

## **Review Article**

### **COMPLICATIONS IN FRACTURE HEALING-A REVIEW**

**Running title:** Complications in fracture healing

**Type of research:** Review

#### **ABSTRACT**

Complications are a reality in healing fractures. Most can be stopped or reduced by being aware of their pathophysiology. Others, though, are inevitable, but their Early diagnosis and effective treatment can help recovery. Significant complications Are Osteomyelitis, delayed union, nonunion, malunion, premature union, which were a result of fracture repair. Keeping these complications into consideration Presurgical patient assessment as well as postoperative treatment should be taken into account. The goal of fracture repair is to ascertain rigid fixation and perfect alignment of the bone to permit each timely and maximized come to perform in the affected space. The particular injury, species and breed conformation, age, general health, concomitant malady processes, nutrition, and medications all play a job in healing and, therefore, response to the repair. However, these factors don't seem to be the sole determinants of outcome. the strategy of repair and surgical technique each play a vital role within the outcome of fracture management. For this reason, it's vitally necessary that the practitioner be aware of potential complications of fracture repair and take steps to stop them. This review centers on how these complications can be prevented, understood and handled.

**KEYWORDS:** Complications, Fracture, Nonunion, Malunion, Myositis Ossification, Joint Stiffness

#### **INTRODUCTION**

Optimizing the results of fracture treatment needs a holistic read of each patient and treatment. the character of the patient determines the priority targets for the outcome, that differ widely between the old and also the young, and between the victims of high and low energy trauma. The effectiveness of the treatment depends on the general method of care and rehabilitation also because of the strategy adopted to attain bone healing(1)(2,3) The rational basis for fracture treatment is that the interaction between 3 elements. (i) the cell biology of

bone regeneration, (ii) the revascularisation of devitalized bone and soft tissue adjacent to the fracture; and (iii) the mechanical setting of the fracture

Fracture restoration aims to set up inflexible fixation and perfect alignment of the bone to allow both well-timed and maximized return to the characteristics of the affected area(4,5). The particular injury, species and breed conformation, age, general health, concomitant sickness processes, nutrition, and medicines all play a function in recovery and, therefore, response to the repair(6,7). But these elements are now not the sole determinants of outcome. The method of restoration and surgical method both play an essential function in the result of fracture management. For this case, it is vitally necessary that the clinician be conscious of achievable issues of fracture restore and to take steps to stop them(8). Osteomyelitis, delayed union, non-union, malunion, untimely physical closure, and sarcoma associated with a fracture are significant concerns(9).

Bones are solid, but when an outside force is applied, they bend or "give" slightly. However, the bones will snap if the impact is too strong, just like a rubber ruler breaks when it is twisted too far. A fracture's magnitude typically depends on the force that caused the crack. If only slightly exceeded the breaking point of the bone, then the bone may crack rather than break all the way through(10). The bone can fracture if the force is serious, such as in a car accident or a gunshot. The fracture is considered an open fracture if the bone fractures in such a manner that bone fragments stick out of the tissue, or a wound penetrates down to the fractured bone. This form of fracture is especially dangerous because once the skin is torn, inflammation will spread to the wound as well as the bone(11,12).

Drops and injuries cause most bone fractures. Disease-induced bone fractures are referred to as pathological fractures(13). There are a variety of different forms of fractures, including avulsion, comminuted, and hairline fractures, a compound fracture that also causes injury to the overlying skin. Bone healing is a normal mechanism that focuses on providing ideal conditions for the bone to repair itself(14). Localization and seriousness of injury are key factors affecting the treatment decision of the surgeon and the anatomical and functional outcome of the patient. These factors are often cataloged according to the description and subsequent classification of fractures and soft-tissue lesions(15).

