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Anatomy of lumbar facet joint: a comprehensive review

S. Kapetanakis[1, 2], N. Gkantsinikoudis[1]

[1]*Spine Department and Deformities, Interbalkan European Medical Centre, Thessaloniki, Greece*
[2]*Department of Minimally Invasive and Endoscopic Spine Surgery, Athens Medical Centre, Athens, Greece*

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Lumbar facet joints (LFJs) are diarthrodial joints which provide articulation between two adjacent lumbar vertebrae. LFJs represent complex anatomic structures with multifaceted biomechanical and functional characteristics. They are theorized as structures of crucial clinical significance since their degenerative morphologic alterations are frequently related to emergence of low back pain. Despite the emerging interest in describing LFJs anatomy in recent years, precise description of LFJs innervation remains controversial. In this comprehensive review, anatomy and biomechanical importance of LFJs and associated adjacent extra-articular structures are thoroughly presented. Furthermore, LFJs innervation in respect to current literature data is punctually analysed. Knowledge of anatomy and innervation LFJs of critical importance for clinicians and spine surgeons, so that patients are properly evaluated and related therapeutic procedures are rationally performed. (Folia Morphol 2021; 80, 4: 799–805)

Key words: lumbar vertebrae, zygapophyseal joints, mammillo-accessory ligament, biomechanics, facet joint tropism, dorsal ramus, medial branch

INTRODUCTION

Facet joints (FJ), which are also classically described as apophyseal or zygapophyseal joints, represent the only synovial joints of spine [16, 26]. They are paired diarthrodial joints, posterolaterally articulating the posterior arch between adjacent vertebral levels [26]. Lumbar facet joints (LFJs) constitute primary stabilisers of vertebral column, enabling alongside movements as extension, flexion and rotation [4, 31].

The aim of this review article is to describe the precise anatomy of LFJs according to contemporary literature data. Particular emphasis is given to innervation of LFJs.

ANATOMY OF ARTICULAR AND EXTRA-ARTICULAR ELEMENTS

Articular processes and cartilage

Lumbar facet joints are comprised by the articulation of superior and underlying adjacent vertebra via the paired inferior and superior articular processes, respectively [10, 16]. The major superior and the minor inferior articular processes (SAP and IAP) represent bony protuberances, emerging vertically from the coalescence of pedicles and laminae of respective vertebral arch, posteriorly to the ipsilateral transverse process [16, 26]. SAP and IAP are lined with articular hyaline cartilage over the subchondral

Address for correspondence: S. Kapetanakis, MD, PhD, Orthopaedic Surgeon-Spine Surgeon, Spine Department and Deformities, Interbalkan European Medical Centre, Thessaloniki, Greece, Athens Medical Centre, Athens, Greece, tel: +306972707384, fax: +302541067200, e-mail: stkapetanakis@yahoo.gr

bone [26]. Hyaline cartilage of LFJs is characterised by poor vascularisation and cellular infiltration, featuring a considerable healing inability after traumatisation [24]. Articular surfaces of SAP and IAP feature a consistently different morphological pattern. Hence, SAP are characterised by a more concave articular surface, whereas IAP by a more convex one [16, 24]. In addition, orientation of SAP and IAP in sagittal and coronal planes features a noteworthy differentiation. IAP of superior vertebral level faces an anterior and lateral direction, whereas SAP lies posteriorly, facing medially [26].

LFJs articular cavity

Lumbar facet joints cavity may be anatomically divided in the FJ articular space and the FJ recesses, featuring a capacity of 1–2 mL [26, 36]. FJ space represents the anatomic space between the articular cartilage of articulating facets [36]. In contrast, FJ recesses are formed by the redundant encapsulation of LFJ by capsular ligament at the superior and inferior parts of the joint, containing adipose tissue or minor synovial villi [10]. Thorpe Lowis et al. [36] studied 19 cadaveric specimens in order to determine the precise anatomic characteristics of FJ recesses in various spinal regions. It was concluded that FJ recesses presented specific characteristics in respect to particular intervertebral levels. LFJs recesses were equally large and anteromedially and posteromedially located. The anteromedial recess was encountered superiorly, emerging over the upper end of SAP of underlying vertebra. In contrast, posteromedial recess surrounded the lower edge of IAP of supernatant vertebra. LFJs cavity featured no direct communication with the retrodural space, demonstrating an anatomically clear delimitation [36]. LFJ cavity and recesses are detectable in radiologic evaluation with magnetic resonance imaging (Fig. 1).

