

Finger Joint Contusion and the Pain Mechanisms behind the Finger Joint Contusion

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Abstract. Finger joint contusion is an unrecognized but common blunt traumatic injury, and it is of great frequency in everyday injuries and professional sports, such as basketball and volleyball. Being a seemingly small musculoskeletal trauma, its slow or even mal-managed treatment tends to result in chronic pain, joint stiffening and irreversible hand impairment, which, in turn, makes this clinical issue indispensable. The proposed study is dedicated to the finger joint contusion and attempts systematically to examine the pathology of the related severe acute and chronic pain and to discuss the existing clinical interventions in terms of the current research progress. It explains the anatomical injuries of damaged joints in the fingers, and refers to three interconnected mechanisms of pain: post-traumatic inflammatory response, peripheral nociceptor sensitization and central sensitization in chronic situations, and differentiates the pathophysiological mechanisms of both acute and chronic pain pathways. The gap in the specific pain studies of this widespread injury, the theoretical basis of accurate clinical pain examination and individualized treatment, and the practical advice on curing injury and preventing the functional sequelae of this injury in clinical and sports medicine is filled in this study.

Keywords: Finger joint contusion, pain mechanism, peripheral sensitization, inflammatory response, joint soft tissue injury

1. Introduction

Finger joint contusion is an adverse injury of the joints of the fingers through direct collisions, forced twisting or pressing, which occurs in everyday life, in the course of manual labor and ball sports (basketball and volleyball). The joints of the fingers have a complicated arrangement of ligaments, joint capsules, articular cartilage and soft tissues and are highly flexible but lowly resistant to external mechanical force, which causes them to be easily affected by contusion. Among the acute symptoms are severe acute pain, localized swelling, effusion and loss of mobility in the joint, but the majority of the patients make it through as a trivial injury without any standardized treatment. Nevertheless, unaddressed contusions frequently lead to chronic pain, joint instability and a permanent malfunction of hands that imposes a significant burden on everyday life and sporting performance. Unlike severe injuries in the form of fracture or dislocation of the fingers, this injury does not present itself with any visible structural impairment in regular imaging, which has caused the injury to be left unaddressed in the past, in orthopedic and sports medicine research.

The focus of current world studies on fracture of the finger joints is based on extreme cases, such as proximal interphalangeal (PIP) fracture of the joint dislocated and rupture of the ligament, which is at a mature stage of surgical repair and orthosis fixation. The effectiveness of PIP joint dorsal blocking orthoses has been studied in relevant studies, local blood flow measurements following severe injuries to the PIP joints and a study of finger ligament biomechanics [1-3]. However, the high-incidence mild to moderate issues of the finger joint contusion have not been subjected to research and the minimal literature of a systematic study to cause severe pain is highly limited. The few associated reports vaguely bring up the concept of post-traumatic inflammation, but do not contribute to the analysis of the transmission of pain or peripheral and central sensitization processes or the injury-pain intensity relationship. Generally, the study of finger joint contusion is still in the preliminary stage, as it is not accompanied by a more thorough theoretical framework and a specific set of interventions to address it, which is not in proportion to its prevalence and the clinical dangers.

Since the trauma of finger joint is very prevalent, yet there is a lack of relevant studies and clinical pain management issues, this widespread injury is a focus to elucidate its pathophysiological and biomechanical aspects of the injury, to disarrange a post-traumatic pain process, and to establish a theoretical frame of reference that allows uniform clinical management of injury. The framework will be subdivided into three sections, including the elaborated anatomical features of the finger joints and biomechanical alterations in the impact site to exemplify the structural foundations of contusion, the analysis of the three fundamental pain mechanisms and the contribution of inflammatory mediators, and lastly, a summary of the functional effects of untreated contusions and suggestions of the clinical intervention improvements to address the research gap and inform clinical practice and preventive strategies of sports injuries.

