

FUNCTIONAL ANATOMY OF THE ALAR LIGAMENTS IN AXIAL ROTATION

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Introduction: The anatomy of the atlantoaxial joint shows that it is comprised of two convex surfaces resting upon each other.(Fig 1). In rotation this will allow vertical translation with descent of the skull.

The range of motion in axial rotation between the atlas and axis is the greatest between any two vertebrae in the entire spine (1) typically 40° to each side (2,3). The rotation is facilitated by the alar ligaments which are short (Fig2)(4) but also provide definitive restraint for head rotation at the extremes of movement.

The changes of insertional angle and elongation of representative fibres of the ligament may be determined graphically through multiplanar reconstruction in axial atlanto-axial rotation.(Fig 3).

We hypothesised that this vertical translation is essential to allow a gradual transition from the neutral to the elastic zone and that a complex interaction of axial rotation and vertical translation via the biconvex articular surfaces is required to achieve this.

Methods: Bilateral alar ligaments including the bony entheses were removed from six adult cadavers aged 65-89 years within 48 hours of death. Dimensions of three representative fibres of the alar ligaments were measured. Multiplanar reconstruction of atlanto-axial rotation was done in the transverse and frontal planes for the neutral position and for rotation to 30° and 40° without vertical translation to assess fibre elongation during axial rotation and to determine the change in the angle of insertion at the odontoid and condylar entheses. This was repeated with a 1mm descending translation of the occipital condyles at 30° and 3mm descending translation at 40° rotation.