Figure 1. Representation of facet joint cavity (red arrow) and the anteromedially located superior recess (white arrow) of L3–L4 facet joint in a normal lumbar magnetic resonance imaging.

LFJs capsular ligament

Lumbar facet joints are, similarly to other synovial diarthrodial joints, completely encapsulated by a capsular ligament (LFCL). LFCL is histologically composed by two distinct layers: an outer layer of parallel with lateral-medial direction and densely organized collagen bundles, and an inner layer of elastic fibres with inconsistent orientation [5, 16]. Furthermore, LFCL features rich innervation with autonomic and nociceptive nerve fibres, which may reproduce pain in cases of inflammatory or mechanical irritation [26, 31].

Lumbar facet joints capsular ligament has an important role in maintaining the stability of LFJs. The presence of collagen and elastin administrates substantial mechanical support against shear and tensile forces developed during motion and vertebral loading. LFCL bears a remarkable biomechanical role during various movements of LFJs. It is extended during LFJs lateral bending or rotation. Hence, lateral-medial orientated capsular fibres feature extension along LFJs direction, providing functional resistance and stability. On the other hand, flexion or extension of LFJs is associated with emergence of crucial shear stress, transverse to LFJs direction. In this dynamic condition, LFCL fibres feature also a shear stress transverse to their alignment, providing great resistance [5].

Mammillo-accessory ligament

Mammillo-accessory ligament (MAL) represents a ligamentous structure bridging the bony mammillary (MP) and accessory processes (AP) of the lumbar vertebra bilaterally. MP constitutes a circular bony protuberance located at the posterior border of SAP. AP is, on the other side, a relatively lesser and sharpening bony structure encountered at the postero-inferior portion of each transverse process root. Ipsilateral MP and AP are connected by the ligamentous MAL (Fig. 2) [12]. MAL constitutes a portion of the medial aspect of intertransverse ligament, featuring a noteworthy tendency to ossification [31].

Shuang et al. [31] dissected 12 cadaveric specimens, in order to determine the precise anatomy of

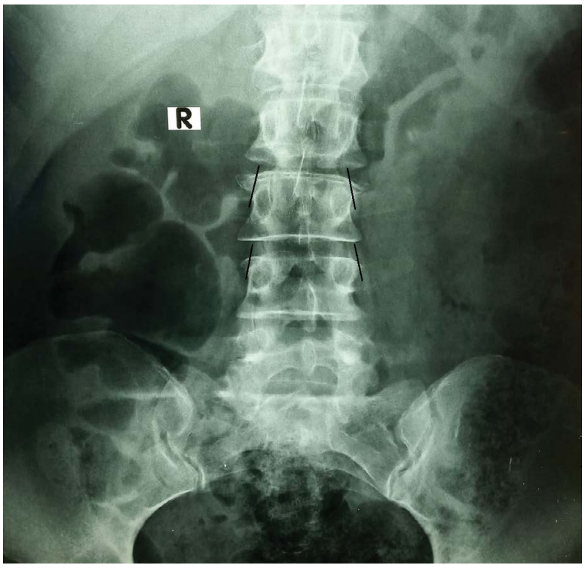

Figure 2. Conceivable representation of mammillo-accessory ligament in an anteroposterior lumbar spine radiograph.

medial branch of spinal dorsal ramus. It was inter alia concluded that the abovementioned anatomic structures form a true fibro-osseous canal, which is anatomically characterized by 4 distinct walls: a superior (MP), an inferior (AP), an anterior (the bony groove between MP and AP) and a posterior (MAL). The fibro-osseous canal displays an oblique direction, encountered at the dorsal portion of SAP and origin of transverse process [31]. In the case of MAL ossification, this canal becomes completely osseous [12, 31].

