# Post-surgery stability of Scaphoid fractures under different fixation configurations: A Finite Element Analysis

Ayush Srivastav[1], John A. Santoshi[2], Prateek Behera[2], R.K. Dwivedi[1]
[1]Dept. of Mechanical Engineering, Maulana Azad National Institute of Technology Bhopal, India
[2]Dept. of Orthopaedics, All India Institute of Medical Sciences Bhopal, India

## 1. Introduction

### 1.1 Anatomy of the Scaphoid bone

Scaphoid is one of the eight carpal bones in the wrist, it sits below the thumb and is shaped like a kidney bean. Blood supply to the distal pole is **adequate** but is **insufficient** to the waist and the distal pole.


Figure 1. Scaphoid bone

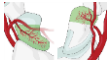
Figure 2. Blood supply

### 1.2 Fractures in the Scaphoid bone

Scaphoid is the most frequently fractured carpal bone, accounting for about 70% of the carpal bone fractures.
**Cause**: Fall onto an outstretched hand.


Figure 3. Proximal pole fracture


Figure 4. Waist fracture


Figure 5. Distal pole fracture

### 1.3 Surgical treatment of Scaphoid fractures

Fractures at the waist or proximal pole are treated by surgery to **realign and stabilize** the fracture.
The two implants used for surgery are:
1. Kirschner wire (K-wire)
2. Herbert screw


Figure 6. Scaphoid fracture


Figure 7. Scaphoid surgery

## 2. Materials and Methods

### 2.1 Specimen and CAD modelling

CAD model of Scaphoid is constructed from a **CT scan**. CAD model of K-wire and Herbert screw are constructed with accurate measurements of the implant specimen.


Figure 8. CAD model of K-wire


Figure 9. CAD model of Herbert screw

### 2.2 Site of fracture in Scaphoid

The most probable site of fracture is located using FEA with impact loads varying between 1600 N to 4000 N.


Figure 10. CAD model Scaphoid


Figure 11. FOS of Scaphoid

### 2.3 Surgery replication in CAD

The three types of surgical treatments for Scaphoid waist fracture are replicated in CAD for the FEA.

| **Single Screw** surgery: | **Screw and Wire** surgery: | **Two Wire** surgery: |
|---|---|---|
| 1. Random 1 | 1. *Parallel* | 1. *Parallel* |
| 2. Random 2 | 2. Random 2 | 2. Random 2 |
| 3. Random 3 | 3. Random 3 | 3. Random 3 |
| 4. Random 4 | 4. Random 4 | 4. Random 4 |
| 5. Random 5 | 5. *Convergent* | 5. *Convergent* |
| 6. Random 6 | 6. *Divergent* | 6. *Divergent* |


Figure 12. CAD model of single screw surgery


Figure 13. CAD model of screw and wire surgery


Figure 14. CAD model of two wire surgery

### 2.4 Post-surgery stability using FEA

**Material Properties**:
1. Scaphoid bone [1]
2. K-wire [2]
3. Herbert Screw [3]

**Loads**:
1. Tensile loading : 100 N
2. Compressive loading: 300 N
3. Bolt pre-tension: 20 N [4]

**Boundary conditions**:
Friction between two parts of the bone ($\mu = 0.4$) [4]

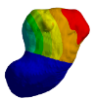
Figure 15. Max. total deformation in single screw surgery


Figure 16. Max. total deformation in screw and wire surgery


Figure 17. Max. total deformation in two wire surgery

## 3. Results

The following two results are extracted from the 32 cases of FEA models in ANSYS and are plotted in the two graphs below:
1. Maximum Total Deformation (displacement) between the two separate parts of the fractured Scaphoid bone
2. Factor of Safety of implants (K-wire & Herbert screw)

*TDef = Maximum total deformation; FOS = Factor of Safety; S = Screw; S&W = Screw and Wire; W&W = Wire and Wire*

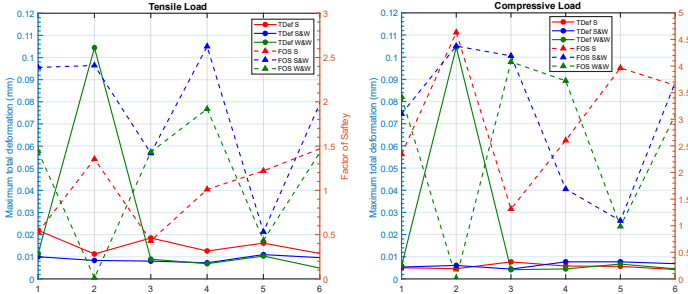


Figure 18. All FEA results of maximum total deformation and factor of safety for (1) single screw, (2) screw & wire and (3) two wire surgical treatment of scaphoid bone fractures

## 4. Conclusions

The two wire surgical treatment can lead to large displacements in case of accident parallel fixation. Moreover, the single screw surgical treatment leads to a low FOS in most cases. Thus, the screw and wire surgical treatment is the best choice among the three.

**Screw and wire** surgery with **parallel or divergent** fixation provides the maximum post-surgery stability for scaphoid fractures.

## References

1. Chamoret, D., Bodo, M. & Roth, S. A first step in finite-element simulation of a grasping task. Computer Assisted Surgery 21, 22–29 (2016).
2. Stainless Steel - Grade 316L - Properties, Fabrication and Applications (UNS S31603). AZoM.com https://www.azom.com/article.aspx?ArticleID=2382 (2004).
3. Titanium (Ti) - The Different Properties and Applications. AZoM.com https://www.azom.com/article.aspx?ArticleID=9118 (2013).
4. Luria, S., Hoch, S., Liebergall, M., Mosheiff, R. & Peleg, E. Optimal Fixation of Acute Scaphoid Fractures: Finite Element Analysis. The Journal of Hand Surgery 35, 1246–1250 (2010).

## Acknowledgements

We thank the Department of Mechanical Engineering at *Maulana Azad National Institute of Technology (MANIT) Bhopal, India* for funding this project. We also thank the Institutional Human Ethics Committee (IHEC) at *All India Institute of Medical Sciences (AIIMS) Bhopal, India* for their ethics permit to work on this project.