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Revisiting the clinical anatomy of the alar ligaments

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Abstract

Purpose. The morphology of the alar ligaments has been inconsistently described, particularly in regard to the existence of an atlantal portion. Despite these inconsistencies, these descriptions have been used to develop physical tests for the integrity of these ligaments in patients with cervical spine problems. The purpose of this study was to describe the detailed macrostructure of the alar ligaments.

Methods. The alar ligaments of eleven cervical spine specimens from embalmed adult cadavers were examined by fine dissection. A detailed description of the macrostructure of these ligaments and their attachment sites were recorded. Measurements were performed with respect to ligament dimensions and relations with selected bony landmarks.

Results. No atlantal portion of the alar ligament was viewed in any specimen. The attachment of the ligaments on the odontoid process occurred on its lateral and posterolateral aspects, frequently below the level of the apex. The occipital attachment was on the medial surface of the occipital condyles in close proximity to the atlanto-occipital joints. The orientation of the ligaments was primarily horizontal. The presence of transverse bands extending occiput to occiput with minimal or no attachment to the odontoid process was a common variant.

Conclusions. The absence of findings with respect to the atlantal portion of the alar ligament suggests that it may be considered an anatomical variant, not an essential component for stability of the craniocervical complex. These findings may inform the use and interpretation of clinical tests for alar ligament integrity.

Key words: alar ligaments; craniocervical anatomy; clinical stability test

Introduction

In recent years, discussion of the structure and biomechanics of the alar ligaments have largely been based upon descriptions of the alar ligaments as commonly consisting of both occipital and atlantal portions [1-3]. Each of these components have been ascribed functional significance in governing the coupling of movements within the craniocervical complex [3,2,4]. Reliance upon this description has particular relevance for practitioners of musculoskeletal medicine where clinical stress tests based upon this description have been described for alar ligament integrity as a component of stability testing of the cervical spine [5-9].

Cave[10] reported distinct bundles of fibres extending from the dens in a similar plane to those fibres extending occipitally, attaching to the pretubercular recess of the atlas. He noted that these bundles served to separate the anterior from the posterior median atlanto-axial joint spaces. This would be consistent with the interpretation of Gardner et al [11] of the description given by Poirier et al[12] which states that synovial cavities both in front and behind the dens each have their own capsular ligament and synovial membrane. Despite these early descriptions, no author revisited the possibility of an atlantal portion of the alar ligament until the work of Dvorak and Panjabi [1]. Of 19 specimens examined by gross dissection, these authors reported a ligamentous connection between the dens and the lateral mass of the atlas in 12 cases. They described this as a distinct portion of the alar ligament of approximately 3mm in length with fibres oriented obliquely craniocaudally from the dens to the lateral mass of the atlas. Based on these findings, it can be assumed that this structure is either not present or not identifiable in approximately one-third of people.

More recent studies have not added strength to arguments for the consistent existence of an atlantal portion of the alar ligament. In a recent examination of the craniovertebral complex in 20 fresh cadavers, no atlantal portion of the alar ligament was observed in any specimen [13]. Magnetic resonance imaging techniques used to examine this area have also cast doubt on the presence of this structure. Krakenes et al [14] did not report an atlantal attachment in a series of 30 people. Whilst other imaging studies have discussed the existence of an altantal portion of the alar ligaments, they have not gone on to state whether they could visualise this in any of the participants in their studies [15,16].

The classical textbook description of the alar ligaments is of two strong, ‘cord-like’ structures extending to the occiput symmetrically placed on both sides of the dens in the sagittal plane [17-21]. The origin of the alar ligaments on the dens has been variously described as the lateral margins of the posterior surface of the upper one-third of the dens [22], the apex of the dens [11,23], the dorsolateral surface of the tip of the dens [24,25,18] or the sides of the dens [19], broadening at this attachment to accommodate the compressive forces incurred during craniocervical rotation [26]. It has been suggested that a small proportion of fibres do not have a medial attachment at all onto the dens, but pass behind or above the dens to be continuous with the contralateral alar ligament [27]. This feature was also described by Testut and Latarjet [28] who described an inconsistently present arc-like cord with superior concavity extending from occiput to occiput, also known as the ‘transverse ligament of the occiput of Lauth’. More recently, this was noted and described as a variant termed the transverse occipital ligament [29].

