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Key Differences Between A Tear, Fissure and Calcification of The Lumbar Disc's Annulus Fibrosus: Surgical and Radiological Perspective

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Abbreviations: **CSF**:Cerebrospinal Fluid; **CT**:Computerized Tomography; **HIZ**:High Intensity Zone (Equivalent of CSF Signal); **LIZ**:Lower Intensity Zone (As Compared to CSF Signal); **MRI**:Magnetic Resonance Imaging; **STIR**:Short Tau Inversion Recovery; **SWI**:Susceptibility Weighted Imaging.

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Perspective

The four authors, who have a cumulative medical experience of over 100 years with spinal imaging and clinical procedure encounters in the many thousands, believe that there are key differences between certain pathologies of the lumbar disc annulus (Table 1) that may be overlooked or not clearly distinguished in clinicoradiological and medicolegal contexts [2,5,14]. Specifically, they believe the terms "annular tear" and "annular fissure" are often erroneously used interchangeably, without due regard to pathological and clinical distinctions. Furthermore, annular calcification (that is distinct from osteophyte formation) is underrecognized [13,15]. For whatever technical reason [4,13] in relation to the tabulated three pathologies, a lack of appreciation of variations in their magnetic resonance imaging (MRI) signal characteristics and specific location (morphology) within the annulus itself, can lead to misdiagnosis [7,10]. For example, an annular fissure (typically degenerative, lower T2 hyperintensity, inner two-thirds annulus location; Figure 1A-C) might erroneously be referred to as an annular tear (typically traumatic, higher T2 hyperintensity, outer one-third annulus location; Figure 1D-F), with different aetiological implications. Furthermore, there may be a failure to recognise that annular calcification [15] (typically chronic, degenerative, inflammation-mediated, and possibly reflective of disc trauma in the quite distant past; Figure 2D-F) can also present with T2 signal hyperintensity on a standard MRI (Figure 2A-C). This may then require computerized tomography (CT) or a MRI susceptibility weighted imaging (SWI) [13] sequence (Figure 2) to verify if the lesion is calcified (thus, longstanding, not recently traumatic, and probably clinically quiescent). We note that annular fissures tend to gradually progress with disc desiccation in natural ageing and are typically asymptomatic, while *bona fide* annular tears tend to be symptomatic, temporally follow a recognizable injury or activity, typically heal clinically within 12 months, and not infrequently radiologically too (Table 1; Figures 3 & 4), in the absence of further injury.

Recognition of annular 'tear' versus 'fissure' versus 'calcification' particularly affects aspects of spinal diagnosis, aetiological mechanism, and natural history prognostication. We strongly advocate for the consideration of incorporating and using *both* short tau inversion recovery (STIR) and SWI sequences in *all* spinal MRIs, as a means of increasing the accuracy of diagnosis, with SWI for confirmation of any calcification [13]. As a surrogate for SWI, we believe CT (a recognised gold standard for calcium detection) to be a realistic and practical option in this regard, in any case frequently having been acquired before an MRI. For brevity and clarity, the clinicoradiological hallmarks of each of the aforementioned disc annulus pathologies, as well as their spinal implications, along with key literature references, are presented (Table 1), in conjunction with classic imaging features (Figures 1-4). The authors believe that an awareness of the differences between these three annular conditions when assessing individuals presenting with spinal symptoms and signs, can aid in diagnostic, mechanistic and prognostic accuracy, and also optimise any opinion as to causation.

Table 1: Key Comparative Features Between Lumbar Annulus Fibrosus Pathologies.

