

Technical note

Development of a new V-shaped implant with locking plates and screws for mandibular fracture fixation: an in vitro study using finite element analysis

James Antony Bhagat^{a,*}, Velmurugan Naganathan^{b,1}, Leela Krishnan^{c,2}, Durai Raj^{d,3}, Raj Prakash^{a,4}

^a Adhiparasakthi Dental College, Melmaruvathur, India

^b Consultant Maxillofacial Surgeon, Seychelles

^c Saveetha Engineering College, Chennai, India

^d Dept of OMFS, Adhiparasakthi Dental College, Melmaruvathur, India

Accepted 14 July 2019

Available online 27 July 2019

We designed a V-shaped plate to involve both lines of osteosynthesis within a single plate. Implant dimensions are shown in [Figure 1](#). An internal locking mechanism is incorporated to accentuate stability across the fracture line.

The V plate can be positioned in four different directions: 0° (∨), 90° (<), 180° (∧), and 270° (>).

We have compared this implant with standard mini-plates that are commonly used for the treatment of anterior mandibular fracture using Finite Element Analysis.

Displacement between the fracture surfaces after fixation

Healing of the fracture is possible only if the displacement between the fracture surfaces is within the range 100–150 μm.^{1,2}

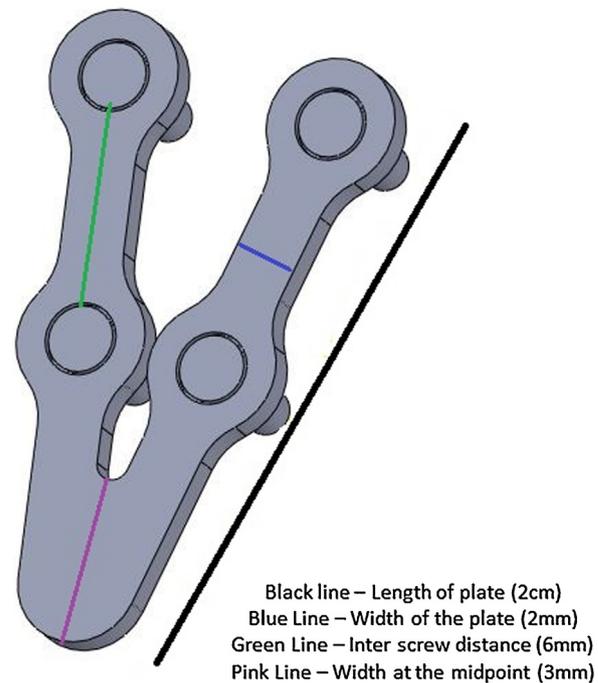


Fig. 1. Diagram of the dimensions of the V-shaped plate.

Tensile stress on the mandible

The maximum permissible tensile stress for cortical bone ranges from 92–188 MPa.³

* Corresponding author at: 5/158 5 th cross street, workers estate, Neelangarai, Chennai 600115, India. Tel.: +91 9941626677.

E-mail addresses: jamesbhagat@gmail.com (J.A. Bhagat), drvselez@gmail.com (V. Naganathan), leelakrishnane@gmail.com (L. Krishnan), omfsapdc@gmail.com (D. Raj), omfsapdc@gmail.com (R. Prakash).

¹ Tel.: +002482725099.

² Tel.: +91 7010808207.

³ Tel.: +91 9444016526.

⁴ Tel.: +91 9894730166.

Table 1

Analysis of the fixation of fractures of the symphysis using a 3-dimensional plate, 2 miniplates (Champy’s principle), and a V-shaped plate with incisor and molar loading.

Plate analysed	Stress on mandible	Stress on plate	Deformation (µm)
Incisor loading:			
3-dimensional plate	102.97 MPa	47.81 MPa	74
2 miniplates	67.52 MPa	54.78 MPa	86
V plate	65.37 MPa	43.23 MPa	26
Molar loading:			
3-dimensional plate	120.33 MPa	31.30 MPa	45
2 miniplates	79.37 MPa	43.77 MPa	102
V plate	77.35 MPa	29.72 MPa	62.5

Table 2

Analysis of the fixation of fractures of the parasymphysis using a 3-dimensional plate, 2 miniplates (Champy’s principle), and a V-shaped plate with incisor and molar loading.