Each ligament runs laterally from the dens in the direction of the occipital condyles, with the two ligaments tilting away from the sagittal plane by approximately 70°, thus creating an included angle between them estimated as being between 140° and 180° [22,1,4]. The orientation of each ligament has often been described as superolateral [18,20,22], but has also been noted as closer to horizontal [30,31,28]. Dvorak and Panjabi [1] list three types of fibre orientation which were dependant on the height of the dens relative to the level of the occipital condyles. These authors found that in their series of 19 specimens, nine specimens displayed alar ligaments oriented craniocaudally, six specimens oriented horizontally and four specimens with a caudocranial orientation. A similar finding was reported by Okazaki[32] in an examination of 44 cadavers. In this study, 19 ligaments were described as caudocranially oriented, 24 as horizontal and one ligament was reported to have a craniocaudal orientation [32].

The occipital insertion is frequently reported to be onto the medial surface of the occipital condyles [2,24,25,17,11,4,18,27], but has also been described as being on to the lateral walls of the foramen magnum [22,19,20].

Predating the work of Cave, Fick [27] described an inconsistently present doubled or accessory portion to the alar ligament. However, rather than having an atlantal attachment, this band of tissue was reported to pass vertically toward the occiput.

Given the inconsistent descriptions of the alar ligaments and the translation of selected works into clinical tests examining alar ligament integrity, the current study was undertaken to examine the gross morphology of this structure. We hypothesise that the presence of an atlantal portion of the alar ligaments is inconsistent and not essential to the stability of the craniocervical region.

Methods

Eleven cervical spine and head specimens (6 male and 5 female) were obtained from embalmed human adult cadavers with a mean age of 84.1 years (range 69 to 91 years). Trauma had not been a cause of death in any of the subjects.

Cervical spine columns were removed from each cadaver by disarticulation through the C6-C7 intervertebral disc and zygoapophysial joints. All muscle tissue was removed from each specimen leaving an osseoligamentous arrangement. The skull was sectioned at a level through the superior portion of the occipital bone and brain tissue removed. In accordance with methods previously described by Dvorak and colleagues [2,1], a wide posterior wedge of was cut from the occipital bone. Anteriorly, the bone was sectioned by a cut in the coronal plane. The posterior arch of the atlas and the posterior elements C2-C6 were resected. Brainstem, spinal cord, dura and tectorial membrane were removed to expose the alar ligaments.

The alar ligaments were examined using a dissecting microscope. Each ligament was progressively dissected by removal of small bundles of fibres. The orientation, location and attachment sites were recorded, sketched and photographed. Measurements of distance of attachment of the alar ligaments along the odontoid process, distance of the superior aspect of the attachment from the tip of the odontoid process, alar ligament length and width at the midpoint and occipital attachment were measured with callipers. Estimation of the orientation of the ligament was made with respect to the horizontal plane.

Results

Situated bilaterally, the alar ligaments were observed to run laterally from the odontoid process to the occiput. Each ligament inspected consisted of a thick bundle of fibres, ovoid in cross-section, oriented along the direction of the ligament passing laterally to the occiput. (Figure 1). No bands of fibres were observed between the odontoid process and atlas in any specimen.

