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Review Article

Understanding the Z–Joint and its Effects on Spinal Nerve Root Compression due to Specific Orthopedic Disorders

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Abstract

Zygapophyseal joints (Z-joints) of the spine are vital for human movement, particularly postero-lateral movements (such as flexion, extension, and rotation) while contributing stability to the spine. However, when compromised, Z-joints can become sources of mild to severe and unrelenting pain. Various factors, such as aging, trauma, gender, facet orientation (tropism), impingement of spinal nerve roots, and specific orthopedic conditions—arthritis, degenerative joint disease (DJD), and degenerative disc disease (DDD)—are contributing factors. The treatment of Z-joint-elicited pain requires multimodal management, consisting of conservative therapy, surgical intervention, and adjunctive methods (such as patient education, exercise, and psychotherapy). This review describes the structure and biomechanics of the Z-joint and the relationship of the Z-joint to adjacent structures that, when compromised, cause pain. Also, descriptions of specific treatment options are provided. Although beyond this review's scope, the growing shift towards in non-opioid analgesia is mentioned and links to two current publications by Flores and Kerna (2020) regarding such are provided in the Supplementary Note section. The structure and biomechanics of the zygapophyseal joint have been an evolutionary boon to human movement and mobility; however, when compromised, have also brought forth a plague of pain, which is problematic to treat, ameliorate, or cure.

Keywords: *Apophyseal; Degeneration; Facet Syndrome; Pain; Spinal Nerve Root; Vertebrae; Zygapophyseal*

Abbreviations

CN: Cryoneurolysis; DDD: Degenerative Disc Disease; MRI: Magnetic Resonance Imaging; NSAID: Nonsteroidal Anti-Inflammatory Drug; PRF: Pulsed Radiofrequency; QoL: Quality of Life; RF: Radiofrequency; Z-Joint: Zygapophyseal Joint

Introduction

The zygapophyseal joint (Z-joint), also termed as a facet or apophyseal joint, is a synovial joint of the spine. The human body has 33 vertebrae, each containing two Z-joints, an upward-facing superior articular facet and a downward-facing inferior articular facet. The facet joints enable postero-lateral movements (such as flexion, extension, and rotation), distributing the load along the spine and stabilizing the spine by connecting to the vertebral arch [1].

The lumbar Z-joints are primary sources of lower back pain caused by various factors, such as altered nerve supply, injury, and degenerative changes. Any alteration in the structure and functions of the Z-joints contribute to spinal disorders. In this review, the anatomy and biomechanical factors contributing to the degeneration of Z-joints and treatment options are presented.

Anatomy of the Z-joint

Z-joints are synovial joints of the spine containing 1–2 ml of synovial fluid [2]. They are composed of soft and hard tissues, such as bony articular pillars, synovia, and fibrous joint capsules [3]. The bony articular pillars are covered by hyaline cartilage and provide compressive load-bearing. The synovium is composed of connective tissue that maintains the articular surface's lubrication, allowing frictionless motion [3]. The ligamentous, fibrous capsule is about 1 mm thick, composed of collagenous tissues, providing resistance to flexion by covering the entire joint [1]. The tissues collectively distribute the load and resist tensile force during various movements, such as rotation and translation [4].

The Z-joint capsules and surrounding structures are encapsulated and unencapsulated, supplied with free nerve endings [5]. The presence of various types of neurons indicates that the Z-joints transmit both nociceptive and proprioceptive information. The presence of nerve fibers in subchondral bone and intraarticular inclusions in the Z-joints implicates the structures adjacent to the joint capsule as acting as points of pain genesis due to aberrant biomechanics [6].