Regardless of the intervention process, restoration of natural anatomy is the primary purpose. In decision-making, problems associated with both non-operational and operative management are a significant consideration(16). Non-operational care is the only suitable control for certain kinds of fractures, e.g. stable undisplaced injuries, since operative management of these types of injuries could subject these patients to the needless complications of surgery which has been called 'over-treatment.' When choosing the type of management, patient preference is vitally important. Patients with diseases such as diabetes and peripheral artery disease are well known to be at higher risk for complications and to have an unsatisfactory outcome. There is also controversy in the treatment of elderly patients with osteoporotic problems(17).

This paper provides an up-to-date review of potential risks and complications in the healing of the fracture.

## CAUSES

When there is more strain added to the bone than the bone can withstand, fractures result. When they are bent, the bones are the smallest(18). Falls, trauma, or as a result of a direct hit or knock to the body may cause fractures in the bones. Via trauma. During a football game, a

fall, a motor vehicle crash, or a tackle can all result in fractures. With osteoporosis. This condition makes the bones weaker and more likely to break. Overexploitation. The repeated movement will fatigue muscles and put more force on the bone. This can lead to fractures from tension. In sports, stress fractures are more prevalent(19).

## TYPES

Avulsion fracture means a muscle or ligament is pulled on by a bone, breaking it. A comminuted fracture means the bone is broken into a lot of pieces. Compression (crush) fracture generally occurs in the spongy bone in the spine(20). The front portion of a vertebra in the spine, for instance, may collapse because of osteoporosis. Fracture dislocation means a joint is dislocated and there is a fracture in one of the bones of the joint. Greenstick fracture means, on one hand, the bone partially cracks but does not crack fully so the rest of the bone will bend. This is more prevalent in children whose bones are more elastic and smoother. A hairline fracture means a partial bone fracture. With routine X-rays, this type of fracturing is often harder to spot. An impacted fracture means One fragment of bone enters another fragment when the bone is fractured(21). An intra-articular fracture means where the fracture reaches through the joint surface. A longitudinal fracture means a break along the lengthwise of the bone. An oblique fracture means a fracture that is diagonal to the long axis of a bone. A pathological fracture means an underlying disease/condition weakens the bone(22). A spiral fracture means a fracture that has bent at least one portion of the bone. Stress fracture means deformation of bone due to the high level of stress(23). In Torus fracture bone deforms but does not crack. In Transverse fracture Right across a tendon, a straight split is seen.

## INVESTIGATIONS

The recovery plan for any fracture depends largely on the diagnosis made. This investigation protocol, therefore, plays a major role in fracture healing. The investigation procedure should first begin with the history that involves the nature of the activity, the nature of the event, the point of impact and the position of foresite, the location of pain, loss of function, and severe co-morbidities(24).

The next stage will be physical inspection, which includes the search for asymmetry, swelling, discoloration, and injury to the skin, accompanied by a sensation of tenderness, crepitus, and pulses, followed by activity regulated by pain and tenderness during movement and decreased ROM.x-ray'S are the major investigation and confirmation method. CT scans are medical imaging tests that provide clear photographs of internal organs, muscles, soft tissue, and blood vessels.Magnetic resonance imaging (MRI): Since certain injuries (such as stress fractures) don't turn up on an X-ray for a couple weeks after the bone begins to hurt, MRI is used as a tool of investigation. A bone scan is an imaging test used to help diagnose problems with your bones(25). A relatively small quantity of a radioactive substance called a radiopharmaceutical is used safely. It has also been identified as a "dye," but the tissue is not stained(26). Specifically, a bone scan is performed to discover bone metabolism disorders. Our team has extensive knowledge and research experience that has translate into high quality publications (1).(2,8,9,17,27–36) ,(22,23,26,37,38)

## TREATMENT

Particular treatment that will be required for the patient will be determined by the doctor based on the patient's health conditions, medical history, age of the patient, the extent of the fracture, tolerance for the medical procedure, treatment, and medicines. Expectations from healing and the patient's thoughts and importance play a major role in determining the type of treatment to be given. Therapy aims to manage the pain, facilitate healing, avoid complications, and recover the injured area to normal use(39).