2. Finger joint contusion- anatomical base

Finger joint contusion is a frequent closed traumatic injury, which is characterised by blunt mechanical force, which directly damages the surrounding soft tissues, capillaries, volar plate or supportive stabilising ligaments. This trauma presents with a typical localized pain, swelling of the soft tissues, joint rigidity and limitation of the functional range of movement, and the most severe ones can result in the inability to perform the vital functions of the fingers, such as gripping, handwriting and fine manual tasks. Sportspeople and workers' umbrella groups are particularly susceptible to this kind of injury because the repeated hand movements and the lack of protective measures against external forces increase the chances of an acute wound to a significant degree. Proximal interphalangeal joint sprain and collateral ligament injury are likely to occur clinically as evidence of finger joint contusion [1]. It is a wide-range clinical injury spectrum that encompasses both simple isolated soft tissue strains to complex joint instability and covert multiple etiological mechanisms (osseous). Most mild cases are ignored in daily life because of the lack of apparent fracture, but if left untimely or untreated and improperly handled, they may directly cause persistent swelling, pain and a long-term restriction in movement. Typical external forces with a trauma are axial impact of the fingertip, direct blunt trauma, and excessive longitudinal traction, three leading causative forces in both clinical and athletic medicine, and sports injury involving over fifty percent of all reported contusions of the finger joints in recent clinical surveys.

In each functional finger, there are three sequential phalanges which consist of the proximal phalanx, middle phalanx and distal phalanx. These bones create three major articulating joints, like the metacarpophalangeal joint, the proximal interphalangeal joint and the distal interphalangeal joint. The part of the finger joint contusion most likely to be affected is the proximal interphalangeal

joint because it carries a lot more mechanical load and stress during grasping and functional movements of the fingers and hence is more vulnerable to trauma due to sporting activities [2]. Finger joint contusion, however, is not confined to the bony injury but is mostly in the specialized soft tissue structures that ensure the stability and movement of the joint, such as the joint capsule, collateral ligaments, volar plate and its tendons [3]. The joint capsule is a fibrous connective tissue structure encircling the articular surface that serves to stabilize the joint as well as maintain integrity in the articular and synovial fluid. A tiny quantity is also produced in the joint capsule, which lubricates the joint. Subsequently, after contusion, there can be stretching, fissures of micro-tearing, and foci of inflammatory alterations of the joint capsule, which directly cause swelling, pain and post-traumatic joint stiffness. Minor micro-tears may lead to the development of ongoing inflammatory exudation, resulting in prolonged swelling that takes weeks to heal, resulting in ongoing swelling that does not resolve during movement, triggering a normal joint gliding cycle of limited motion and more tissue irritation. Within the PIP joint, there are bilaterally positioned collateral ligaments with reference to the ulnar and radial collateral ligaments. These structures ensure that the coronal plane joints remain steady and do not deviate too far to the right.

Given the instability of the joints and the painful movements in finger joint contusion, these ligaments have a high likelihood of being sprained and damaged partly. The volar plate is a volar (palmar) based fibrocartilaginous feature of the PIP joint and is located along the volar side of the articulation. Its main action is to inhibit the overextension of the joints and sustain the PIP joints at their station. Volar plate sprain and avulsion injury are the common types of injuries that commonly present as hyperextension-based pain and diffuse swelling of the joint. The movement of the fingers is dependent on two functional tendon categories, such as flexor tendons and extensor tendons. Flexor tendon complex refers to the flexor digitorum profundus and flexor digitorum superficialis that control the head-flexion and grasping of fingers.

Tendon irritation and inflammatory alterations in contusion can result in painful active flexion and a decrease in grip strength. The extensor tendon complex facilitates extension of the fingers and inflammatory or traumatic injuries result in painful extension and a decreased active range of motion. The fingers are very heavily endowed by double digital nerves, such as the radial digital nerve and ulnar digital nerve that serve to convey tactile sensation and perception of nociceptive pains. Nerve involvement associated with contusion can result in cutaneous hypersensitivity, local numbness and neuropathic pain, which is the reason behind the excessive pain intensity necessitating seemingly minor injuries on fingers. The digital blood source is provided by normal digital arteries, and microvascular damage due to contusion results in soft tissue blood loss, topical edema, exaggerated inflammatory reactions and heightened pain diffusion. To conclude, finger joint contusion entails injury to a mixture of functionally linked complex anatomical units comprising bones, ligaments, joint capsules, tendons, peripheral nerves and vascular units. Joint structural injury causes the typical clinical manifestation: pain, swelling and functional deficits.