Each Z-joint has a dual nerve supply, one from the medial branch of the posterior primary spinal nerve and another from the Z-joint's upper level [7]. Thus, the Z-joints of L4/L5 receive nerves from the L4 medial branch (corresponding segment) and the L3 medial branch (one level above). The interspinous ligament, the interspinous ligament, and the periosteum of the neural arch are also innervated by the medial branches [1]. The medial branch of L1–L4 posterior spinal nerve runs downward along the junction of transverse and superior articular processes and crosses the transverse process at one level below each spinal nerve (e.g. L1 crosses the transverse process of L2). The nerves then pass through the mamillo-accessory ligament and divide into multiple branches as they cross the vertebral lamina.

Function of the Z-joint

The Z-joints contribute to load transmission over the spine and stabilize motion during flexion, extension, and rotational movement. Regarding load transmission, the Z-joints form part of the spine's posterior element [4,8]. The load-bearing is dependent on posture and increases during extension. The percentage of the segmental load increases by up to 47% in degenerated joints, from 3–25% in healthy joints [4,5]—one of the reasons that Z-joints undergo wear and tear.

Etiology of Z-joint pain

Various factors—such as aging, trauma, sex, facet orientation, abberant in nerve arrangement, and conditions like arthritis and disc degeneration—are responsible for Z-joint pain.

Age is one of the critical factors of degenerative changes in Z-joints. Sixty percent of adults show signs of degeneration by age 30 years. The joints show a further decline at age 60 years—the L4-L5 Z-joints being the most adversely affected [8].

Lifestyle plays a crucial role in the development of Z-joint disorders. The amount of heavy work done at an early age is positively correlated with lumbar facet joint osteoarthritis [9]. Obesity, incorrect posture, and sedentary lifestyle also contribute to Z-joints disorders.

Trauma is a significant cause of lumbar facet dislocation. Trauma patients—having injuries in the occult bones (35% of the cases) and soft tissue-joint capsule or articular cartilage (77% of the cases)—experience lower back pain [1].

Osteoarthritis contributes to the degeneration of Z-joints and the manifestation of joint pain. Magnetic resonance imaging (MRI) studies show that facet joint osteoarthritis is more pronounced and is always associated with the presence of advanced degenerative disc disease (DDD) [10]. Moreover, DDD precedes facet osteoarthritis. Osteoarthritis involves several changes in the Z-joints, including cartilage loss, bony hypertrophy, loss of joint space, loss of synovial fluid, weakening of ligaments, and compromise of joint capsules, periarticular paraspinal muscles, and other soft tissues. Although Z-joint and surrounding tissue degeneration are primarily responsible for joint pain, the association between DDD, facet joint disorders, and pain remains debatable [9].

Z-joint compromise can occur due to degenerative spondylolisthesis resulting in the displacement of one vertebra in relation to another in the sagittal plane [5]. This type of displacement is prevalent in Z-joint osteoarthritis, causing motion impairment. L4–L5 is found to be affected mainly by spondylolisthesis, similar to osteoarthritis [9].

Congenital abnormalities, acute or stress-related fractures, and dysplastic (type I) and isthmic (type II) spondylolisthesis are observed more frequently in the younger population—with the L5–S1 Z-joints affected in most cases [11]. Inflammatory arthritis (such as rheumatoid arthritis, ankylosing spondylitis, and reactive arthritis) is also implicated in Z-joint disorders [3]. Recurrent rotation strain leads to disc height loss, osteophyte formation, and degenerative hypertrophy of the facets [12].

Calcification of Z-joints, synovial cysts, synovial inflammation, and asymmetrical facet hypertrophy are factorial in Z-joint pain [1,6,13]. Compression of the exiting nerve root by facet joint hypertrophy or synovial cysts results in spinal stenosis and pain elicited by compressed or impringed spinal nerve roots [14].

Treatment of Z-joint-elicited pain

Multimodal Z-joint pain management consists of conservative approaches, surgical intervention, and alternative and complementary methods, such as patient education, exercise, and psychotherapy.

