CRANIAL LIGAMENTS
INTRODUCTION

Ligaments may be defined as a flexible dense white fibrous connective tissue joining and sometimes encapsulating the articular surfaces of bones. On the other hand, a tendon, as defined by Eaton (1966), is a thick cord or band continuous with the epimysium and serving to attach the muscle to a part which it may not reach by itself. Skeletal muscle is also fastened to bony elements by a flat tendon, termed aponeurosis.

Dobben (1937), Sarkar (1960), Kayser (1962), Alexander (1967a,b), Dutta (1968), Liem (1970) and Bandyopadhyay (1980) mentioned some important ligaments as a part of the study of myology of fishes. Hasselt (1979a) and Lauder (1980) stressed the functional importance of ligaments.

Besides ligaments there is another kind of tape like structure which serves to bind skeletal parts and are known as connective tissue bands.

MATERIAL AND METHODS

Cranial ligaments were studied along with the cranial bones and muscles, in all the four species, *Parambassis thomassii* (Day), *Ambassis commersoni* Cuvier, *Chanda nama* Hamilton-Buchanan and *Pseudambassis ranga* (Hamilton-Buchanan), representing four genera of the Indian ambassids.

After dissection, each cranial ligament was traced out and its origin, insertion and disposition were noted under stereoscopic binocular microscope. Drawings were made either free hand or under camera lucida.

The classification of the ligaments follows the system of Liem (1970) broadly. Nomenclature is mainly based on the nature of disposition, i.e., the points of attachments.
OBSERVATION

A. Ligaments of the neurocranium

1. Prefrontal - 1st infraorbital (lachrymal) ligament (PF-LA.LIG)

In *P. thomassi* (Fig. 182) a small but strong ligament holds prefrontal and lachrymal together.

In *A. commersoni* (Fig. 183) the structure and disposition of the ligament is same as that of *P. thomassi*.

In *C. nama* (Fig. 184) and *P. ranga* it is short, flat and thin.

B. Ligament between neurocranium and jaws

1. Maxilla-nasal ligament (MX.-N.LIG)

In *P. thomassi* (Fig. 182) and *A. commersoni* (Fig. 183) it is thick and short which originates from the head of the maxilla and inserts to the tip of the nasal.

In *C. nama* (Fig. 184) and *P. ranga* it is moderately elongated and flat.

2. Maxilla-ethmoid ligament (MX.-E.LIG)

In *P. thomassi* (Fig. 182) it is thin and elongated.

In *A. commersoni* (Fig. 183) it is very elongated, thin and narrow, joining the head of maxilla and tip of ethmoid.

In *C. nama* (Fig. 184) and *P. ranga* it is similar to that of *P. thomassi*.

3. Maxilla-rostral ligament (MX.-R.LIG)

In *P. thomassi* (Fig. 182) this ligament is attached between a point on the head of maxilla and lateromedial point of ventral surface
of rostral. This thick ligament lies adjacent to PMX.-MX ligament.

In *A. commersoni* (Fig. 183) it extends from the head of the maxilla to the posteriormost tip of the ventral side of the rostral cartilage.

In *C. nama* (Fig. 184) and in *P. ranga* it is of moderate length and thickness.

4. Maxilla - 1st infraorbital (lachrymal) ligament (MX.-LA.LIG)

It is short, thick and well developed in all the ambassids (Figs. 182, 183 and 184). It connects the maxilla with the first infraorbital.

C. Ligaments between neurocranium and pectoral girdle

1. Cleithrum-basioccipital ligament (Baudelot's ligament) (CL.-BOC.LIG)

In *P. thomassi* and *A. commersoni, C. nama* and *P. ranga* (Fig. 188), it is elongated, strong, thick and runs from the side of basioccipital to the medial aspect of the cleithrum.

D. Ligaments of the jaw apparatus

1. Maxilla-mandibular ligament (MX.-MND.LIG)

In *P. thomassi* (Fig. 182) it is a thick, elongated ligament connecting the head of maxilla and the articular. Adductor maxillaris is directly attached on this ligament.

In *A. commersoni* (Fig. 183) this ligament is similar to that of the former.

In *C. nama* (Fig. 184) and *P. ranga*, the disposition of the ligament is same as that of *P. thomassi*.
2. Premaxilla-maxilla ligament (PMX.-MX.LIG)

This ligament is very well developed in all ambassids. It is short and very thick.

In *P. thomassi* (Fig.182) it runs from the head of the maxilla to the middle point of joint between two premaxillae.

In *A. commersoni* (Fig.183) it is similar to that of the former but it is smaller.

In *C. nama* (Fig.184) and *P. ranga* it is thick and rounded.

E. Ligaments between opercular apparatus and the jaws

1. Mandible-interopercular ligament (Figs.182,183,184; MND.-IOP.LIG)

It is short, thick and straight but strong ligament which connects the lower posterior surface of the retroarticular (mandible) with the anterior part of the interopercular. It remains partly covered by the lower part of preopercular. It is more or less similar in all the four genera of Indian ambassids.

