muscles (see Fig. 3). The myosepta separting successive myotomes are folded so that the muscles in each quadrant of the tail assume a shape roughly tracing a "W". Each extension of the "W" is roughly cone-shaped. These appear, in corss section, as muscle bundles (Figs. 3 & 4). From the dorsal side of the centrum arise the neural arches on both sides, directing apically and meating together where the neural spine is present (Figs. 5 & 6).

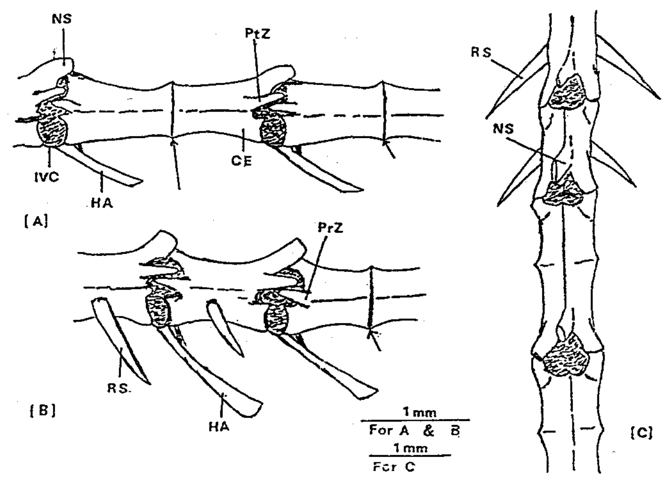

Fig. 1: Diagrammatic illustration of some caudal vertebrae of *Cyrtodactylus*. (A) Lateral view of the caudal vertebra number eight which has complete autotomy separation (arrows). (B) Lateral view of the caudal vertebra number five which has no autotomy separation. (C) Dorsal view of the caudal vertebrae numbers five (without autotomy separation) and six (with autotomy separation). The vertebrae of *Cyrtodactylus* as well as of *Bunopus* are amphicoelous and the shaded areas represent the intervertebral cartilage (IVC). CE, centrum; HA, haemal arch or chevron bones; NS, neural spine; P_rZ. Prezygapophysis; P_tZ, Postzygapophysis; RS, Transverse process.

Bunopus tuberculatus:

The tail is covered by sclaes with tapering projecting protrusions but not as sharply prominent as in *Cyrtodactylus*. The scales are also arranged in regualr transverse rows of rings around the tail, each ring has 3-4 rows of scales. The skeletal configuration of the ventebrae (amphicoelous) and anatomy, histology and positions of the fracture planes are nearly similar to those of *Cyrtodactylus*. The chevron bones are also attached to the vertebrae from number five to fifteen. Posterior to the last visible vertebra extends a rod-like bone representing the centra, without any recognizable articulation surfaces or processes.

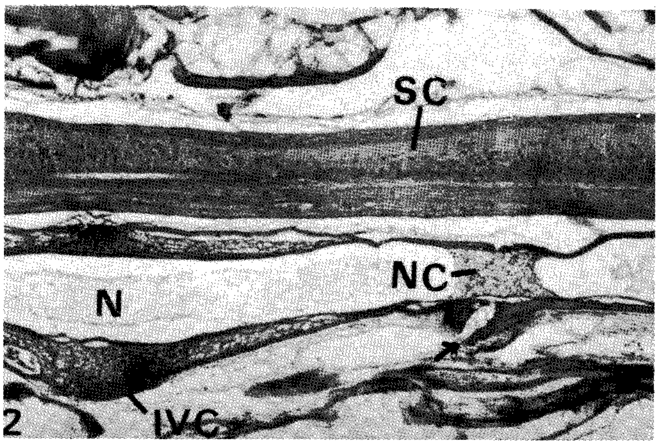

Fig. 2: Longitudinal section through the tail of the adult *Cyrtodactylus*. The arrows indicates the fraction plane in the centrum of the vertebra; the plane does not pass through the spinal cord. IVC, intervertebral cartilage; N, notochod; NC, notochordal cartilage; SC, spinal cord. X 185.

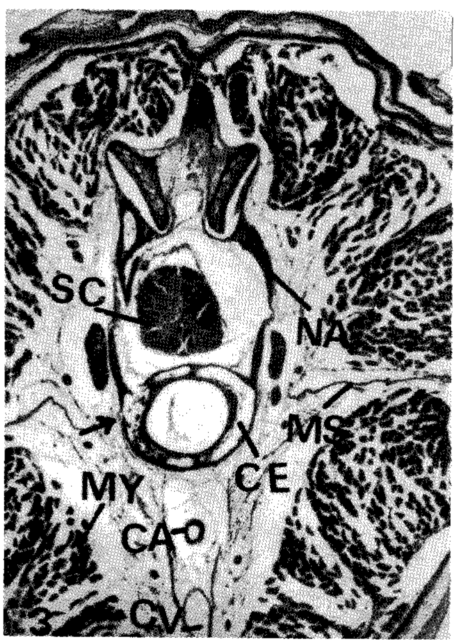

Fig. 3: Cross-section through the tail of the adult gecko, *Cyrtodactylus*. The arrows indicates the fraction plane in the centrum of the vertebra. CA, Caudal artery; CE, Centrum; CV, Caudal vein; MY, Myotomes; MS, Myoseptum; NA, neural arch, SC, Spinal cord. X 185.