The superior border of the medial attachment of the alar ligaments onto the odontoid process was frequently observed to be below the tip of the process (mean distance below odontoid process tip 1.72mm, SD 1.85). Attachment occurred variably on either the lateral or the posterolateral aspect of the odontoid process, typically extending down its superior one-third but encompassing one-half of the distance down the odontoid process in some specimens. Distance of the attachment extended between 5 and 8 mm inferior to its superior margin (mean attachment distance 6.06mm, SD 0.97). The variation in attachment distance from the tip of the odontoid process and the extent of the attachment onto the process reflected differences in magnitude of the ligament in individual specimens.

The lateral attachment of each ligament onto the occiput was observed to be a discrete area between 2 and 4 mm in diameter on the medial surface of the occipital condyles in ten specimens. The remaining specimen demonstrated a more diffuse attachment onto this area. Each attachment site was located in close proximity to the atlanto-occipital joint.

In progressing toward their attachment onto the occiput, the bands of the alar ligaments were observed to be oriented horizontally in seven specimens, with the remainder assuming a slightly cranio-caudal orientation. The length of the alar ligaments between bony insertions ranged between 11 and 15 mm (mean length 12mm, SD 1.25). The superior-inferior width of the ligaments viewed from a coronal plane ranged from 4 to 5 mm.

Five of the eleven specimens exhibited substantial bands passing between the medial surfaces of each occipital condyle which spanned the dens posteriorly with either minimal or no attachment to it (Figure 2). Each band had a horizontal orientation with a width of up to 4 mm. Fascia and capillaries could be observed passing through the space between the two bands of the ligament in some specimens. These posterior bands of ligament permitted a degree of mobility as they passed behind the posterior aspect of the dens. Each of the five ligaments with transverse bands displayed a large proportion of fibres traversing directly from occipital condyle to occipital condyle. Whilst the transverse band in one of these specimens did not have any attachment to the dens (Figure 3), the remaining four specimens displayed a weak but definite attachment to the posterior aspect of the superior portion of the odontoid process below the level of the tip. The thickest of these bands, displaying no attachment to the odontoid process, possessed a cartilaginous anterior surface similar to the under-surface observed in the transverse ligament.

Discussion

No atlantal portion of the alar ligament was noted in any specimen examined. This is a significant departure from the findings of Dvorak and Panjabi [1] who reported a distinct ligamentous connection between the odontoid process and the lateral mass of the atlas in 12 of 19 specimens examined by gross dissection. Whilst the existence of these bands would not be expected in all specimens, it would seem unexpected that if these structures were commonly existing anatomical features they would not be apparent in any of the eleven specimens examined in this series. Two possible explanations may exist for this anomaly. Variation is common within normal anatomy and specific populations may exhibit some variations which may not be widely present beyond that population. One explanation could therefore be that the ligamentous bands described by these authors were specific to a population present within their study sample and hence may not be commonly present in other individuals. A second explanation is that is also possible that the structures reported were not, in fact, elements of the alar ligaments. Previous authors have noted bundles of connective tissue arising from the axis and passing to the atlas. These reports have attributed this tissue to elements of the median atlantoaxial joint capsule rather than the alar ligaments [10-12]. It was also noted in the present dissection series that elements of loose connective tissue associated with small vessels were present in this region. This could also be a possible source for the observations of Dvorak and Panjabi.

In this dissection series, the majority of alar ligaments were observed to be oriented horizontally, with four ligaments observed to run slightly cranio-caudally. This finding suggests that the orientation of the ligaments may be more horizontal than has previously been described. Whilst appreciating that atlantoaxial articular cartilage height may be reduced in specimens drawn from an elderly sample, horizontal orientation of the alar ligaments would be more in keeping with the described role of these structures in gradually developing tension through range under the influence of the vertical translation resulting from the biconvex atlantoaxial articulation, providing restraint against the extremes of rotation of the occiput on the atlantoaxial complex in the horizontal plane [33]. The rationale for variation in alar ligament orientation is given by Dvorak [3] as being due to variation in height of the odontoid process. This presupposes that the alar ligaments are attached to the tip of the odontoid process. This is not supported by the findings of this study. No alar ligament was observed to arise from the tip of the odontoid process in any specimen examined, with the mean distance being 2 mm from this bony landmark and the extent of attachment onto the process was measured as being up to 8 mm inferior to this. Hence, this explanation does not provide an adequate rationale for ligament orientation. It is more likely to simply be a function of normal variation between individuals.