Conservative therapy

Conservative therapy in pain management includes the administration of analgesics, physiotherapy, and acupuncture [1]. Physical therapy entails posture correction, stretching (to increase flexibility), and exercise (to increase muscle strength) [15]. The use of "pain killers"—such as nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen—are generally considered as first line of treatment for such back pain. At times, muscle relaxants and antidepressant drugs are utilized. When first-line treatment fails, more aggressive treatments, such as nerve blockers, steroid injections, and denervation, are considered for ameliorating facet joint pain.

Pain blockers

Local anesthetic drugs (lidocaine or bupivacaine) with or without steroid injections are applied to block either the medial branch nerve or intraarticular tissues to reduce pain [1]. For patients to undergo medial branch neurotomy, they must demonstrate at least 80%

pain reduction following controlled medial branch blocks [16]. A double-blind, randomized control trial showed that medial branch blockers' use led to 80% pain reduction for 10–12 weeks [17]. Another study demonstrated that the blocking of the medial branch results in both short-term (< 3 months) and long-term (> 3 months) pain relief [18]. Medial branch blockers are more selective than intraarticular injections and technically uncomplicated to administer, using anatomic landmarks [19]. The intraarticular structure is anatomically complex, making the introduction of medicine less efficient. Moreover, the medial branch blockers' outcome is more favorable than the intraarticular medication in both short– and long–term cases [17].

Since the Z-joints have a dual nerve supply, a single joint is blocked at two levels [17]. As a rule, patients are administered medial branch blockers twice before a denervation procedure [1]. The success rate of lumbar facet joint radiofrequency (RF) denervation with one round of medial branch blocker treatment was 39%, whereas, it increased to 64% when having a double round of medial branch blocker treatment [20].

Steroid injections

Along with blockers, steroids are administered in the treatment of Z-joint-elicited pain. The presence of inflammatory cytokines in and around degenerative Z-joints justifies steroid injections for short-term pain relief. Z-joints are injected with long-acting corticosteroids, resulting in anti-inflammatory and anti–edematous effects. Steroids are immunosuppressive and inhibit neural transmission. Although generally used, the efficacy of steroid injections in pain reduction is debatable [17,21]. European guidelines do not recommend intraarticular steroids to manage chronic nonspecific low back pain [22]. A controlled trial conducted by Perolat., *et al*. (2018) showed no difference in outcomes for intraarticular and periarticular injections with and without steroids [6]. However, a recent report by Kwak., *et al*. (2019) indicated that corticosteroid injection is clinically beneficial for facet joint pain caused by osteoarthritis [21].

Neurolysis (denervation)

An interruption of the nerve supply to degenerated joints can be accomplished by denervation of the medial branch, being another option for pain relief caused by Z-joint disorders. Patients refractive to pain medicines—who have demonstrated significant pain reduction from a medial branch procedure—are considered for the denervation procedure. A shortcoming of this procedure is that the pain relief is often temporary and the procedure needs repeating [23]. Physical techniques and chemical treatments achieve denervation. The physical techniques include radiofrequency (RF) and cryoneurolysis (CN).

Physical neurolysis

Physical neurolysis includes thermal RF, low temperature, and laser techniques. Thermal RF denervation is performed by "burning" the target nerves at 900°C for 1–2 mins by passing RF energy through a needle. Several randomized control trials have been performed regarding RF denervation's efficacy; all of them revealed similar efficacy [6]. Reports detailed 90% pain relief in 60% of patients and 60% pain relief lasting for one year in 87% of patients [24]. Another study investigating patients suffering from minor degenerative spondylolisthesis displayed 80% pain relief in 60% of patients for 12 months [25]. It is noteworthy that there were various issues with the sample selections, methods, and technical aspects of RF denervation in all trials. However, RF is a reasonably safe procedure with minimal (1%) short-lasting, minor complications [26]. The side effects of RF include painful sensations in the skin (cutaneous dysesthesias), chronic nerve pain, and neuroma formation. Another unintended complication of this procedure is damage to the spinal nerve, which can be avoided by stimulating the sensory and motor neurons during the procedure [27].