Splints stop the broken limb's movement Braces are used for protecting the bone from further hard actions during the healing period. To provide protection and immobilize the bone, plaster casts are mostly used. Traction is a less prevalent option done to treat the fracture(40). To keep the fragments of bone together, surgically inserted implanted metal rods or plates are highly preferred. Intra-medullary nails are positioned in the middle of long bones with internal metal rods. In infants, flexible wires can be used(41). External fixators can be made of metal or carbon fiber; they have pins of steel that go straight through the skin through the bone. Outside the body, they are a type of scaffolding(42). Usually, for 2-8 weeks, the broken bone region is immobilized. The length depends on which bone is damaged and if complications, such as a problem with blood flow or an infection, are present. Pain killers are generally suggested for Relieving pain(43).

## COMPLICATIONS

### OSTEOMYELITIS INFECTION

Osteomyelitis, a rare but dangerous disease, is an inflammation of the bone. Bones can become infected in a variety of ways: infection can spread through the bloodstream through the bone in one part of the body, or an exposed fracture or surgery can expose the bone to infection or form a complication in the healing of the fracture(44). The etiology of this complication is an entry on bacteria during trauma or surgery. The Gross character of this complication is fever, chills, and bone pain; later, swelling and redness may develop around the area of infection. X-RAY for this type of complication is done through radionuclide bone scans. Treatment options available for this typically require surgery to remove dead parts of the bone. This is followed by strong, sometimes intravenous, antibiotics for at least six weeks.

### MALUNION

The bone will heal with a deformity called a malunion if the two ends of the fractured bone are not lined up correctly. A malunion fracture occurs when fresh tissue has filled a wide gap between the displaced ends of the bone(45). The etiology of this complication is -improper reduction, unchecked muscle pull, excessive communication. Gross characters appear to be deformity, shortening of the limb, limitation of movements. In X-RAY new bone growth can be seen. Treatment options available for this are osteoclasts: refracture, done in children to correct mild to moderate angular deformities, redoing the fracture surgically: most common, corrective osteotomy: performed at a site away from the fracture, excision of protruding bone.

### NON-UNION

Nonunion is a permanent healing deficiency after a fractured bone before an operation is done (such as surgery)(46). Etiology of Nonunions happens when the bone lacks adequate stability, blood flow, or both. Gross characters appear to be a pain, swelling, improper

mobility In X-RAY ends are rounded, the smooth sclerotic. The medullary cavity may obliterate with visible fracture line. Treatment options available are Bone grafting, excision of fragments: when it can be done with minimal loss of function, Ilizarov method, no treatment: when there is no disability

### DELAYED UNION

A delayed union means that the bone has taken or is taking longer to recover than expected, but without the need for further surgery, it is expected to finally heal(47). The etiology of these complications are malnutrition, diabetes, smoking, use of tobacco, using of NSAIDs. Gross characteristics appear to be deformity, abnormal mobility, refracture. In X-RAY inadequate callus can be seen. Treatment can be prolonged conservative management, surgical-intervention: bone grafting with or without internal fixation

### JOINT STIFFNESS

The sensation that a joint's mobility is constrained or impossible is joint stiffness(48). The etiology of this disease is Intraarticular or para articular adhesions secondary to immobilization, contracture of the muscles around a joint because of prolonged immobilization, tethering of muscles at the fracture site, myositis ossificans. Gross characteristics hamper normal physical activity, result in late osteoarthritis, pain, hyperaesthesia, tenderness, swelling. X-RAY shows spotty rarefaction. Treatment options available are heat therapy, manipulation of the joint under anesthesia, surgical interventions.