BIOMECHANICAL DATA

The three-dimensional LFJs and the anteriorly located intervertebral disc at each lumbar spine level compose an anatomic entity described as spinal segment, "three-joint complex" or articular triad [15, 16, 21, 23, 26, 32, 38]. These articular structures are theorised to constitute a single unit since the emergence of degenerative alterations in one joint has a subsequent influence on the biomechanical behaviour of the whole unit [26]. Furthermore, the harmonised function of these structures prevents potentially injurious dynamic states, warranting alongside physiological motional activity.

Functionally, the intervertebral disc is majorly responsible for the transmission of axial-compressive forces [16]. In contrast, osseous LFJs are primarily charged with the stabilization of spinal motion segment [2, 3, 16]. However, many biomechanical studies have demonstrated that LFJs also contribute to transfer of implemented axial compressive load on the spine [1, 24, 26, 28, 32]. LFJs may bear up to 25% of this load, depending on the motion status at each case [24, 41]. However, the underlying mechanisms of this transmission remain unclear. The nearly vertical inclination of LFJs articular surfaces in conjunction with the existent low friction considerably complicates this description. Inoue et al. [16] reviewed existing literature data on the biomechanical behaviour of LFJs in various dynamic conditions. It was concluded that LFJs may contribute to axial compressive load transfer by three potential mechanisms: by articular surfaces, by LFCL and by the direct connection between the vertebral arch or the pars interarticularis and the tips of articular processes [16].

As stated above, LFJs have been delineated as the primordial lumbar spine stabilizers [22, 32]. LFJs stabilize the respective motion segment in extension and flexion, restricting also axial rotation [26, 39]. More specifically, medial and posterior portion of LFJs instates the major resistance to antero-olisthesis [3]. Comparatively, anatomic construction of LFJs relatively allows flexion-extension motions in sagittal planes, but noteworthy limits axial rotation, so that rotatory instability is prevented [32, 39].

Nevertheless, this motion-restrictive pattern may vary according to each lumbar level. This variation is majorly attributed to the differentiated LFJs orientation. LFJs are oriented 82–86 degrees in regards to the axial plane and 15–70 degrees in regards to the sagittal [5]. Nonetheless, LFJs orientation features a gradual coronal to sagittal conversion from proximal to distal levels [3]. At L1–L2 spinal motion segment, the angle between articular surfaces of SAPs is 30 degrees. However, this angle features a considerable distribution from 30 to 90 degrees in distal (L4–S1) segments. This peculiarity of LFJs orientation in distal segments is profoundly responsible for the emergence of lower resistance to rotational motion [3, 22]. Particular anatomic studies have depicted that the orientation of LFJs gradually approaches the sagittal plane with age [19]. However, the precise contribution of this alteration to further degenerative damage of spinal segment is not adequately understood [18].

LUMBAR FACET JOINTS TROPISM

Lumbar facet joints tropism (LFJT) is defined as the existing asymmetry between right and left LFJs angle [8, 13, 17, 37, 40]. Bogduk [6] initially described LFJT as the status where LFJs feature a rotational incongruity in respect to axial plane, resulting in subsequent asymmetry. More recent studies identified that LFJT may be present in all planes. Therefore, LFJT may also be theorised as the subsistence of asymmetry between left and right LFJs angles in sagittal or coronal planes as well [3, 26]. This asymmetry is in the majority of cases relatively negligible, under 5 degrees in range. There is currently no universal consensus about the consideration of clinically significant LFJT. Hence, LFJs angulation may normally vary from 5 to 10 degrees [3].

Mohanty et al. [23] performed a retrospective cross-sectional study, in order to elucidate the prevalence of LFJT. For this purpose, 566 intact spinal motion segments from 124 computed tomography scans of spinal trauma patients were analysed. Results showed that LFJT featured greater prevalence in L4–L5 and L5–S1 levels, with the percentages of 47.82% and 38.5%, respectively. Authors concluded that these results may offer an explanation for the more frequent occurrence of lumbar disc herniation and related degenerative disorders as lumbar arthrosis and degenerative spondylolisthesis encountered at these levels [23]. This thesis has been also adopted from other studies in recent literature [3, 14, 26].