Feature (Ref.)	Annular Tear	Annular Fissure	Annular Calcification
Definition [1,4,10,15]	Marked annulus disruption, including outer one-third; lesion often discontinuous with the nucleus pulposus	Milder annular disruption; especially inner two-thirds; often continuous with outer edge of nucleus pulposus	Chronically degenerative or previously injured disc can undergo local fibrosis and calcification
Pathology [1,4,6,9,15]	Radial or transverse disruption involving the outer annulus; sequestered fluid, +/- nucleus tissue; inflammatory cells; neovascularization; granulation; nociceptor stimulation	Circumferential inner annulus degradation; undisrupted outer annulus; no oedema or inflammation	Calcium phosphate (crystal) deposition in the annulus fibrosus; 'disc stiffening' as microcalcification progresses
Aetiology, mechanism [8,9]	Typically traumatic	Typically degenerative	Degenerative +/- remote history of trauma
Probable length of history	Acute (recent past)	Chronic (longstanding)	Chronic (remote past)

Natural history [3,6,10,12]	Resolution (25%) or improvement (15%) in absence of further injury or aggravation; or unchanged (40%) or degenerative progression (desiccation and/or frank herniation)	Typical slow progression with natural aging and disc desiccation. Can predispose towards future disc trauma	Typically unchanged in time; or progressive calcification
Back pain association [1,3,4]	Frequent (for *bona fide* annular tear)	Infrequent, unexpected	Remote past, if any
Complications, sequelae [15]	Progression to acute disc herniation upon further aggravation	Annular bulging but unexpected acute disc herniation	Reduced disc pliability predisposing to accelerated degeneration
Classic CT appearance	Isodense	Isodense	Focal hyperdensity along posterior annulus
MRI T2 sequence at the posterior annulus [1,2,4]	High intensity zone (HIZ; equivalent of CSF hyperintensity; i.e., bright white); typically pronounced in one disc	Lower intensity zone (LIZ; less than CSF hyperintensity); may be focal but often multiple adjacent discs affected similarly	Variable intensity (more often isointense or hypointense, and infrequently hyperintense)
MRI STIR sequence at the posterior annulus [3,4]	HIZ; typically pronounced and quite focal hyperintensity in one disc	LIZ; patchy, speckled pattern of hyperintensity; often multiple adjacent discs affected similarly	Variable intensity (more often isointense or hypointense, and infrequently hyperintense)
MRI SWI sequence at the posterior annulus [13]	Non-dephasing (no drop in signal intensity)	Non-dephasing (no drop in signal intensity)	Dephasing (hypointense signal; dark, black)
MRI T1 + contrast at the posterior annulus [4,10,11]	Frequent enhancement	Typically unenhancing	Typically unenhancing