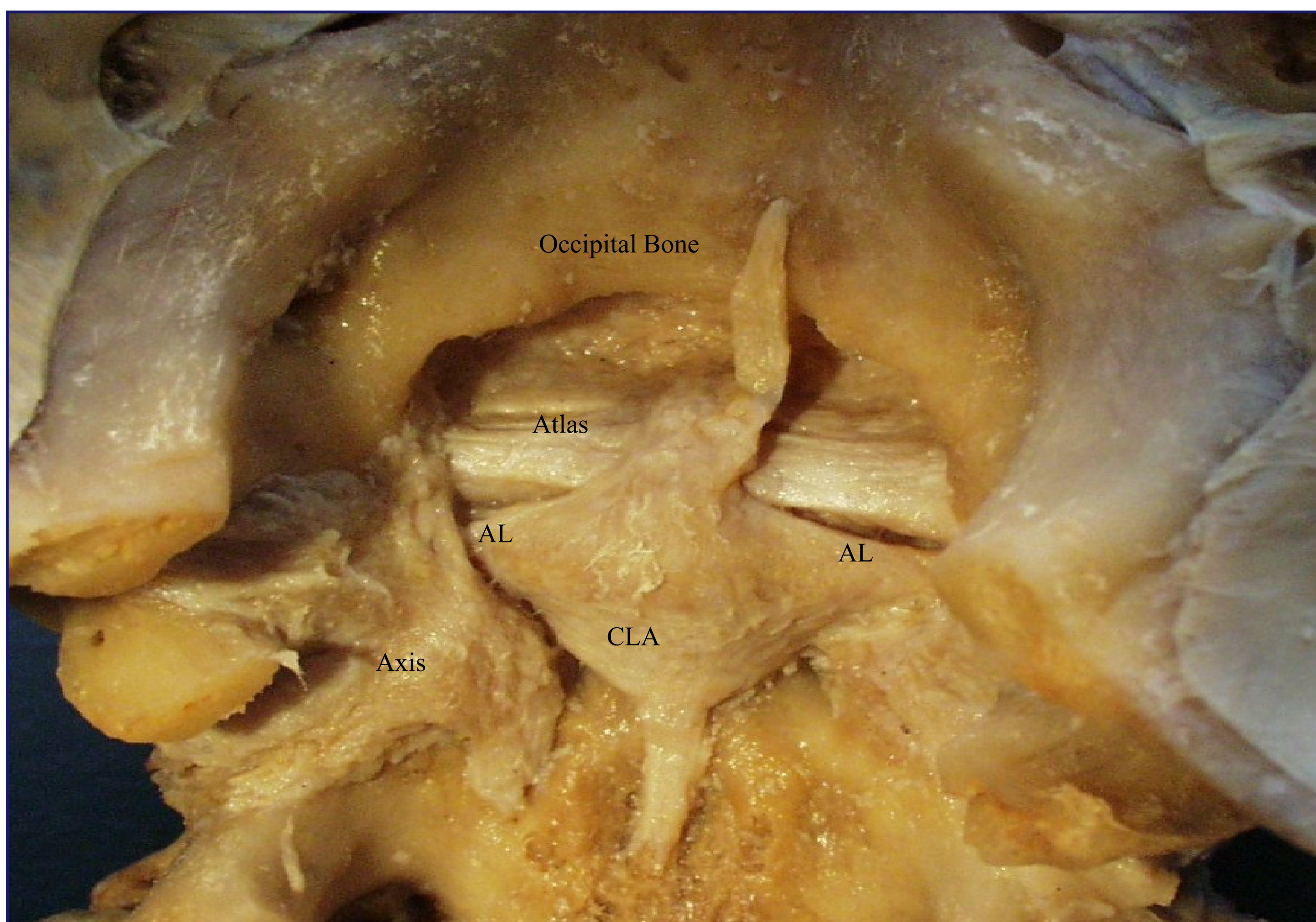


Figure 2 Macroscopic view of the deep ligaments of the craniocervical junction after removal of the dorsal elements of the spinal canal. Viewed in neutral (0°) position. **AL** Alar Ligament. **CLA** Cruciform Ligament of the Atlas.

Discussion: The maximal stretch that can be applied to a ligament prior to mechanical failure is 6-8% (5). There is a potential of 3% elongation for ligaments with fibres crossing at 30° when straightened by tensing (5). Even when the potential of both of these factors are combined, the theoretically required elongation of the almost exclusively collagenous alar ligaments(2,4) cannot be reached.

These factors may suffice for a solitary elongation within the elastic (axial rotation between 30° and 40°), which was calculated as 5.8 – 7.1%. However, this would exclude any loading of the alar ligaments throughout the neutral zone (axial rotation between 0° and 30°) necessitating the fibrocartilagenous enthesis to abruptly withstand the force of rotation within 10° (rotation from 30° to 40°). As the enthesis appears to be the site most prone to failure(2) and is probably susceptible to increased loading rate(6) but such abrupt loading seems disadvantageous.

A factor which is largely disregarded in its influence on alar fibre tension is the vertical translatory motion along the longitudinal axis of the odontoid process facilitated by the biconvexity of the atlanto-axial articular surfaces(1,7,8). This range was determined as 0.5 to 1.0 mm at 20° and 2 mm at 35° rotation by Putz and Pomaroli (7). Allowing a descending translation motion of 3 mm at 40° rotation reduces the required fibre elongation of the posterior fibres of the alar ligament to a much more realistic 7.8%.

Conclusions: This theoretical model reveals that the bi-convex shape of the atlanto-axial joints and the oblique orientation of the alar ligaments function as a finely tuned system in allowing a large range of motion, but facilitating gradual restriction of motion at the extremes of rotation. This provides a baseline for further research with functional MRI which will be useful for rheumatoid and post traumatic craniocervical disorders.