Another form of RF denervation is pulsed radiofrequency (PRF) at a temperature lesser than 42°C. A study by Bogduk., et al.(2009) offered pain relief in 59% of patients for only four months with PRF in addressing lumbar Z–joint pain [28]. Thus, denervation using PRF seems effective in terms of the long–term mitigation of Z–joint pain and, thus, may not be a desirable substitute for conventional thermal lumbar medial branch neurotomy [23]. However, the use of PRF offers several advantages, such as avoidance of accidental damage to the neighboring nerve roots and reduction in the multifidus muscle denervation associated with secondary spinal instability [29].

Laser-induced nerve ablation is also another form of physical neurolysis. A small study of 21 patients exhibited 70% pain relief for one year in 17 patients after the laser mediated innervation of superior, middle and inferior portions of the Z capsule on the dorsal surface [30].

Cryoneurolysis

Cryoneurolysis (CN) is a process of denervation using low temperatures of up to −70°C. This ultra-low temperature is accomplished by decompressing nitrogen or carbon–dioxide gas in liquid forms. The low temperature causes blockage in nerve conduction [31]. This procedure is a reasonably safe, less painful, and effective process and provides long–term pain relief via nerve cell death. Although superior to chemical neurolysis, CN is less accurate than RF denervation. A study by Wolter., *et al*. (2011) reported a 50% decrease in Z–joint pain within 6–24 weeks [32]. CN has various advantages, including less tissue damage, less risk of neuroma or neuritis, and accessibility of a larger denervation area at the needle tip [32,33]. Notably, the procedure's success depends on the selection of patients and proper placement of probes.

Chemical neurolysis

Chemical neurolysis involves the use of chemicals, such as alcohol and phenol, to degrade the nerve cells. Both phenol and alcohol provide pain relief for 3–6 months [34].

Nerve extinction requires a high concentration (95–100%) of alcohol [35]. The use of alcohol has several side effects: short-lasting intense pain, irritation to neural structures and surrounding tissues, and local hypersensitivity. Alcohol is associated with a higher rate of neuritis than phenol [6].

The efficacy of 3% phenol in saline is comparable to that of 40% alcohol. Thus, the concentration of phenol is much lower than that of alcohol in achieving the desired neurolysis. Phenol is responsible for the absence of a temporary local anesthetic effect (between 5 and 20 weeks). Aqueous phenol is uncomplicated to use, with a low potential of diffusion, and the absence of severe pain on injection [35].

Imaging–guided decompression of synovial cysts

A synovial cyst is one of the major causes of joint pain and generally presents as nerve root compression. It can cause radicular and neurogenic claudication symptoms, depending on their location, size, and adjacent structures. Computed tomography [CT]–guided decompression of synovial cysts involves injecting the affected joint with a mixture of steroid, anesthetic, and contrast followed by insertion of an image-guided needle into the cyst, rupturing it. This procedure is considered to be an efficient and minimally-invasive process—in which steriods reduce procedural inflammation [36].

Surgical management

Surgical management of Z–joint-generated pain is recommended in severe cases when facet joints are fractured or displaced, and are beyond the scope of nonsurgical methods and management. Other facet joint conditions treated by surgical means include synovial cysts, spinal stenosis (narrowing of the spinal canal), and degenerative disc disease [6,21,37]. Spinal nerve root compression can be addressed by surgical means. The surgical intervention for facet joint disorders includes decompressive laminectomy, foraminotomy, facetectomy, and use of a prosthetic implant. However, surgical intervention is not the first choice of treatment, as it involves various risks and complications.

Other surgical methods include decompressive laminectomy followed by removal of synovial cysts. During the laminectomy, the vertebrae's rear portion is removed along with bones and ligaments [37]. Large synovial cysts can cause nerve root impingement and radiculopathy. Medial facetectomy is performed with a laminectomy to mitigate such conditions [21]. The complications associated with laminectomy are neural tissue damage, instability, neurogenic claudication, and anesthesia-related complications.

