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Biomechanical analysis of a bone-plate system to treat forearm fractures

Abstract

The degeneration of the human body due to the passage of time in conjunction with the increase in life expectancy, have led to the evolution in the treatment of fractures. In Mexico, traffic accidents and falls account for a 40% risk of muscle injury, especially fractures in patients aged 15 to 29 years, and are the leading cause of medical disabilities. Radius/ulna fractures rank second in patients between the ages of 19 and 59, this frequency makes the treatment of these fractures paramount to the health system. Currently, the treatment of radio fractures is done using stents such as bone plates, as these offer greater mechanical support compared to the old methods (plasters, bandages and tablets), providing a correct stability and improvement in the healing of bone tissue. The internal fixation device modeled in this work for the treatment of radio fractures is a plate made of 316L steel, medical grade, which thanks to its mechanical properties and biocompatibility with the human body, ensure a bone remodeling reducing the risk of possible infections and/or malformations in patients.

Keywords: Stents, surgical and fractures

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Abbreviations: FEM, finite element method; CT, computed tomography; CAD, computer aided design software

Introduction

By the technological advances exposed in recent years, a great leap has been produced in different disciplines of Medicine and Orthopedics, which by Physics interpretation can be explain and better understood. In the past, specifically in Orthopedics, there were applied rudimentary methods (massages, herbs, rubbing, cast, plasters, etc.), that were established as traditional procedures for healing. Nevertheless, sometimes this kind of procedures could derive in detrimental consequences for the patient. It was until the year 1895 that physicist *Wilhelm Röntgen* produced and detected electromagnetic radiation in a wavelength range known as *X-rays* or *Röntgen rays*[1] which become a graphical support tool for aid into the observation of injuries (type and degree) that the medical doctors and surgeons would be able to treat in a more efficient manner. So, by the application of this new technique, these specialists could provide the best possible and successfully treatment for patients under the effect of bone fracture or malformation. Subsequently, many years later (1972) computed tomography (CT) scanners appear, but then again with the combination of *X-rays* techniques allow medical experts to observe many other conditions into the human body (tumors, malformations, radiological treatments, etc.).[2,3]

Today, the application of scanning has become a habitually and customary process as auxiliary tool for the treatment of health deficiencies, even when the scanning equipment remains very expensive to buy, need specialize persons to operated and maintenance is extremely complicated. When first computerized axial tomography (CT) scans appear, provide images or graphics in a three-dimensional way and also offer digital files, which can be developed on a computer system as numerical models and can be reproduced by a great variety of different computer programs (Figure 1).[4,5] Finally, through the layer method of scanning, it will be possible to reconstruct any bone structure of the human body and any kind of malformation that could appear.[6]

In this work, it is presented the treatment of forearm bone fracture by the application of CT scanning and it´s structural evaluation by the practice of the Finite Element Method through a commercial computational program. The fracture represents a forearm malformation into the distal area of the radius, and it applied a metallic plate as healing procedure for giving the bone structure a much better structural support and try to reduce the risk of the appearances and develop of new fractures. The main objective of this research is to analyze the mechanical behavior of the bone-plate system introduced into the forearm, subjected to loading conditions and necessary restrictions, agreeing to visualize the different patterns of stresses and displacements. From this result, it is possible to establish the most critical zones and implement the optimum rehabilitation procedure.[7]