The presence of transverse bands in nearly one-half of the specimens examined suggests that this is a common variant of the alar ligament. Complete overarching or minimal attachments to the odontoid process suggest that these bands, when present, may have a role assisting in maintenance of the relationship between occiput, atlas and odontoid process in the sagittal plane. Such a role has been previously described for the alar ligaments in the absence of an intact transverse ligament [12] and the similarity in orientation to the transverse ligament would make this a logical inference. Their mobile nature in relation to the odontoid process suggests that they do not encumber the odontoid process during craniovertebral rotation. In this case, these bands will not contribute to the coupling of lateral flexion and rotation occurring at the craniovertebral segments that has been attributed to tension developed within the alar ligaments.

The existence of a strong cord-like structure between the odontoid process and the medial aspect of the occiput is consistent and beyond dispute. The absence of findings with respect to the previously described atlantal portion of the alar ligament suggests that it may be considered an anatomical variant, and therefore not an essential component for stability of the craniocervical complex. Although clearly described by previous authors [1] and ascribed functional significance in descriptions of the biomechanics of this region [2], the inconsistency of findings in regard to their presence should lead the clinician to conclude that no weight should be attributed to any physical test finding regarding its integrity.

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Figure Legends

Figure 1. The alar ligaments arising from the odontoid process. The transverse and cruciform ligaments have been removed.

Figure 2. Band of fibres of the alar ligament traversing from occiput to occiput.

Figure 3. Alar ligament with no medial attachment being lifted from the odontoid process