### MYOSITIS OSSIFICATION

Myositis ossificans is a disease in which bone tissue develops following an injury within the muscle or other soft tissue(49). The etiology of myositis ossificans can be an acute deep-muscle bruise or repeated muscular trauma to the same spot, and rarely is caused by a bad muscle strain. Gross characteristics appear to be pain, tenderness, focal swelling, joint/muscle contraction. X-RAY: Radiographs show peripheral bone formation with a central lucent area and may appear as a “dotted veil” pattern. MRI with gadolinium shows rim development in the initial weeks. CT scan shows that the lesion has an eggshell appearance. Massage following injury is strictly prohibited, in early-stage rest is advised, NSAIDs may help to reduce pain.

### CONCLUSION

Complications are a truth of fracture repair. However, surgeons can limit the incidence of these problems by understanding their pathophysiology and etiology. Additionally, the effect on fracture can be decreased by using instant analysis and treatment. The cornerstone of avoidance remains to be a commitment to sound surgical procedures, effective fracture fixation judgments, and a detailed understanding of nearby anatomy.

Table 1. Comparative overview of literature

LITERATURE COMPARISON	RELATION TO COMPLICATION IN FRACTURE HEALING	DEPENDENT VARIABLE
	++++	Excessive bleeding, infection

	++	Neurovascular injury
	+	Joint stiffness
	nil	Treatment of fracture
	++	Bone scintigraphy, CT scan
	+	Fibrocartilaginous callus, remodeling
	++	Myositis ossificans
	++++	Tenderness, swelling
	++	Malunion
	+	Non-union
	++	Bone scan, radiopharmaceutical
	nil	
	++	Bone healing, Repairing
	+	Delayed union
	+++	Osteomyelitis
	+	Stress fracture, overexploitation
	++	Hematoma, bony callus

## REFERENCES

1. Anita R, Paramasivam A, Priyadharsini JV, Chitra S. The m6A readers YTHDF1 and YTHDF3 aberrations associated with metastasis and predict poor prognosis in breast cancer patients. *Am J Cancer Res.* 2020 Aug 1;10(8):2546–54.
2. Jayaseelan VP, Paramasivam A. Emerging role of NET inhibitors in cardiovascular diseases. *Hypertens Res.* 2020 Dec;43(12):1459–61.
3. Harsha L, Brundha MP. Prevalence of Dental Developmental Anomalies among Men and Women and its Psychological Effect in a Given Population. *Journal of Pharmaceutical Sciences and Research; Cuddalore.* 2017 Jun 20;9(6):869–73.
4. Sivakumar S, Smiline Girija AS, Vijayashree Priyadharsini J. Evaluation of the inhibitory effect of caffeic acid and gallic acid on tetR and tetM efflux pumps mediating tetracycline resistance in *Streptococcus* sp., using computational approach [Internet]. Vol. 32, *Journal of*

King Saud University - Science. 2020. p. 904–9. Available from:  
<http://dx.doi.org/10.1016/j.jksus.2019.05.003>