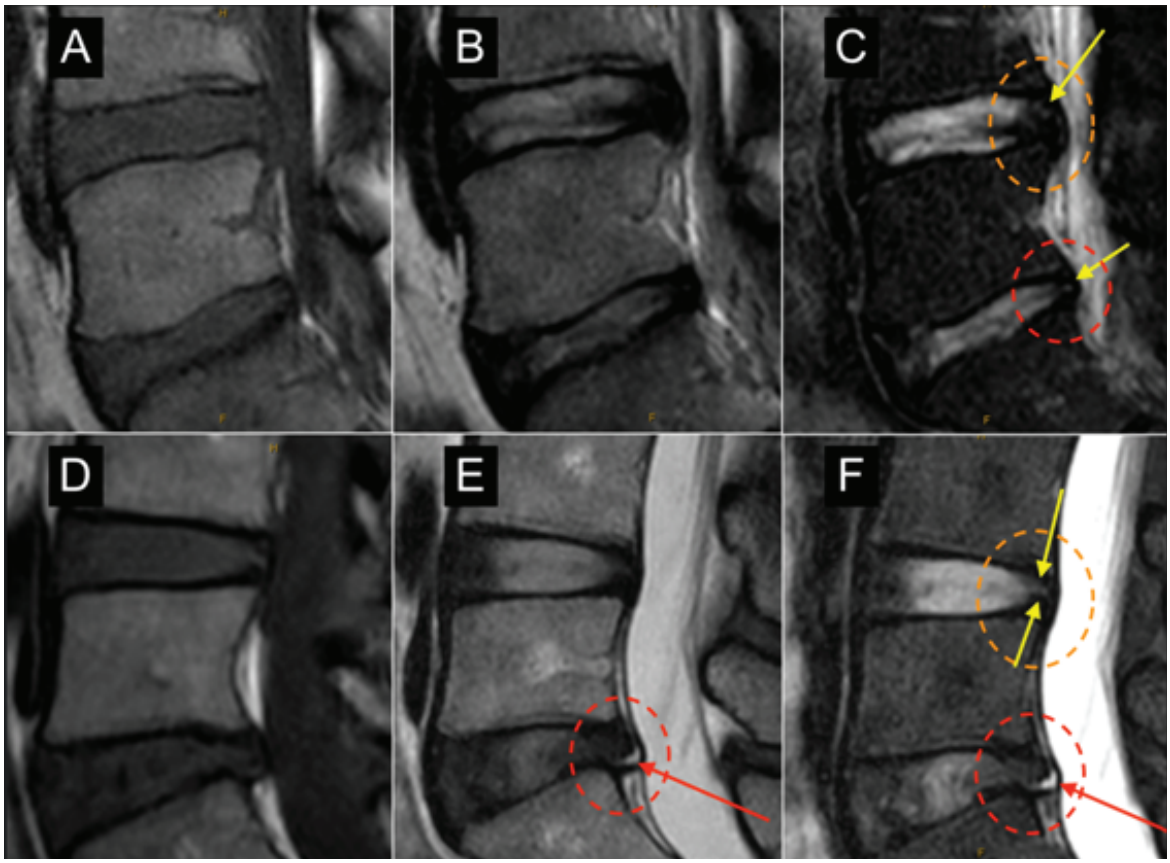

Figure 1: Typical MRI Characteristics of Annular Fissure Versus Annular Tear. A-C from a Male in his Late 20s, and D-F from a Female in Her Early 30s. A. Early annular fissures on T1 sequence (unremarkable). **B.** Early annular fissures on T2 sequence (unremarkable). **C.** Early annular fissures on STIR sequence (tips of yellow arrows point to patchy/speckled posterior annulus of L4/5 and L5/S1 with lower hyperintensity; LIZ). **D.** Annular tear at L5/S1 on T1 sequence (unremarkable). **E.** Annular tear at L5/S1 on T2 sequence (tip of red arrow; CSF-like hyperintensity). **F.** Annular tear at L5/S1 on STIR sequence (focal 'bright white' annular hyperintensity; HIZ; tip of red arrow). Note the more mature annular fissuring at L4/5 posteriorly with nucleus material entering the inner two-thirds of the annulus (between tips of yellow arrows in **1F**).