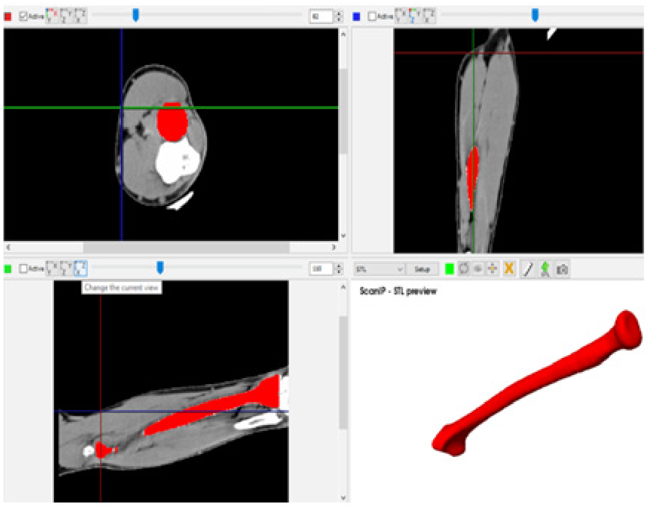

Figure 1 Reconstruction of bone into a numerical model from a CT.

Theoretical background

The forearm is a complex anatomical and functional unit with unique osseous, soft tissue and articular composition. Disruption of this complex biological relation due to posttraumatic changes can have significant impact on the functional system, leading to pain, instability in both the proximal and/or distal radioulnar articulation and reduced range of forearm motion (Figures 2&3). Corrective osteotomy for malunited fractures or other posttraumatic deformities of the upper extremity, especially in the forearm are challenging procedures and should be performed in specialized centers. In this review we will discuss the essential aspects of anatomy and path mechanics, clinical and radiological assessment, and the pathway from preoperative planning to the actual deformity correction surgery, either with one-stage correction or using external fixation (callostasis techniques) and finally the functional outcome we can expect for our patients.

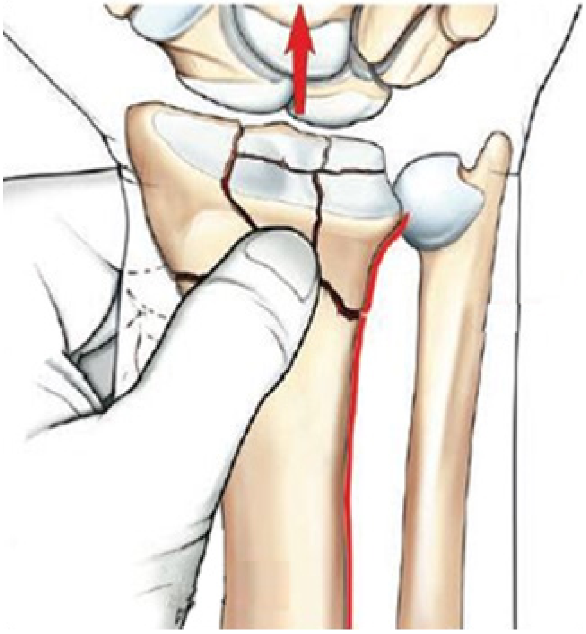

Figure 2 Graphic representation of distal radius fractures.

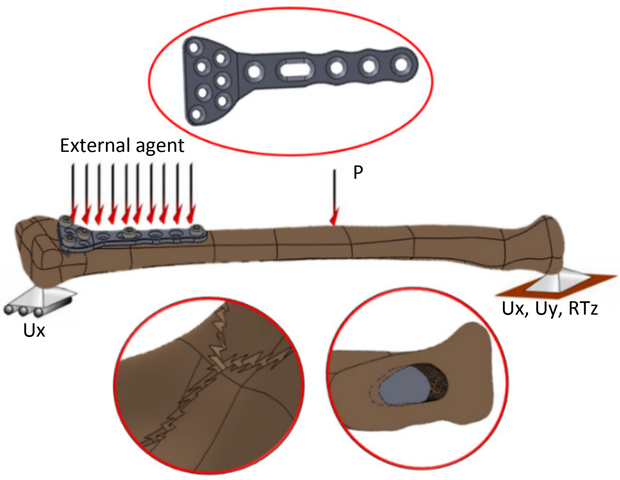

Figure 3 Bone-nail system under numerical study conditions.