5. Girija ASS, Smiline Girija AS. Delineating the Immuno-Dominant Antigenic Vaccine Peptides Against *gacS*-Sensor Kinase in *Acinetobacter baumannii*: An in silico Investigational Approach [Internet]. Vol. 11, *Frontiers in Microbiology*. 2020. Available from: <http://dx.doi.org/10.3389/fmicb.2020.02078>
6. Jaisankar AI, Smiline Girija AS, Gunasekaran S, Vijayashree Priyadharsini J. Molecular characterisation of *csgA* gene among ESBL strains of *A. baumannii* and targeting with essential oil compounds from *Azadirachta indica* [Internet]. Vol. 32, *Journal of King Saud University - Science*. 2020. p. 3380–7. Available from: <http://dx.doi.org/10.1016/j.jksus.2020.09.025>
7. Girija ASS, Smiline Girija AS. Fox3 CD25 CD4 T-regulatory cells may transform the nCoV's final destiny to CNS! [Internet]. Vol. 93, *Journal of Medical Virology*. 2021. p. 5673–5. Available from: <http://dx.doi.org/10.1002/jmv.26482>
8. Arumugam P, George R, Jayaseelan VP. Aberrations of m6A regulators are associated with tumorigenesis and metastasis in head and neck squamous cell carcinoma. *Arch Oral Biol*. 2021 Feb;122:105030.
9. Girija SA, Priyadharsini JV, Paramasivam A. Prevalence of carbapenem-hydrolyzing OXA-type  $\beta$ -lactamases among *Acinetobacter baumannii* in patients with severe urinary tract infection. *Acta Microbiol Immunol Hung*. 2019 Dec 9;67(1):49–55.
10. Timothy CN, Samyuktha PS, Brundha MP. Dental pulp Stem Cells in Regenerative Medicine--A Literature Review. *Research Journal of Pharmacy and Technology*. 2019;12(8):4052–6.
11. Mathivadani V, Smiline AS, Priyadharsini JV. Targeting Epstein-Barr virus nuclear antigen 1 (EBNA-1) with *Murraya koengii* bio-compounds: An in-silico approach [Internet]. Vol. 64, *Acta virologica*. 2020. p. 93–9. Available from: [http://dx.doi.org/10.4149/av\\_2020\\_111](http://dx.doi.org/10.4149/av_2020_111)
12. As SG, Vijayashree PJ, Paramasivam A. Prevalence of Acb and non-Acb complex in elderly population with urinary tract infection (UTI) [Internet]. Vol. 76, *Acta Clinica Belgica*. 2021. p. 106–12. Available from: <http://dx.doi.org/10.1080/17843286.2019.1669274>
13. Preethikaa S, Brundha MP. Awareness of diabetes mellitus among general population. *Research Journal of Pharmacy and Technology*. 2018;11(5):1825–9.
14. Spanswick PJC, Whittier DE, Kwong C, Korley R, Boyd SK, Schneider PS. Improvements in radiographic and clinical assessment of distal radius fracture healing by FE-estimated bone stiffness. *Bone Rep*. 2021 Jun;14:100748.
15. Hachemi Y, Rapp AE, Lee S, Dorn A-K, Krüger BT, Kaiser K, et al. Intact Glucocorticoid Receptor Dimerization Is Deleterious in Trauma-Induced Impaired Fracture Healing. *Front Immunol*. 2020;11:628287.
16. Girija ASS, Smiline Girija AS, Shoba G, Vijayashree Priyadharsini J. Accessing the T-Cell and B-Cell Immuno-Dominant Peptides from *A.baumannii* Biofilm Associated Protein (bap) as Vaccine Candidates: A Computational Approach [Internet]. Vol. 27, *International Journal*

of Peptide Research and Therapeutics. 2021. p. 37–45. Available from:  
<http://dx.doi.org/10.1007/s10989-020-10064-0>