LUMBAR FACET JOINTS INNERVATION

Lumbar facet joints innervation is derived by the medial branch of the lumbar dorsal rami, or, as also known, posterior branches of the lumbar spinal nerves [31]. For many years, clinical importance of these structures was not adequately recognized. Hence, precise description of their anatomy was not present even in well-established anatomy atlases [19]. Bogduk et al. [7] were the first to provide a thorough analysis of posterior branches of lumbar spinal nerves anatomy in 1982.

The spinal nerve is divided into four distinct branches, after its exit from the respective intervertebral foramen; the communicating branch, the meningeal branch, the ventral ramus and the smaller dorsal ramus (DR) [31]. At levels L1–L4, DR is separated from the spinal nerve at an approximately right angle [19, 29]. They subsequently traverse the vertebral foramen, featuring then a dorsal and caudal course [7, 9, 30]. DR is from that point encountered at the orifice formed by the superior border of the adjacent transverse processes and the inferior border of the respective LFJ [19, 20]. This final aspect of DR is located at the medial portion of intertransverse musculature (Fig. 3) [31].

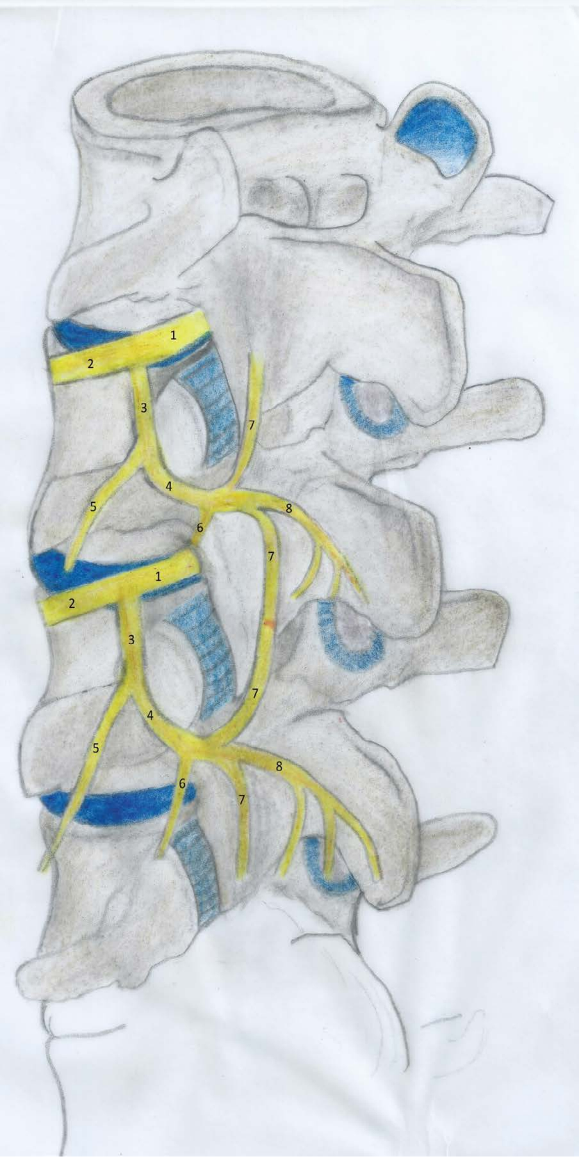

Figure 3. Schematic representation of lumbar dorsal ramus and its branches; 1 — lumbar spinal nerve; 2 — ventral ramus, 3 — dorsal ramus; 4 — medial branch of dorsal ramus; 5 — lateral branch of dorsal ramus; 6 — muscular branch of medial branch of dorsal ramus; 7 — articular branches of medial branch of dorsal ramus; 8 — cutaneous branches of medial branch of dorsal ramus.