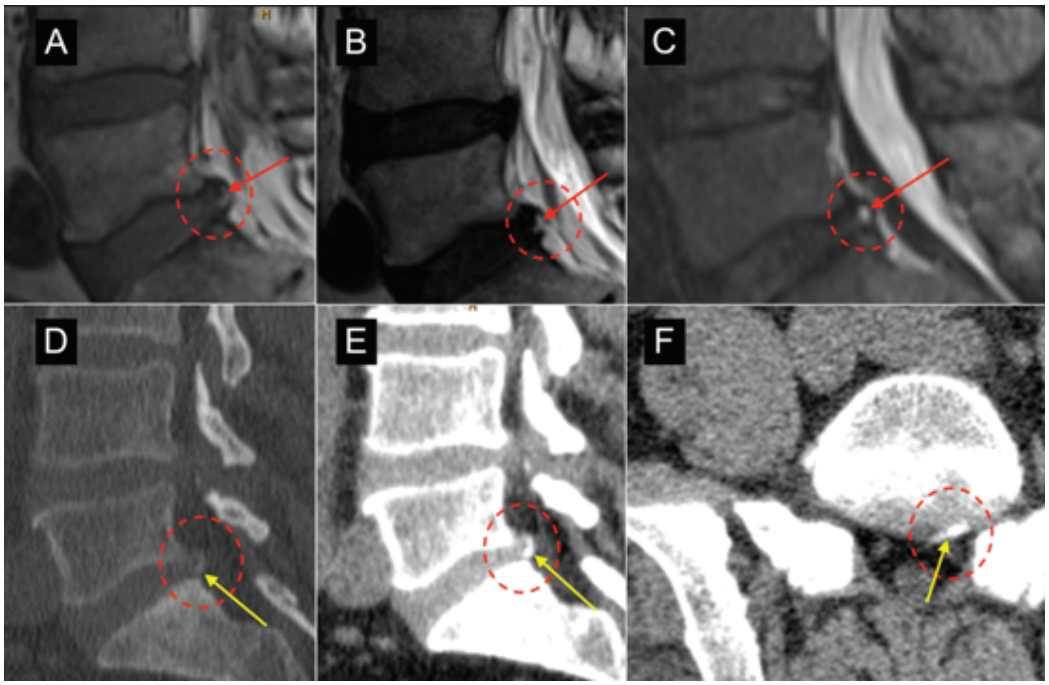

Figure 2: Presumed Annular Tear, but Actual Annular Calcification. A-F From the Same Person. This male in his mid 50s was initially diagnosed as a traumatic L5/S1 annular tear but it was actually low back pain in the context of longstanding recurrently symptomatic lumbar spondylosis. **A.** Presumed annular tear L5/S1 on MRI T1 sequence (tip of red arrow). **B.** Presumed annular tear L5/S1 on MRI T2 sequence (tip of red arrow). **C.** Presumed annular tear L5/S1 on MRI STIR sequence (tip of red arrow). **D.** CT bone window (left parasagittal) confirms L5/S1 posterior annular hyperdensity (tip of yellow arrow). **E.** CT soft tissue window (left parasagittal) confirms focal hyperdense calcification in the posterior annulus of L5/S1 (tip of yellow arrow). **F.** CT soft tissue window (L5/S1 axial) confirms calcification in the anatomical left annular region (tip of yellow arrow).