17. Anchana SR, Girija SAS, Gunasekaran S, Priyadharsini VJ. Detection of *csgA* gene in carbapenem-resistant *Acinetobacter baumannii* strains and targeting with *Ocimum sanctum* biocompounds. *Iran J Basic Med Sci.* 2021 May;24(5):690–8.
18. Arora A, Mehra A, Saif T. Fracture and Fracture Healing [Internet]. *Orthopedics Quick Review.* 2018. p. 51–51. Available from: [http://dx.doi.org/10.5005/jp/books/13113\\_6](http://dx.doi.org/10.5005/jp/books/13113_6)
19. Zhang L, Jin L, Guo J, Bao K, Hu J, Zhang Y, et al. Chronic Intermittent Hypobaric Hypoxia Enhances Bone Fracture Healing. *Front Endocrinol.* 2020;11:582670.
20. Arvind P, Jain RK. Skeletally anchored forsus fatigue resistant device for correction of Class II malocclusions—A systematic review and meta-analysis [Internet]. Vol. 24, *Orthodontics & Craniofacial Research.* 2021. p. 52–61. Available from: <http://dx.doi.org/10.1111/ocr.12414>
21. Venugopal A, Vaid N, Jay Bowman S. Outstanding, yet redundant? After all, you may be another Choluteca Bridge! [Internet]. Vol. 27, *Seminars in Orthodontics.* 2021. p. 53–6. Available from: <http://dx.doi.org/10.1053/j.sodo.2021.03.007>
22. Varghese SS, Ramesh A, Veeraiyan DN. Blended Module-Based Teaching in Biostatistics and Research Methodology: A Retrospective Study with Postgraduate Dental Students. *J Dent Educ.* 2019 Apr;83(4):445–50.
23. Ramadurai N, Gurunathan D, Samuel AV, Subramanian E, Rodrigues SJL. Effectiveness of 2% Articaine as an anesthetic agent in children: randomized controlled trial. *Clin Oral Investig.* 2019 Sep;23(9):3543–50.
24. Yadav R, Yadav A, Dhond P. Fracture Healing and Biomechanics of Mandible. *Fracture Mandible.* 2012;2(3):6–6.
25. Perlepe V, Michoux N, Kirchgessner T, Lecouvet F, Vande Berg B. Semi-quantitative CT scoring of nailed shaft fractures during normal healing and in non-unions: comparison with radiographic scoring. *Eur J Radiol.* 2021 Feb 25;138:109618.
26. Mathew MG, Samuel SR, Soni AJ, Roopa KB. Evaluation of adhesion of *Streptococcus mutans*, plaque accumulation on zirconia and stainless steel crowns, and surrounding gingival inflammation in primary molars: randomized controlled trial [Internet]. Vol. 24, *Clinical Oral Investigations.* 2020. p. 3275–80. Available from: <http://dx.doi.org/10.1007/s00784-020-03204-9>
27. Sivakumar S, SmilineGirija AS, VijayashreePriyadharsini J. Evaluation of the inhibitory effect of caffeic acid and gallic acid on tetR and tetM efflux pumps mediating tetracycline resistance in *Streptococcus* sp., using computational approach. *Journal of King Saud University - Science.* 2020 Jan 1;32(1):904–9.
28. SmilineGirija AS. Delineating the Immuno-Dominant Antigenic Vaccine Peptides Against *gacS*-Sensor Kinase in *Acinetobacter baumannii*: An in silico Investigational Approach. *Front Microbiol.* 2020 Sep 8;11:2078.

29. IswaryaJaisankar A, SmilineGirija AS, Gunasekaran S, VijayashreePriyadharsini J. Molecular characterisation of csgA gene among ESBL strains of *A. baumannii* and targeting with essential oil compounds from *Azadirachta indica*. *Journal of King Saud University - Science*. 2020 Dec 1;32(8):3380–7.
30. Girija ASS. Fox3+ CD25+ CD4+ T-regulatory cells may transform the nCoV's final destiny to CNS! *J Med Virol* [Internet]. 2020 Sep 3; Available from: <http://dx.doi.org/10.1002/jmv.26482>
31. Jayaseelan VP, Ramesh A, Arumugam P. Breast cancer and DDT: putative interactions, associated gene alterations, and molecular pathways. *Environ Sci Pollut Res Int*. 2021 Jun;28(21):27162–73.
32. Kumar SP, Girija ASS, Priyadharsini JV. Targeting NM23-H1-mediated inhibition of tumour metastasis in viral hepatitis with bioactive compounds from *Ganoderma lucidum*: A computational study. *pharmaceutical-sciences* [Internet]. 2020;82(2). Available from: <https://www.ijpsonline.com/articles/targeting-nm23h1mediated-inhibition-of-tumour-metastasis-in-viral-hepatitis-with-bioactive-compounds-from-ganoderma-lucidum-a-comp-3883.html>
33. Priyadharsini JV, Paramasivam A. RNA editors: key regulators of viral response in cancer patients. *Epigenomics*. 2021 Feb;13(3):165–7.
34. Mathivadani V, Smiline AS, Priyadharsini JV. Targeting Epstein-Barr virus nuclear antigen 1 (EBNA-1) with Murrayakoengii bio-compounds: An in-silico approach. *Acta Virol*. 2020;64(1):93–9.
35. Girija As S, Priyadharsini J V, A P. Prevalence of Acb and non-Acb complex in elderly population with urinary tract infection (UTI). *Acta Clin Belg*. 2021 Apr;76(2):106–12.
36. Girija ASS, Shoba G, Priyadharsini JV. Accessing the T-Cell and B-Cell Immuno-Dominant Peptides from *A.baumannii* Biofilm Associated Protein (bap) as Vaccine Candidates: A Computational Approach. *Int J Pept Res Ther*. 2021 Mar 1;27(1):37–45.
37. Arvind P TR, Jain RK. Skeletally anchored forsus fatigue resistant device for correction of Class II malocclusions-A systematic review and meta-analysis. *OrthodCraniofac Res*. 2021 Feb;24(1):52–61.
38. Venugopal A, Vaid N, Bowman SJ. Outstanding, yet redundant? After all, you may be another *Choluteca* Bridge! *Semin Orthod*. 2021 Mar 1;27(1):53–6.
39. Hejazi F, Ebrahimi V, Asgary M, Piryaeei A, Fridoni MJ, Kermani AA, et al. Improved healing of critical-size femoral defect in osteoporosis rat models using 3D elastin/polycaprolactone/nHA scaffold in combination with mesenchymal stem cells. *J Mater Sci Mater Med*. 2021 Mar 8;32(3):27.
40. Zhang L-Y, Chi Y-J, Liu F-X, Gong W-H, Yu C, Tang J, et al. [Comparison of surgical effects between extension and flexion type of distal radius fracture]. *Zhongguo Gu Shang*. 2021 Feb 25;34(2):101–7.