2. Mandible-preopercular ligament (Figs.182,183,184; MND.-POP.LIG)

It is very short, thick and stout which connects the posterior part of the mandible with lower anterior part of the preopercular. It is oblique and remains in folded condition. It is similar in all the ambassids studied.

F. Ligaments of the opercular apparatus

1. Opercular-preopercular ligament (Figs.182,183,184; OP.-POP.LIG)

It is a thin ligament connecting the anterior surface of opercular with anteroventral surface of the preopercular and is comparatively long in *C. nama* (Fig.184). This ligament is straight and partly covered by preopercular. It is more or less similar in all the ambassids studied.
G. Ligaments between suspensory apparatus and jaws

1. Palatine-premaxilla ligament (P.-PMX,LIG)

In *P. thomassi* (Figs.182,187) it is very well developed strong, elongated and quite thick. It extends from the premaxilla to the anterior part of the palatine.

In *A. commersoni* (Fig.183) it is thin and elongated joining at a point a little below the tip of palatine and middle of articular process of premaxilla.

In *C. nama* (Fig.184) and *P. ranga* it is moderately thick and elongated.

2. Palatine-maxilla ligament (P.-MX,LIG)

In *P. thomassi* (Fig.182) and *A. commersoni* (Fig.183) it is elongated, thin, strong, running from the anterior tip of the broad blade of the palatine to the ventral side of the head of the maxilla.

In *C. nama* (Fig.184) and *P. ranga*, it is moderately long, and relatively thick.

3. Mandible-quadrate ligament (Figs.182,183,184; MND.-Q,LIG)

In *P. thomassi*, *A. commersoni*, *C. nama* and *P. ranga* it is very short but stout which connects the lower posterior angle of the mandible with the lower condylar part of the quadrate. It remains hidden in between the quadrate and mandible.

H. Ligament between suspensory apparatus and neurocranium

1. Prevomer-Palatine ligament (Figs.182,183,184; PV.-P,LIG)

In both *P. thomassi* and *A. commersoni*, *C. nama* and *P. ranga* palatine is connected to the prevomer through this strong and elongated ligament.
I. Ligaments between opercular elements and neurocranium

1. Opercular-Pterotic ligament (OP.-PT.LIG)

It is moderately developed in P. thomassi (Fig.182) and A. commersoni (Fig.183). It is poorly developed in C. nama (Fig.184) and P. ranga.

2. Preopercular-pterotic ligament (POP.-PT.LIG)

This ligament is moderately developed in P. thomassi (Fig.182) and A. commersoni (Fig.183). In C. nama (Fig.184) and P. ranga it is short, thin, broad and flat.

J. Ligaments between hyoid apparatus and suspensorium

Interhyal-hyomandibular ligament (Fig.185; IH.-HM.LIG)

It is visible after removing the opercular. In P. thomassi, A. commersoni, C. nama, P. ranga it is short, thin, broad and flat and runs from interhyal to inner aspect of the symplectic process of hyomandibular, very close to its meeting point with symplectic.

K. Ligaments between the opercular and hyoid apparatus

1. Epiphyal-interopercular ligament (Fig.185; EH.-IOP.LIG)

In P. thomassi, A. commersoni, C. nama and P. ranga it is a short, thick and strong ligament connecting the interopercular and epiphyal. It remains attached with the entire dorsolateral surface of the epiphyal and laterally it is attached behind the medial surface of the interopercular.

L. Ligaments of hyoid apparatus

1. Urohyal-hypohyal ligament (Fig.186; UH.-HH.LIG)

This pair of straight, strong, thick and cylindrical ligaments
lie parallel to each other connecting the lower hypohyals with the anteroventral part of the urohyal. It is similar in all the studied ambassids.

2. Interhyal-epihyal ligament (Fig.185; IH.-EH.LIG)

It is short, connecting the proximal end of interhyal with the distal end of the epihyal and is similar in all the ambassids studied.

3. Basihyal-hypohyal ligament (Fig.185; BH.-HH.LIG)

It is a short and thick ligament extending from medial part of the ventral surface of the basihyal to the corner of the hypohyal. In all ambassids studied, it is similar in disposition.

Connective tissue bands

There are a number of connective tissue plates or bands in the cranium, performing the identical function as ligaments, i.e., binding the bones rigidly, thus limiting the mobility to a desired degree. Connective tissue plates observed in the ambassids are described below. It is interesting to note that connective tissue plates do not display any variation at the generic level.

(1) The two ascending processes of the neighbouring premaxillae lie side by side and are attached to each other by the connective tissue plates.

(2) A greatly extended and thick tissue band connects the upper and lower jaws, it runs along the maxilla-mandibular ligament from the coronoid process of dentary to the maxilla.

(3) A broad and thin strap of connective tissue plate is present in between the interopercular and the opercular. It is visible only when the inner aspect of the opercular apparatus is examined.

(4) Between the dorsolateral part of the opercular and the dorsal part of the cleithrum is present a moderately developed connective tissue band.
(5) Connecting the inner side of preopercular and opercular a connective tissue band is observed.