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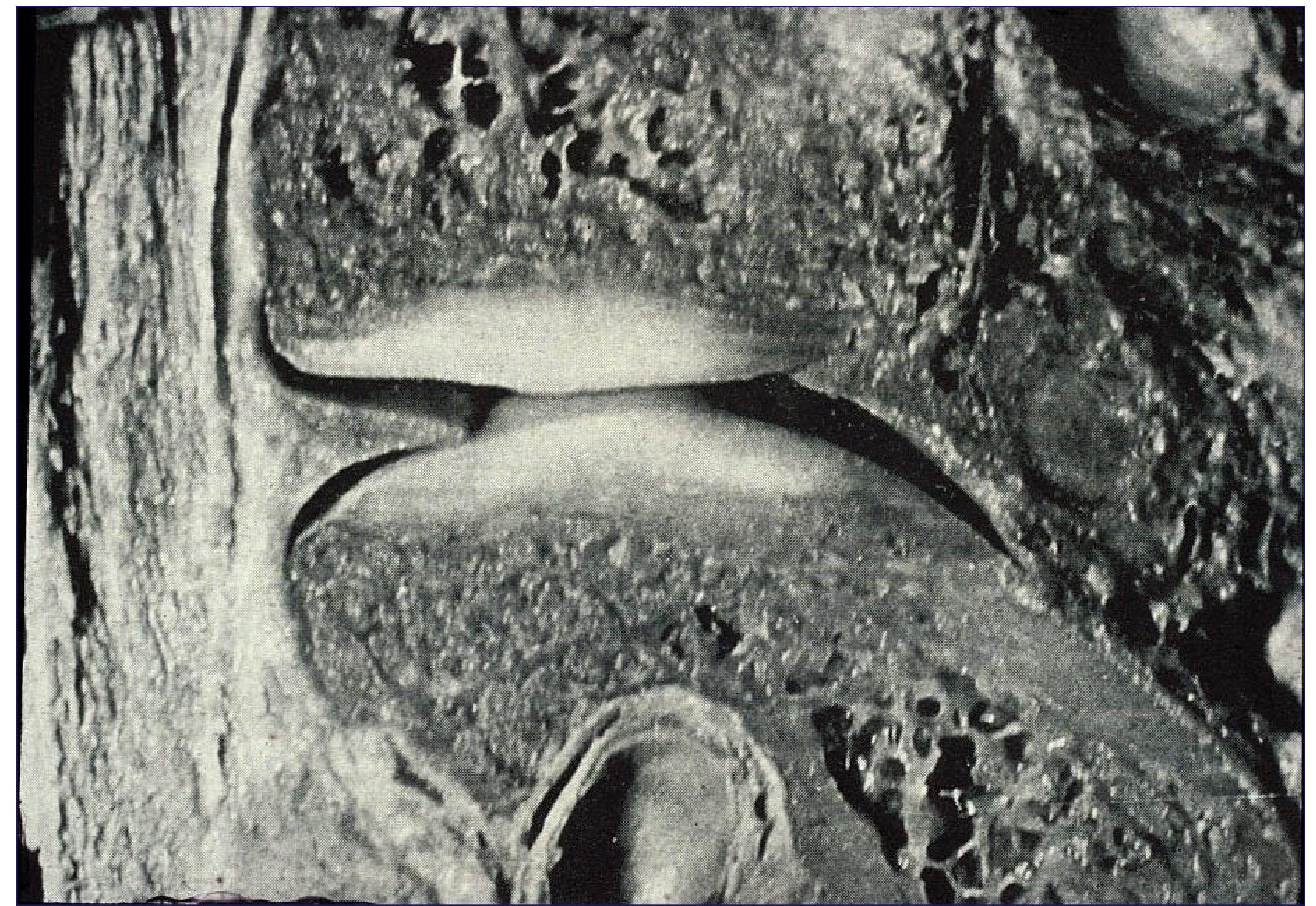


Fig 1 A Transverse section through the atlanto-axial joint showing the biconvex joint surfaces

Results: The mean diameter of the odontoid process in the sagittal plane was 10.6 mm (SD 1.1). The longest fibre length was measured from the posterior border of the odontoid enthesis to the posterior border of the condylar enthesis with an average of 13.2 mm (SD 2.5) and the shortest between the lateral (anterior) border odontoid enthesis and the anterior condylar enthesis with an average of 8.2 mm (SD 2.2).

The greatest elongation was for the posterior fibres of the alar ligament in both scenarios with lesser elongation for anterior and medial fibres.

Scenario 1) 40° axial rotation without vertical translation of C1/C2: Fibre elongation reaches 27.1% for the longest fibres.

Incompatible with collagenous ligament

Scenario 2) 3mm caudal translation of C1 on C2 as facilitated by the biconvex joints at the 40° of axial rotation. Fibre elongation reaches 7.8% for the longest fibres.