41. Grubhofer F, Bachmann E, Gerber C, Wieser K, Ernstbrunner L, Warner JJ, et al. Cow-hitch-suture cerclage for fixation of the greater tuberosity in fracture RTSA. *JSES Int.* 2021 Mar;5(2):270–6.
42. Kabiri A, Liaghat G, Alavi F. Biomechanical evaluation of glass fiber/polypropylene composite bone fracture fixation plates: Experimental and numerical analysis. *ComputBiol Med.* 2021 Mar 2;132:104303.
43. Polo TOB, Momesso GAC, Silva WPP, Santos AM de S, Fonseca-Santos JM, da Cruz NC, et al. Is an anodizing coating associated to the photobiomodulation able to optimize bone healing in ovariectomized animal model? *J PhotochemPhotobiol B.* 2021 Feb 26;217:112167.
44. Wu X, Sun J, Li Y, Wu X, Wang Z, Li T, et al. Atypical fungal thoracic vertebral osteomyelitis resembling metastatic tumor and literature review of fungal vertebral osteomyelitis. 2(3):23–8.
45. Oki S, Furuhashi R, Sakamoto Y, Iwabu S. Distal clavicle fracture malunion associated with scapular dyskinesia treated with 3D preoperative planning. *BMJ Case Rep.* 2021 Mar 2;14(3):32–5.
46. Patel S, Baker L, Perez J, Vulcano E, Kaplan J, Aiyer A. Risk factors for nonunion following tibiototalcalcaneal arthrodesis: A systematic review and meta-analysis. *Foot Ankle Surg.* 2021 Mar 1;3(2):45–52.
47. Su Z-B, Li J, Dai Y-C, Luo G, Hao Y, Zhang X, et al. [Clinical application of dynamic locking screw in treating humeral shaft fracture]. *Zhongguo Gu Shang.* 2020 Jul 25;33(7):631–5.
48. Copeland SA, Gschwend N, Landi A, Saffar P. *Joint Stiffness of the Upper Limb.* CRC Press; 1997. 416 p.
49. Isikli G, Akyol L, Ucak SS, Aslan K, Ozgen M, Sayarlioglu M. Heterotopic ossification (myositis ossificans progressiva): A condition interfering with rheumatic disease. *European Journal of Rheumatology.* 2017;4(1):79–80.