Dorsal ramus bifurcates, circa 5–10 mm distal to the abovementioned orifice, into a medial and a lateral branch, forming a 30-degree angle [19, 20]. This division is encountered at the superior edge of the underlying transverse process. There are multiple communicating branches between the adjacent lateral branches, medial branches and dorsal rami [31]. Nerve fibres composition for both branches is duplex, containing sensory as well as motor fibres. Ramification of DR presents also a regional significance; lateral branch innervates tissues lateral to LFJs whereas medial provides innervations to the structures located medially to LFJs line [33] (Fig. 3).

Bogduk et al. [7] proposed that ramification of DR was triple, describing also a distinct intermediate branch in addition to medial and lateral. This thesis was later adopted from other authors as well. Middle or intermediate branch may co-exist with lateral branch in a short common trunk or separate directly from the DR. It is theorized that middle branch provides innervation to the longissimus lumbar muscle [19]. Furthermore, middle branch may also feature rich anastomoses with the other branches, thereby composing complex neural plexuses. Despite the published data about the anatomy of intermediate branch, dichotomy of DR into medial and lateral branches represents the majorly acceptable standard in the literature [31].

After its emergence, medial branch traverses the superior border of the underlying transverse process, proximal to its origin [27]. It then passes between the bases of SAP and adjacent transverse process, traversing the dorsal portion of intertransverse ligament. Medial branch is at this locus accompanied by the posterior branch of the lumbar artery, adhering to the adjacent periosteum via connective tissue [19]. Farther on, it features a medial course passing under the MAL into the fibro-osseous canal. Medial branches of L1–L4 dorsal rami are encountered at the posterolateral portion of this canal, featuring greater proximity to AP than the MP [11]. They subsequently follow a medial and caudal route towards the vertebral lamina, demonstrating thereafter a deep course into the adipose tissue of multifidus muscle [19]. Medial branch is there ramified into three distinct branches; muscular, articular and cutaneous branch, supplying LFJs, multifidus muscles and supra- and inter-spinous ligaments (Fig. 3) [7, 19, 31].

The anatomic course and distribution of medial branch may feature considerable variability, thus complicating the punctual description of LFJs innervation [19]. Bogduk et al. [7] stated in their paper that medial branch provides innervation to LFJs of respective level and one level caudally with descending branches. This statement was in general validated from the vast majority of subsequently published papers (Fig. 3) [11, 19, 29, 31]. There is, however, existing literature data supporting that LFJs innervation may be more complex, with emerging branches of sympathetic trunk and adjacent spinal ganglion participating as well [19, 25, 34, 35].

In their cadaveric study, Shuang et al. [31] concluded that innervation of a particular LFJs is provided by medial branches of the two adjacent DR. Medial branches of lumbar DR demonstrate a terminal descending portion, which may extent to 1–3 intervertebral levels. Medial branches of cranial DR tend to finally exhibit a shorter descending course in contrast to caudal. Furthermore, it was elucidated that articular branches from medial branch are also derived prior to entrance in fibro-osseous canal. These branches provide regional innervation to lateral and inferior portion of LFJs, whereas the terminally separated articular branches supply superior and medial aspects of LFJs [31].

L5 spinal segment features special anatomic characteristics in terms of neural distribution. First, DR presents a longer course than ventral ramus, rising at the excavation between the superior surface of sacral ala and the base of S1 SAP [19, 26]. Perolat et al. [26] reviewed existing literature on FJ syndrome, quoting alongside data about LFJs anatomy. It was stated that L5 DR is bifurcated into a medial and an intermediate branch, with no presence of lateral branch [26]. However, this thesis is not universally accepted [31]. Medial branch of L5 DR subsequently runs caudally, giving rise to communicating branches to S1 DR [26].

CONCLUSIONS

Existing literature evidence indicates that LFJs represent complex structures in terms of anatomy, biomechanical sententiousness and functional importance. Despite the emerging interest on describing LFJs anatomy, a precise and universally accepted description of LFJs innervation remains absent. Future anatomic and radiologic studies with greater size of specimens may clarify this issue, contributing thus to better comprehension and optimisation of particular interventional procedures as LFJs denervation.

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