Compatible with collagenous ligament

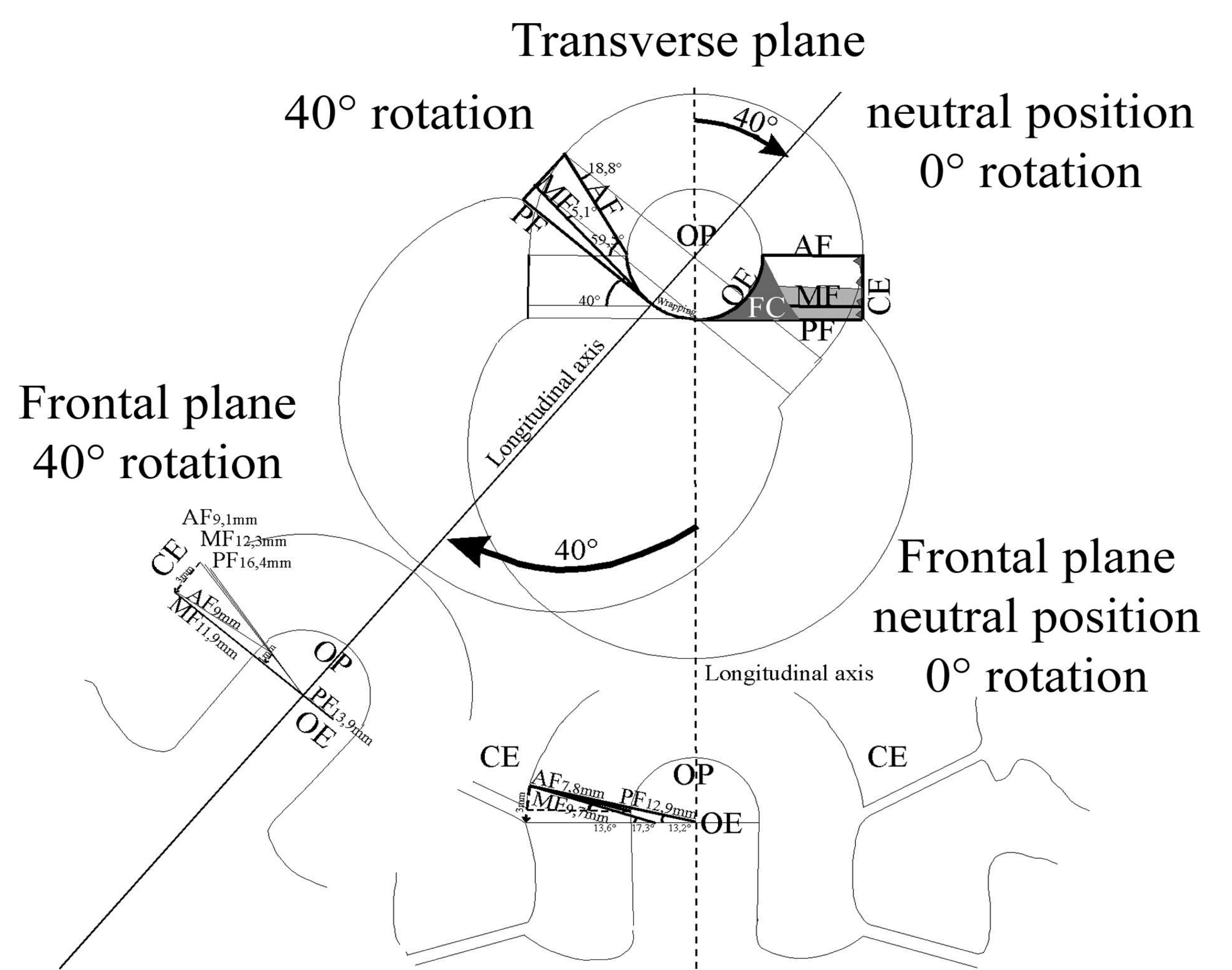


Figure 3 One of the diagrams used for the multiplanar reconstruction at 0° and 40° axial rotation in the neutral plane. **AF** Anterior fibres of Alar ligament **MF** Middle fibres of Alar ligament **PF** Posterior Fibres of Alar Ligament **OP** Odontoid peg **OE** Odontoid entheses **CE** Condylar entheses