Figure 1

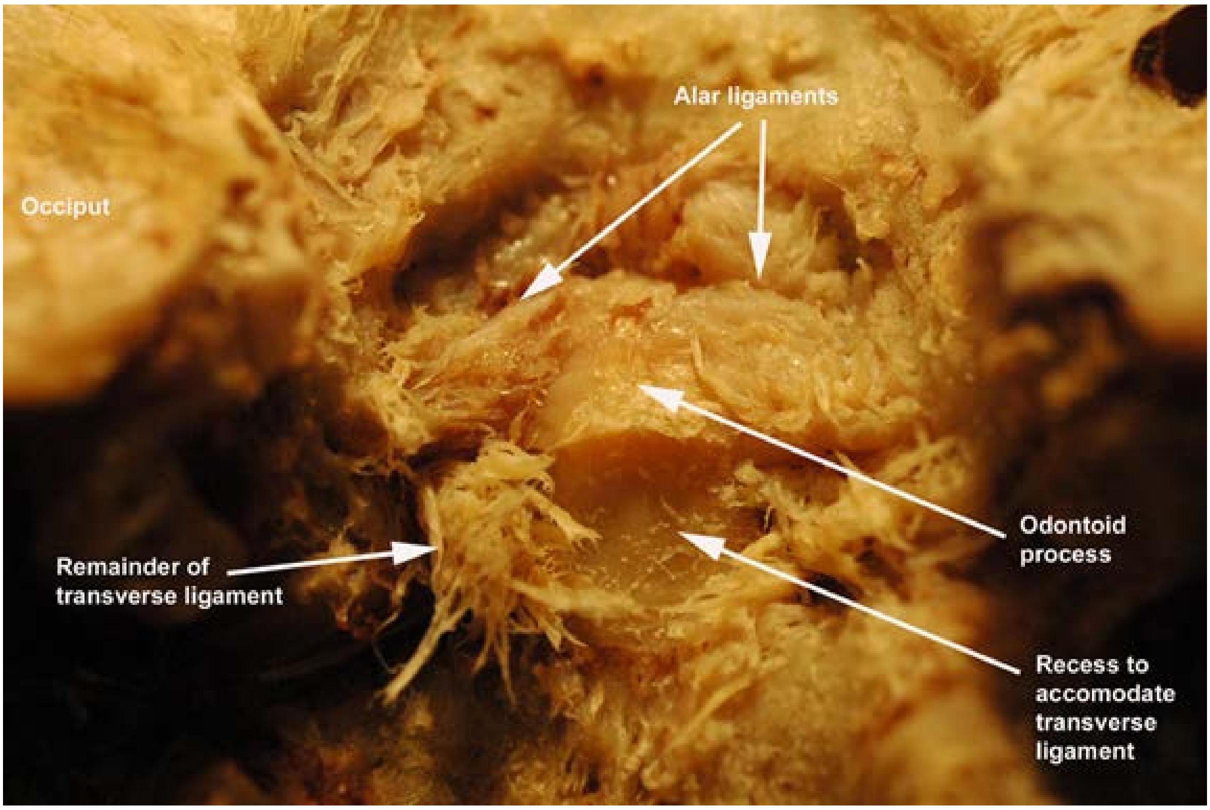

Alar ligaments
Occiput
Odontoid process
Remainder of transverse ligament
Recess to accomodate transverse ligament