Another type of decompression surgery, termed foraminotomy, involves removing bones and tissue to reduce pressure on spinal nerve roots. The conventional midline open foraminotomy is being replaced by minimally-invasive lateral foraminotomy. The latter being an effective alternative technique for treating radiculopathy due to foraminal stenosis [38].

Facetectomy is a surgical process to alleviate compression on the spinal nerve root near the facet joint. The most common facetectomy procedure is medial facetectomy with laminectomy and foraminotomy to treat leg pain and radiculopathy. Complete facetectomy is performed in lumbar fusion, such as transforaminal or posterior lumbar interbody fusion and pedicle screw fixation, or for far lateral disc herniation. This procedure involves removing the entire joint, while having more severe complications, such as pronounced spinal instability [39]. In far lateral disc herniation, unilateral facetectomy, which has less instability risk (< 3%), is performed. Unilateral facetectomy does not disrupt other posterior elements (i.e. preservation of the spinous processes, interspinous and supraspinous ligaments, laminas, and the contralateral facet joint). Other types of facetectomy are partial, medial, and lateral facetectomies that preserve almost 50% of the facet joint and carry a lower risk of instability [40,41].

Z-joints of the cervical spine

Z-joints are present in the postero-lateral aspect of the spine. Degeneration in the cervical spine facet joints (Z-joints) is one of the most common causes of chronic neck pain; 55% of the facet joint complications arise from cervical vertebrae, whereas 31% are from lumbar vertebrae [42]. Moreover, C2-C3 Z-joint arthropathy—responsible for 70% of the cervicogenic headaches—is experienced in approximately 4% of the middle-aged population [43]. Genetic aberrations, unhealthy lifestyle, disease, and depression are various risk factors associated with cervical facet joint complications [44].

The anatomy of cervical facet joints is similar to those of the lumbar region; both areas consisting of bony articular pillars, synovium, and fibrous joint capsules. In the cervical spine, Z-joints are oriented in a coronal-oblique plane, whereas, in the thoracic spine, they are oriented in a coronal plane.

Generally, the Z-joints are innervated by the nerves from the medial branch of dorsal rami of the same level and above it. However, there are two exceptions to the cervical facet joints. The third occipital nerve and a separate articular branch of the posterior ramus of C3 innervate the Z- joint of C2- C3. The C3-C4 Z-joint is innervated by the C3 medial branch nerve [45].

An uncovertebral joint, also known as Luschka's joint, is present in the developed cervical spine at levels C3–C7, also containing bony pillars and responsible for specific neck pain when compromised. There are multiple causes in the etiology of cervical joint pains. Whiplash (rapid flexion-extension) injuries can result in neck pain [46]. Radiculopathy can occur due to synovial cysts [47], among other causes. Compromise of the intervertebral disc (IVD) can result in various forms, types, and intensities of discogenic pain [48].

Arthropathy in the upper cervical region can lead to limited head rotation, making it difficult to perform daily tasks and reduce the patient's quality of life (QoL). A reduction in Qol contributes to depression, especially in elderly patients [48]

Pain in the cervical facet joints is treated by blocking the medial branch of the dorsal rami that pass through the painful joints. Local anesthesia is regularly used to block pain [49]. Medial branch blockers are preferred for intervention over intraarticular Z-joint injections due to their ease of administration. Moreover, intraarticular Z-joint corticosteroid injections are mostly ineffective for cervical Z-joint pain [50]. The chances of a false-positive result after nerve-blocking is 27-63% in the cervical spine and 58% in the thoracic spine. A second diagnostic block using a different anesthetic is performed [50].