3. Finger joint contusion biomechanical mechanisms

Finger joint contusion is the sudden application of external mechanical forces in damaging strategic joint stabilizing structures such as collateral ligaments, joint capsules and volar plates, which also causes local inflammatory processes and consequently causes functional disability. Clinical and biomechanical studies have determined five main interdependent mechanisms of injury that may cause this condition, where most clinical cases entail isolated or conjoined mechanical loading patterns. The most frequent method of contusion of the finger joints is axial loading. The pattern of force in this case arises when the tip of the fingers suddenly contacts, but in a direct blow, and the

stress is being exerted along the length of the finger. Examples would be getting hit by a ball in the catching process, a direct blow of a hard object or abrupt axial strain when playing a sport, a common phenomenon known as a jamming finger injury. This mechanism is very prevalent in the ball sports like basketball, volleyball and baseball, whereby the players often make attempts to block or catch with their extended fingers and leave the joint vulnerable to impulsive tangential force. The biomechanical evidence proves that the axial load that is known to be transferred to the fingertip causes notable compressive forces on the PIP joint and in the soft tissue structures that surround it, mainly, the collateral ligaments, volar plate and joint capsule, where the stretching or micro-tearing is observed [4].

The focused pressure on the PIP joint is one of the reasons why the region is much more liable to contusion compared to the other joints of the fingers when subjected to such a force. The second most common mechanism is called hyperextension injury and it takes place when the joint of the fingers is subjected to an extension, enhancing the typical physiological extent of the joint. This mechanism exerts excessive tensile stress on the volar plate; it causes volar plate strain, joint capsule injury and soft tissue contusion. Hyperextension force has been clinically found to cause isolated PIP joint injury in a majority of cases and biomechanical testing shows that joint hyperextension causes axial load distribution and structural stress in the PIP joint to increase significantly [5]. The mechanism is quite prevalent in ball sports such as basketball and volleyball. The lateral joint deviation is a movement of the finger that is directed to a radial or ulnar direction by a coronal plane force exerted on the digit. The result of this pattern of forces is unilateral collision of collateral ligaments, sprains, and consequent joint instability. The collateral ligaments are the main stabilizers of the PIP joint and are very vulnerable to trauma in case of lateral loading conditions [4].

Rotational injury or twisting injury occurs when the finger is caught unawares and the distal digit is stationary, resulting in multiple torsional and shear loads inside the joint. This pattern of forces impairs the stability of the soft tissue and can lead to strain on joint capsules, micro-tearing of the ligaments, diffuse contusion of the soft tissue, as well as in low-demand daily physical activities and competitive sports. Biomechanical research now validates that rotational force induces intra-articular shear stress, which is thought to be damaging soft tissues and secondary instability in the joint [6]. High-energy trauma is a rarer yet more extreme pathology, which happens after being inflicted by sudden, intense, external force in contact sports, occupational accidents or high-impact falls. This is a high-impact, high mechanical stress mechanism that often causes concomitant soft tissue and intra-articular injury [7]. Combined loading patterns, such as axial loading with hyperextension or axial compression with lateral deviation, are the cause of most injuries in the case of isolated mechanical forces on the joints of the fingers in clinical practice. These compressive and tensile stresses are combined at the same time, resulting in simultaneous ligamentous, capsular and volar plate trauma. In sum, five fundamental biomechanical processes lead to finger joint contusion and might occur independently or interactively to ruin important joint stabilizing structures.