(6) In the medial plane, below the neurocranium, a broad, long connective tissue plate is present. It covers the total length of the m. adductor arcus palatini and remains attached anteriorly with the lateral ethmoid and anterior part of palatopterygoid bar and runs along the basicranium and terminates into the lower aspect of hyomandibular and metapterygoid and in some cases into quadrate. This is a thick and tough tissue band.

(7) In ambassids, a connective tissue plate is present between the interhyal and inner aspect of the symplectic process of hyomandibular.

(8) In the branchial region quite a good number of connective tissue plates are discernible. The basibranchials, hypobranchials, ceratobranchials, epibranchials and pharyngobranchials, are bounded by such plates.
DISCUSSION

Extreme importance of the thorough study of the joints and ligaments in functional analysis has been stressed by Liem (1970). In addition to the function of fastening the various loose skull elements, the ligaments also restrict the movement of many a versatile bone of the cranium, thereby achieving the desired action. Ligaments determine the direction, degree and speed of motions between two or more bony elements as well as often causes a long chain of motions in a series (Liem, 1970). In spite of all these important roles in the kinetics of the cranial bones, the available literature depicts a little information about the real nature of ligaments in various groups of teleostean fishes.

Though workers like Dobben (1937), Kayser (1962), Alexander (1967), Yazdani (1969) and Winterbottom (1974a) observed some of the cranial ligaments in different groups of teleosts, a really in depth study has been made by Osse (1969), Liem (1970), Hasselt (1979a) and Lauder (1980).

In the family Ambassidae, the ethmoid-nasal ligament is absent. Prefrontal-lachrymal ligament is present which helps in adhesion and stability of the more mobile lachrymal.

Palatine-premaxilla ligament helps in holding the premaxilla on the ridge and limits its forward movement. Protrusion and so the screw movement is halted by tension in the palatine-premaxilla ligament. These have little or no effect on the swinging movement.

Premaxilla-maxilla ligament helps in holding the premaxilla and maxilla together.

Maxilla-ethmoid ligament helps in restraining the movement of the lateral face of the head of the maxilla. Maxilla-rostral ligament prevents the dorsal movement of premaxilla. The presence of maxilla-lachrymal ligament ensures cohesive strength in bite.
Due to absence of a direct articulation between the upper and lower jaws and thus, to maintain a cohesion between the jaws and to affect relatively antagonistic rotation, very strong and broad ligaments often quite complex in form, link the maxilla and the mandible both at their anterior and the posterior aspects, irrespective of the degree of protrusion. The finding corroborates the view of Winterbottom (1974a) who held that the freeing of the maxilla from the cheek and a more mobile premaxilla results in a consolidation of the maxilla-mandibular ligament.

Ligaments between opercular apparatus and the jaws, and the opercular apparatus ligaments either help in movement or as a binding element.

The universal occurrence of the strong urohyal-hypohyal ligament is the indicative of its functional importance. It is most suitably oriented so as to effect the downward and outward rotation of the hyoid.

The absence of many of the ligaments in the ambassid species are compensated by connective tissue. The various ligaments along-with connective tissue are asserting strength and sometimes restraining the versatility.

At the moment it can only be said that a thorough exploration of these curious components of the fish cranium is needed to assess their potentiality and significance in functional anatomy of the cranium.
EXPLANATION OF FIGURES (182-188) AND ABBREVIATIONS USED

Lateral view of cranium showing different cranial ligaments

Fig. 182 : *P. thomassi*
Fig. 183 : *A. commersoni*
Fig. 184 : *C. nama*
Fig. 185 : Hyoid arch-ligaments of ambassid
Fig. 186 : Urohyal showing urohyal-hypohyal ligament
Fig. 187 : Dorsal view of cranium showing cross-ligaments
Fig. 188 : Ventral view of the neurocranium showing cleithrum-basioccipital ligament

ABBREVIATIONS :

- BH-HH.LIG - basihyal-hypohyal ligament
- CL-BOC.LIG - cleithrum-basioccipital ligament
- EH-IOP.LIG - epiphyal-interopercular ligament
- IH-EH.LIG - interhyal-epiphyal ligament
- IH-HM.LIG - interhyal-hyomandibular ligament
- MND-IOP.LIG - mandible-interopercular ligament
- MND-POP.LIG - mandible-preopercular ligament
- MND-Q.LIG - mandible-quadrate ligament
- MX-E.LIG - maxilla-ethmoid ligament
- MX-LA.LIG - maxilla-lachrymal ligament
- MX-MND.LIG - maxilla-mandibular ligament
- MX-N.LIG - maxilla-nasal ligament
- MX-R.LIG - maxilla-rostral ligament
- OP-POP.LIG - opercular-preopercular ligament
- OP-PT.LIG - opercular-pterotic ligament
- PF-LA.LIG - prefrontal-lachrymal ligament
- P-MX.LIG - palatine-maxilla ligament
- P-PMX.LIG - palatine-premaxilla ligament
- PMX-MX.LIG - premaxilla-maxilla ligament
- POP-PT.LIG - preopercular-pterotic ligament
- PV-P.LIG - prevomer-palatine ligament
- UH-HH.LIG - urohyal-hypohyal ligament