DISCUSSION

In geckos, as in many lacertilian reptiles, the tail possesses a series of fracture planes through which breackage can occur with the minimum of damage. As reported by many authors, this breackage is due to autotomy which involves active contraction of the tail muscles.

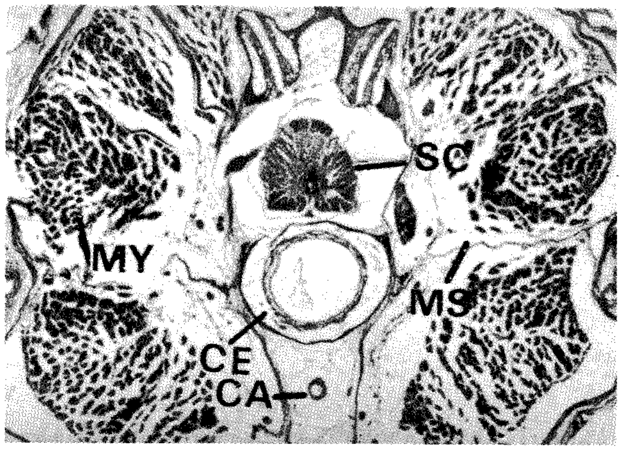

Fig. 4: Cross section through the tail of the adult gecko, *Bunopus*. CA, Caudal artery; CE, Centrum; MY, Myotomes; MS, Myoseptum; SC, Spinal cord. X 185.

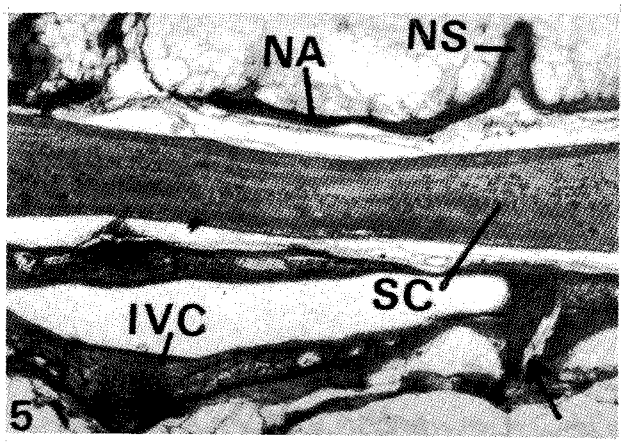

Fig. 5: Longitudinal section through the tail of adult gecko, *Bunopus*. The arrow indicates the separation plane in the centrum. IVC. Intervertebral cartilage; NA, Neural arch; NS, Neural spine; SC, Spinal cord. X 185.

The caudal vertebrae have basic structure and configuration among the different lacertilians, but some differences were observed in the structure of the autotomy planes, the positions of the autotomy splits along the vertebrae, the transverse processes and chevron bones. The present observation demonstrated that the centrum of the caudal vertebra in *Cyrtodactylus* and *Bunopus* is amphicoelous, supporting the earlier results of Woodland (1920) and Werner (1967) on the geckonid lizard, *Hemidactylus*. In *Lacerta vivipara* (Pratt, 1946; Quattrini, 1954; Moffat and Bellairs, 1964) and in *Anolis carolinensis* (Cox, 1969), the caudal vetebrae are procoelous. The centrum in *Cyrtodactylus* or in *Bunopus* is formed of two layers of bones, as distinguished in cross sections. The splits are passing through both layers and therefore, the autotomy separation plane is complete. The notochord passes through the centrum but is replaced by the notochordal cartilage at the autotomy septum. The same results were earlier obtained by Woodland (1920) and Werner (1967) who demonstrated the persistence of the notochord in the adult *Hemidactylus*, and its transformation into cartilage at the autotomy plane.