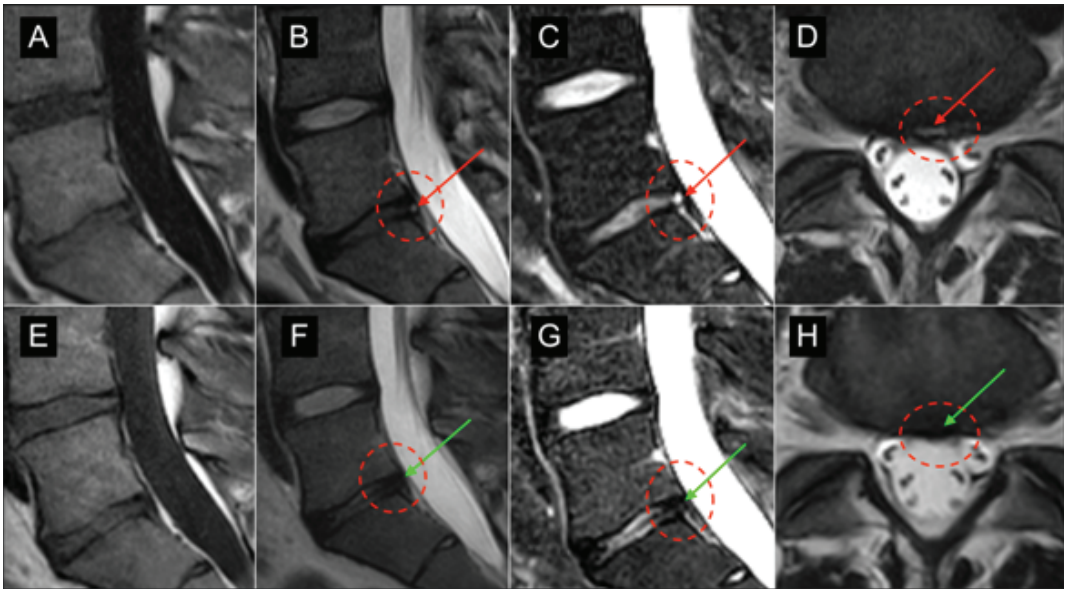

Figure 3: Example of a Healed Annular Tear. A-H from the Same Person. This male in his mid 20s reported low back pain from an innocuous workplace incident, but happened to be involved in a prior work-unrelated motor vehicle accident around that time. On re-assessment 3 years later, he reported no improvement in his low back symptoms and marked disability. However, the examination revealed numerous clinical discrepancies consistent with a non-organic presentation. **A.** Initial MRI T1 sagittal appears unremarkable but for moderate desiccation of the L5/S1 disc. **B.** Initial MRI T2 sagittal shows hyperintensity in the posterior annulus of L5/S1 (tip of red arrow). **C.** Initial MRI STIR sagittal shows a classic HIZ along the posterior annulus of L5/S1, consistent with an annular tear (tip of red arrow). **D.** Initial MRI T2 axial shows hyperintensity in the posterior annulus of L5/S1 centrally and to the anatomical left of midline (tip of red arrow). A MRI was repeated 3 years later (E-H). **E.** Unremarkable MRI T1 sagittal. **F.** Unremarkable MRI T2 sagittal, except there is no longer any focal T2 hyperintensity in the annulus (tip of green arrow; compare with tip of red arrow in 3B). **G.** Unremarkable MRI STIR sagittal, except for chronic desiccation of the L5/S1 disc and resolution of the previous focal HIZ (tip of green arrow; compare with tip of red arrow in 3C). **H.** Unremarkable MRI T2 axial but for healing of the previously identified annular tear (tip of green arrow; compare with tip of red arrow in 3D). The persistent symptoms were not consistent with the expected natural history nor with the current clinical and radiological findings.

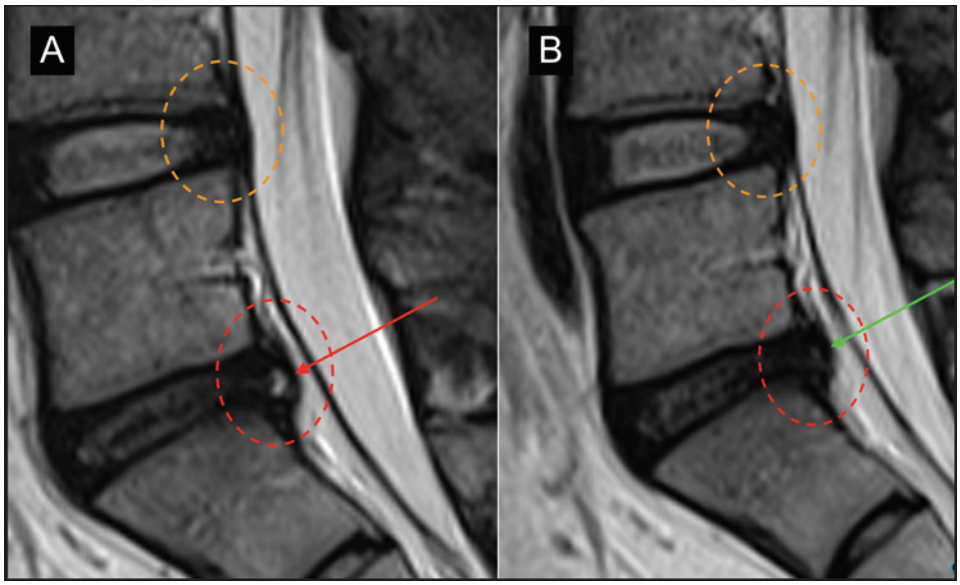

Figure 4: Example of An Almost Healed Annular Tear. This male in his late 20s fitting a truck tyre experienced acute-onset lower back pain. **A.** MRI T2 sagittal shows a relatively normal posterior annulus of L4/5 (orange dashed oval), but an annular tear (tip of red arrow) at L5/S1; note the focal HIZ in the posterior annulus of CSF-like hyperintensity. **B.** MRI T2 sagittal 7 months later shows an almost healed annular tear (tip of green arrow) at L5/S1. The substantial clinical improvement in this young man matched the radiological findings.

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