Figure 2

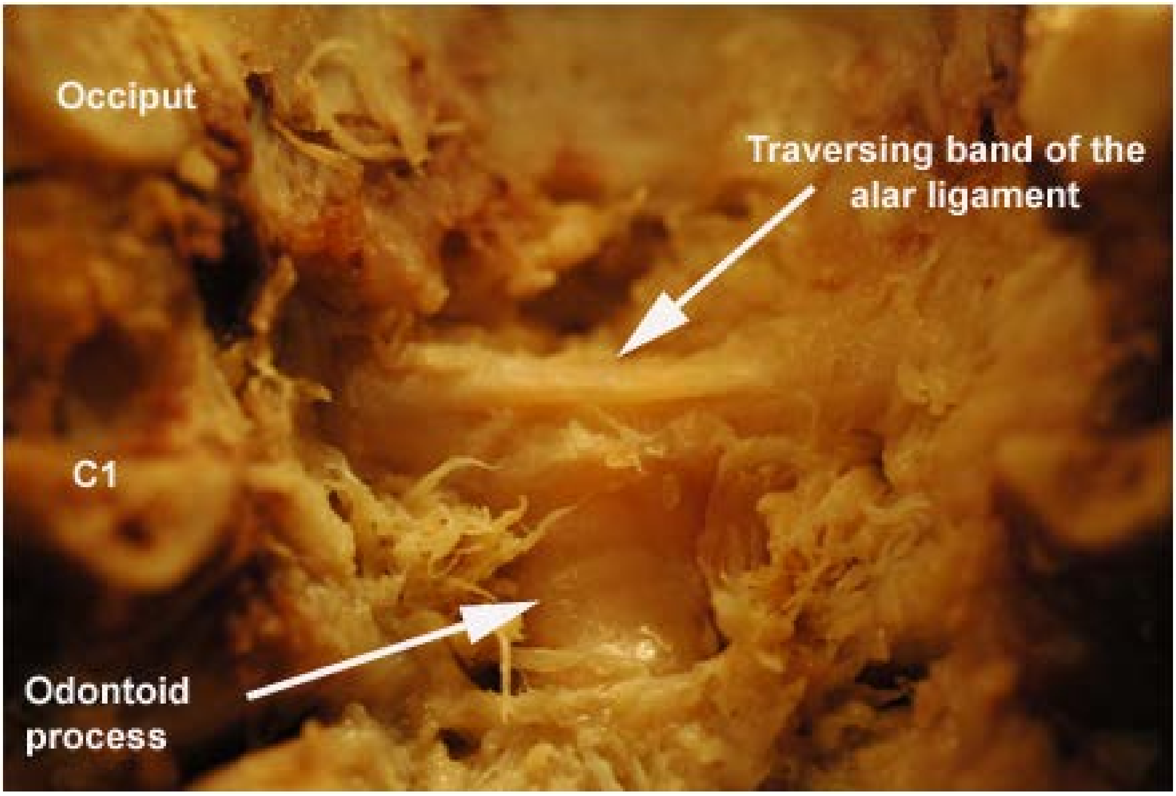
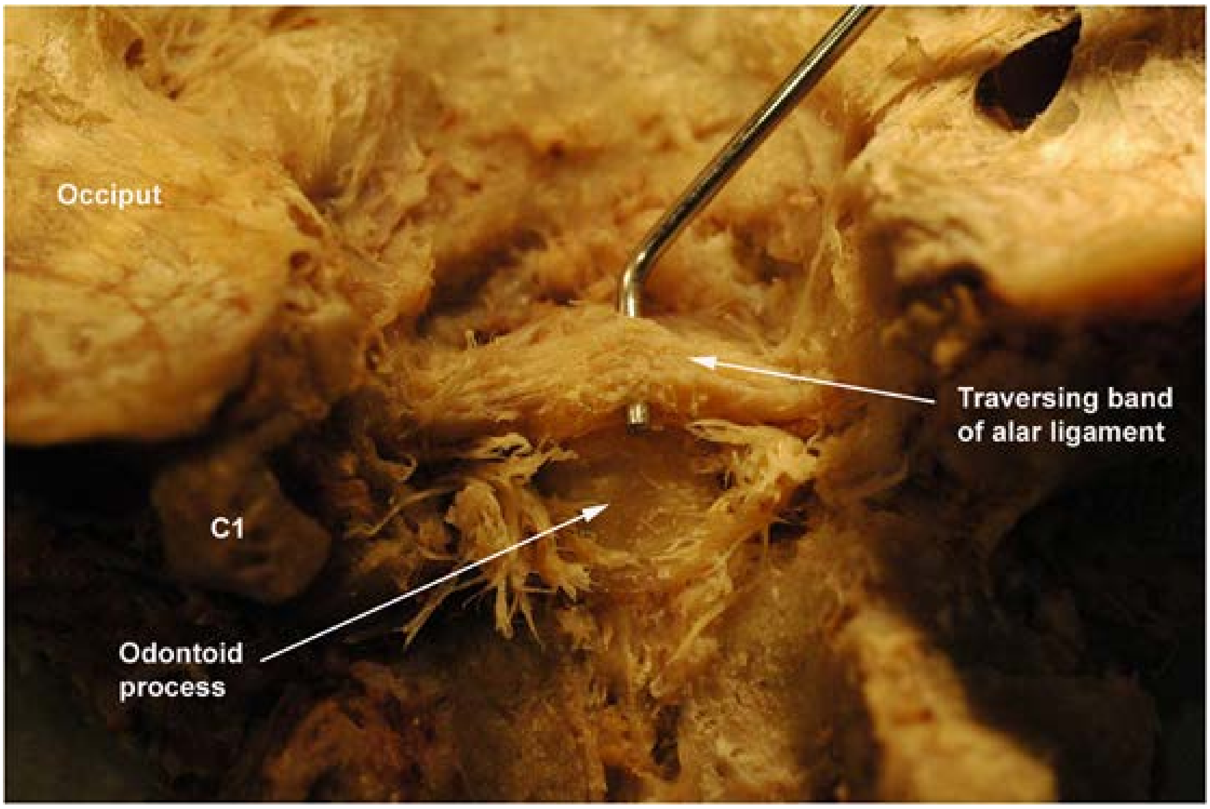

Occiput
Traversing band of the alar ligament
C1
Odontoid process

Figure 3


Occiput
Traversing band of alar ligament
C1
Odontoid process