Z-joints of the thoracic spine

The treatment for Z-joint-related pain of the thoracic spine is similar to that of the lumbar and cervical spines. However, Z-joint disorders of the thoracic spine are far less prevalent (3rd) that those occurring in the lumbar spine (1st) and cervical spine (2). Thus, to avoid repetition, no further mention is made herein regarding treatment methods for the Z-joints of the thoracic spine, except to note that the thoracic spine, in general, has unique characteristics that present distinct treatment challenges, requiring particular surgical interventions [51].

Emerging treatments

An emerging treatment for chronic zygapophysial-generated pain employs a minimally-invasive facet restoration implant. Patients no longer responsive to nonsurgical treatments are chosen for the implant. This procedure is a relatively new with only two studies completed to date. The of FENIX implant (bilaterally implanted FENIX facet resurfacing device) displayed a positive effect on patients—a 72% reduction in back pain severity in 1 year [52].

A study by Meisel., *et al*. (2014) involved a Glyder device implant and showed a 41% reduction in the back pain severity in 1-year follow-up [53]. The complication for implant technique involves migration of implant (12.5% cases for FENIX and 8% for Glyder). The Glyder implantation process is straightforward and preserves the native anatomy of the spine as opposed to FENIX. However, a comparative superiority analysis of implants and other surgical treatment methods is needed.

Non-opioid analgesia

According to Flores and Kerna (2020): “Currently, the United States is in the throes of an opioid epidemic. Opioid use disorder (OUD) accounts for significant national, state and local resource allocation in an attempt to reduce the number of deaths related to opioid overdose” [45]. The authors continue: “Specific and current studies indicate that opioids are not necessary when using a comprehensive integrative approach for opioid-free perioperative acute pain management of nonspinal orthopedic surgical procedures. Utilizing opioid-free perioperative acute pain management in nonspinal orthopedic procedures is a vital factor in achieving UOD-reduction and curtailing and eliminating the opioid epidemic” [54].

Conclusion

Chronic back pain is one of the leading causes of disability experienced worldwide [55]. The risk factors in zygapophyseal joint degeneration are trauma, age, lifestyle, inadequate nutrition, overuse, and lack of exercise. The treatment for back pain due to facet joints involves both conservative and surgical modes. However, one of the most significant issues with a Z-joint disorder is recurrence. Therefore, patients with a Z–joint disorder tend to experience a lesser quality of life. Chronic low back and neck pain of facetal origin are serious global healthcare issues, The the diagnosis, treatment and management, and work lost from such conditions are a significant emotional and financial burden to the patient, their family and community, and society as a whole. Z– joint disorder symptomatology can mimic those of other causes of spinal nerve root compression. Thus, the competent use of imaging techniques and other testing procedures are crucial to differentially diagnosis and select and apply appropriate treatment. The management and treatment of Z-joint disorders is a team effort and the radiologist’s role is crucial in identifying the anatomical cause of the condition.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Supplementary Note

As the opioid epidemic continues, unabated, non-narcotic and non-opioid alternatives to pain management and surgical analgesia are actively sought. It is beyond the scope of this paper to delve into this specific, albeit imperative topic. However, the reader is referred to two publications on this topic by John V Flores, PhD, MBBS, DC and Nicholas A Kerna, PhD, MD, MPH, DNBCE. The citations and links are provided as follows:

- John V Flores and Nicholas A Kerna. "Eliminating Opioid Dependency by Knowing the APTA (Anatomy, Pathophysiology, Treatment and Assessment) of Pain". EC Orthopaedics 11.5 (2020): 31–39. DOI: 10.31080/ecor.2020.11.00616. LINK: https://www.ecronicon.com/ecor/pdf/ECOR-11-00616.pdf.
- Flores JV, Kerna NA. "Opioid-Free Perioperative Acute Pain Management in Nonspinal Orthopedic Procedures". EC Orthopaedics 11.6 (2020): 22-37. DOI: 10.31080/ecor.2020.11.00629. LINK: https://www.ecronicon.com/ecor/pdf/ECOR-11-00629.pdf.

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