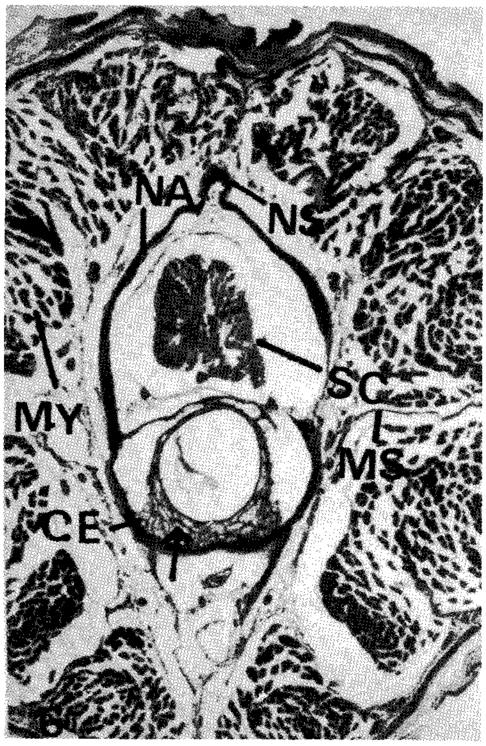

Fig. 6: Cross section through the tail of the adult gecko, *Cyrtodectylus*. The arrow indiactes the intervertebral cartilage close to the autotomy plane (see Fig. 2). CE, Centrum; MY, Myotomes; MS, Myoseptum; NA, Neural arch; NS, Neural spine; SC, Spinal cord. X 185.

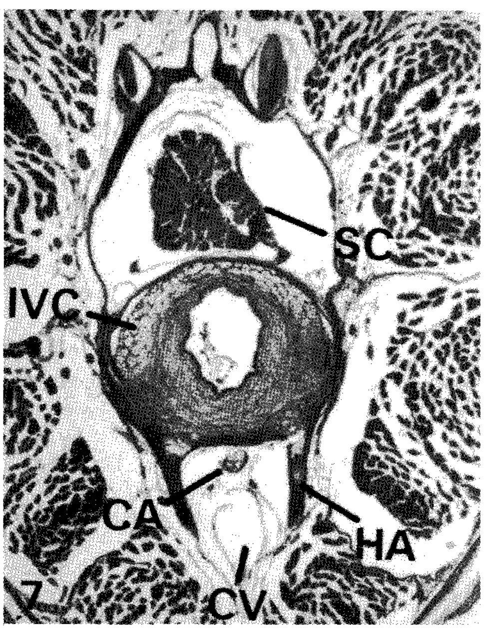

Fig. 7: Cross section through the tail of the adult gecko, *Bunopus*. CA, caudal artery; CV, Caudal vein; HA, Haemal arch; IVC, Intervertebral cartilage; SC, Spinal cord. X 185.

In *Lacerta vivipara* (Pratt, 1946; Quattrini, 1954) and in *Lygosoma laterale* and *Anolis carolinensis* (Cox, 1969), the notochord is absent and the centrum is filled with hemopoetic tissue. In Anolis, the centrum is reduced in size and consists of a single layer of hone with no well defined seperation at the autotomy plane. This may be due to the fact that the bone is slightly thickened at the autotomy plane forming a delta-shaped ridge around the lateral and dorsal aspects of the vertebra. The present observations have shown that the autotomy separations in *Cyrtodactylus* as well as in *Bunopus* are found on all caudal vertebrae except for the first five, also the bone rod at the tail end possesses no such separations. The autotomy separation plane lies on the middle of the caudal vertebra or slightly shifted to its anterior region. In *Anolis carolinensis* (Cox, 1969), the first autotomy plane occurs in caudal vertebra number eight or nine. The next eight or nine vertebrae exhibit true preformed vertebral autotomy separations, but distal to them no such separations exist. The preformed autotomy break planes of the epidermis and vertebral column, in *Anolis,* are intravertebral about one-fourth of the distance caudal to the anterior aspect of a given vertebra. The autotomy planes in *Lacerta vivipara* (Moffat and Bellairs, 1964) are to be found on the caudal vertebrae from number seven or eight. However, it was recently observed, in *Scincus* (Mohammed, 1990) that the first autotomy separation occurs in caudal vertebra number ten.

The present investigations demonstrated that the fracture plane is formed of the vertebral split and connective tissue elements represented by the connective tissue septum in the large fatty layer surrounding the vertbrae, and the myoseptum separating the myotomes from each other. The fracture planes in vertebral centra appear to arise as the result of the invasion of the bone and notochodal caitilage by vascular connective tissue. These results are in accordance with the earlier observations of Moffat and Bellairs (1964). The structure of the fracture planes in geckos, as has been established in the present study, seems to be different from that in the lizard, *Anolis carolinensis* (Cox, 1969) in which there is no contribution of connective tissue to the formation of the autotomy planes. Numerous muscle attachements were found entering the bone near the autotomy planes. In the present work such muscles were also observed near the plane of fracture but without entering the bone.

In *Cyrtodactylus* and *Bunopus,* the first five caudal vertebrae possess slender transverse processes, however, posterior to the fifth vertebra, these processes were greatly reduced or even nearly absent. The chevron bones are carried on the centre of the caudal vertebrae from number five to fifteen and are directed backwards. In *Scincus* (Mohammed, 1990), the 17 caudal vertebrae bear well developed transverse processes. The chevron bones undergo a slight forward migration and retain only their anterior articulation under the centra of the preceding vertebrae.

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