Additionally, this kind of biological systems, presents an extremely difficult composition and almost an impossible task to be analysis by common mechanical structural analysis, which make it an ideal case of study for computational programs that applied the Finite Element Method. Finite Element Analysis allows to solve any kind of Mechanical Engineering necessity, which it is possible to verify a product/structure without any prototypes. Correspondingly, Finite Element Analysis allows a great diversity of analysis into the case of study by modifying the interaction of external agents and boundary conditions with the structural system. Likewise, provides a countless presentation of outcomes.[8]

Taking into consideration theoretical foundations of Biomechanics.[9,10] A mechanic al bending study was conducted to observe the behavior of the orthopedic implant designed to treat radius bone fractures. The bo ne-plate system is analyzed by the Finite Element Method (FEM), through a commercial computational program. The numerical model for such numerical analysis shall subject the radius bone and steel plate system to an external load of 15kg, which will produce a bending effect. In addition to this load, the total weight of the forearm, that is 2kg, was considered and applied into the center of gravity of the forearm. The system is statically determinate, and the numerical analysis is structural. For the structural analysis a high-order element (solid brick 186, 20 nodes and 6 degrees of freedom) was applied. To obtain the discretization of the model was performed freely resulting in 48 875 nodes and 23 651 elements. The conditions for applying the external agent and movement restrictions into the model are very important for the performance of the numerical simulation and the determination of the effects caused by the external agent. Obviously, the mechanical structural effects will have a direct relation to the manner him which these variables (external agents and boundary conditions) are considered. In Figures 4&5, can be observe basically output of the numerical analysis. Attention was placed into the effects derived into maximum stress and displacement of the bone system.

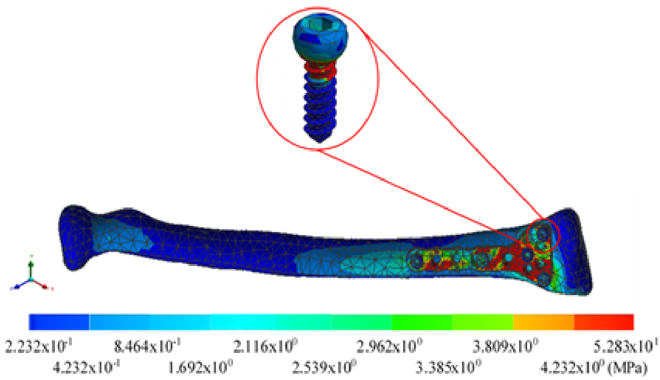

Figure 4 Biomechanical analysis using the fine element method of the bone-plate system to obtain maximum stress (Mpa).

Methodology

The bone-plate system (numerical model) was developed by applying a computed axial tomography (CT) scan of the forearm. This kind of study (scan) provides DICO format files capable of reproducing de data and generate a numerical model by computational programs and systems. Auxiliary tools to develop the numerical model were performed by the application of a Scan IP® software, which allows to manipulate the data to achieve a reconstruction of the trabecular and cortical bone zones corresponding to the radius bone.[9] By applying a computer-aided design software (CAD), the numerical model of the

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steel plate 316L and its fastening screws were obtained. Subsequently a complete assembly of the bone-plate system was developed as can be seen in Figure 3.

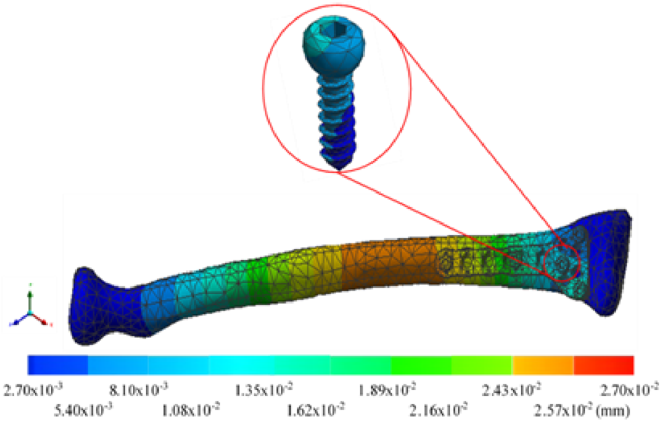

Figure 5 Biomechanical analysis using the finite element method of the bone-plate system to observe the maximum elongation (mm).