4. Pathophysiological pain mechanisms

Four different yet interrelated pathophysiological processes mediate pain following contusion of the joints of fingers, and all of them combined frequently result in greater pain than one would have expected with the minor soft tissue damage. The first acute process invoked by the discharge of inflammatory mediators, prostaglandins, and cytokines, after the damage of the soft tissue, is inflammatory pain. These chemical messengers are emitted several hours after the trauma, and they not only excite the peripheral nociceptors, but they also raise the vascular permeability, adding to local swellings and further squeezing nerve endings to enhance the signal of pain. Such chemical

mediators stimulate the peripheral nociceptors directly, and result in local swelling, inflammatory pain and joint stiffness and such kind of pain typically reaches a peak in 24 to 48 hours following an injury and subsides slowly with adequate anti-inflammatory treatment [8]. Neuropathic pain occurs in cases where the digital nerves are traumatized, resulting in burning pains, cutaneous hypersensitivity and parasthesias resembling electric shock pain [9]. Mechanical pain is a direct result of structural injury of joint tissues, such as tension of ligamentous fiber, capsular distention and stress due to post-traumatic edema, which indicates the immediate nociceptive reaction to injury. The various forms of central sensitization might be attained following extended or intense acute pain, which consists of spinal cord sensitization and enhanced processing of pain in the central nervous system. This pathophysiological change manifests itself in long-lasting unremitting pain and hyperirritability of the responses the pain shows to the stimuli that otherwise are not noxious. In difficult refractory cases, the process can advance to complex regional pain syndrome that constitutes a chronic pain disorder that is indicated by intractable pain, excessive swelling, changes in skin temperature and color, as well as significant functional impairment.

5. Joint contusion of the finger: functional effects

Functional effects of finger joint contusion result in pain and structural damage that have quantifiable effects in three clinical domains of interest: acute recovery and long-term musculoskeletal function and these effects are not well captured by clinicians because of the minimal size of the finger joints. Primarily, there is a severe deterioration of the overall hand motor functions, an objective decrease in grip strength, fine motor dexterity and the active joint range of motion has been reported in clinical research [10]. Even simple pain is enough to make patients avoid the use of the injured finger and this is followed by disuse atrophy of small hand muscles and a further loss of function as time goes by. Secondly, there is a drastically disrupted way of people living their everyday lives, as the affected people complain that they have problems in everyday routine, such as writing, manipulation of objects, typing, and using computerized gadgets, and all these activities involve the use of stable and flexible fingers. Third, unresolved tissue injury and failed acute pain may develop into chronic functional disability and lasting activity restriction, dysfunctional work performance, and loss of life quality among high-risk groups, including manual workers, athletes and students who have to use their hands extensively in their daily activities and in their professional activities.

6. Conclusion

Finger joint contusion is a common but generally under-investigated traumatic injury with complex structural effects and multifactorial pain processes. As this paper has shown, even though it is commonly viewed as a low-level trauma, finger joint contusion can cause severe functional disability in instances when not identified and treated in time. The paper was a systematic analysis of the anatomy of the finger joint contusion with emphasis on the critical structures that include the joint capsule, collateral ligaments, volar plate, tendons, and neurovascular structures. It also has established five major biomechanical processes, such as axial loading, hyperextension, lateral deviation, rotational force, and high-energy trauma, that usually interplay with one another to cause tissue damage. More to the point, the research indicated that the presence of pain after a finger joint contusion is not purely mechanical, as it is caused by the interplay of various pathophysiological mechanisms. Cytokine and prostaglandin-mediated inflammatory responses cause acute pain, whereas peripheral sensitization reduces nociceptive thresholds, whereby small stimuli become

painful. In other instances, a sustained nociceptive input can cause central sensitization, which increases pain sensitivity and causes chronic pain. These processes combine to result in disproportional amounts of pain as well as lengthy recovery due to seemingly mild injuries. The results of the current research are much more acceptable in relation to understanding the underlying process of finger joint contusion and present a theoretical foundation in terms of the enhancement of clinical appraisal and management approaches. This paper also defends the value of early intervention and specific management to avoid the chronic complications and functional deterioration through incorporating recent research evidence. Nonetheless, there are quite a few limitations of this study. Studies of finger joint contusion have not been as numerous as those investigations that have been made on bigger joints like the knee and shoulder. Moreover, some of the inferences cannot be generalized due to the absence of quality clinical trials specifically addressing finger injury. Future studies are encouraged to work on providing standardized diagnostic criteria, researching more accurate pain modulation processes, and performing longitudinal and experimental research to determine the usefulness of a particular type of a treatment intervention. These attempts will help to prevent, manage, and rehabilitate knee and finger joint contusions in both clinical and athletic groups better.

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