Conclusion

For an effective bone fixation, the plates used must offer extraordinary mechanical support, in the analysis made to the bone-plate system proposed in this work it can be observed that the maximum elongation suffered by the internal forearm fixation plate is not considerable so it would not cause any involvement in the patient, because there is no loosening of the plaque, nor the possibility of bone splintering. With the effort obtained, it is concluded that the prosthesis works within the elastic linear zone, the maximum stress generated in the prosthesis is less than the material yield stress, which guarantees that there will be no deformations or permanent stress that can cause any failure in the system. These results ensure the continuity and correct alignment of the fractured parts, as well as the correct transmission of the external loads applied during rehabilitation and/or daily activities, which allows a primary bone remodeling of the bone, that is, without bone callus formation. Which allows the reduction in the recovery time of the patients.

This research leaves the precedent for future studies to evaluate the behavior of the different cases of forearm fractures (radio) through bone modeling and fixation devices to be used with the help of computer programs, which allow an improvement in the design or the materials of the internal fixation plate, attending to the shape, severity of the lesion to be treated and the particular conditions of the patient, without generating prototypes. In addition, with the use of the MEF, it allows to evaluate the loading conditions in the virtual models both to ensure that the mechanical behavior of the proposed designs is adequate, as well as to seek an improvement in the implemented therapies that promote a correct physical rehabilitation of the patient, seeking the reduction of recovery time. The use of these computational tools, grant a high reliability of the design of the proposed prosthesis, saving material, economic and human resources. And it would allow orthopedics to be made to manufacture custom prostheses, avoiding the adaptations that are currently made in the devices because they are manufactured in a standardized way.

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Conflict of interest

Authors declare that there is no conflict of interest.

Funding details

None.

References

1. Crespo Villalba FJ. A pioneer among pioneers: Dr. Herman Gocht and the first manual of applications of X-rays in medicine. *Diagnostic Imaging*. 2013;4(2):65–68.
2. Bhidé A, Datar S, Stebbins K. Case Histories of Significant Medical Advances: Computed Tomography, Harvard Business School. 2019. p. 1–19.
3. Mader K, Koolen M, Flipsen M, et al. Complex forearm deformities: Operative strategy in posttraumatic pathology. *Obere Extremitat*. 2015;10(4):229–239.
4. Mastache Miranda OA, Urriolagoitia Sosa G, Marquet Rivera RA, et al. Three-dimensional reconstruction for use in medicine and biomechanics. *MOJ Applied Bionics and Biomechanics*. 2018;2(5):310–311.
5. Hernández Vázquez RA, Romero Ángeles B, Urriolagoitia Sosa G, et al. Numerical analysis of masticatory forces on a lower first molar considering the contact between dental tissues. *Applied Bionic and Biomechanics*. 2018;1:1–15.
6. Steiner H, Staudach A, Spitzer D, et al. Diagnostic techniques: Three-dimensional ultrasound in obstetrics and gynaecology: technique, possibilities and limitations. *Human Reproduction*. 1994;9(9):1773–1778.
7. Islas Jiménez DI. Mechanical design and numerical analysis of the application of a Titanium plate for radius fracture, Tesis de Maestría, ESIME Zacatenco, Instituto Politécnico Nacional, 2019. p. 60–65.
8. Driscoll M. The impact of the finite element method on medical device design. *Journal of Medical and Biological Engineering*. 2019;39(2):171–172.
9. ANSYS. Mechanical APDL Basic Analysis Guide Relay 16.1, ANSYS Inc Company, 2015.
10. Knudson D. Fundamentals of Biomechanics. *Springer*. 2013.