Plate analysed	Stress on mandible	Stress on plate	Deformation (µm)
Incisor loading:			
3-dimensional plate	82.99 MPa	54.94 MPa	106
2 miniplates	125.4 MPa	84.32 MPa	108
V plate – 0°	166.08 MPa	125 MPa	1048
V plate – 90°	71.93 MPa	85.82 MPa	140
V plate –180°	84.68 MPa	130 MPa	160
V plate –270°	87.655 MPa	73 MPa	98
Molar loading:			
3-dimensional plate	89.04 MPa	91.23 MPa	141
2 miniplates	123.1 MPa	84.25 MPa	138
V plate – 0°	160.48 MPa	263.64 MPa	1400
V plate – 90°	69.23 MPa	140.11 MPa	173
V plate –180°	82.53 MPa	165.33 MPa	780
V plate – 270°	89.2 MPa	92.85 MPa	55

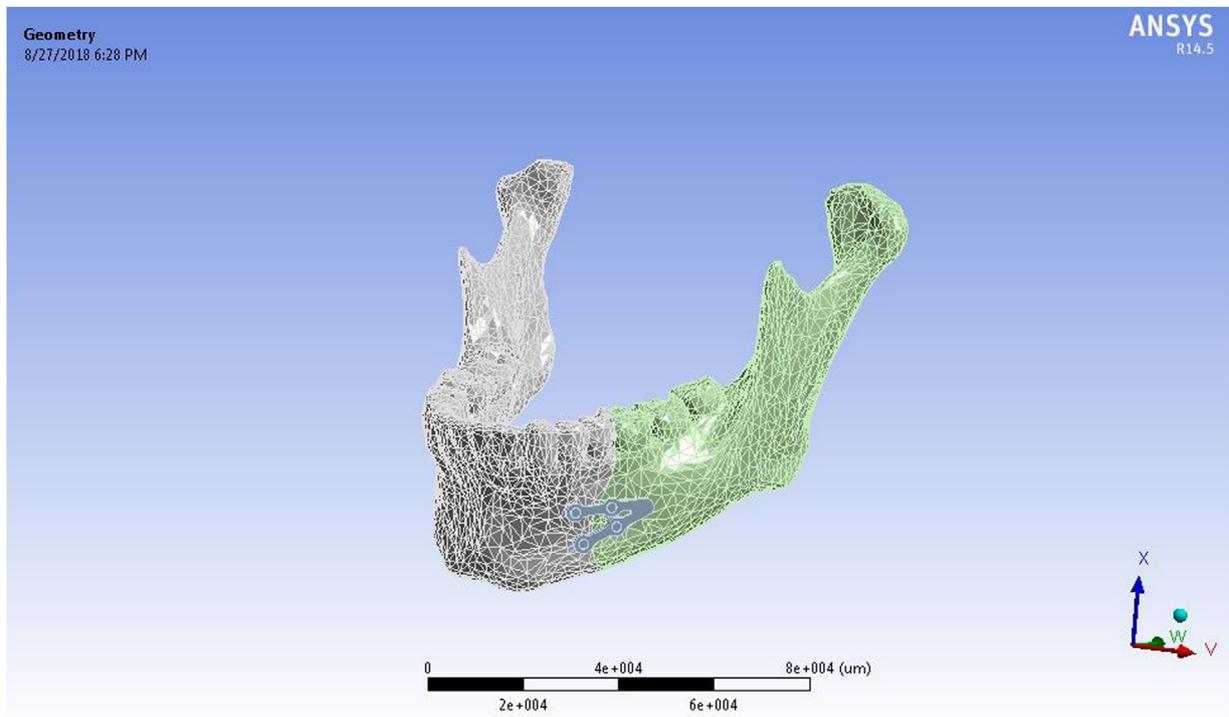


Fig. 2. V-shaped plate placed at 270° for fixation of a fracture of the parasymphysis.

Yield limit of titanium miniplate

The yield limit of titanium is 1000 MPa.⁴

If the measurements of the V-shaped implant are within this range it is likely to be successful.

According to Tate et al.,⁵ the mean incisor bite force within six weeks of operation should be 62.8 N, and the mean bite force in the molar region 119 N. Finite Element Analysis was done using these occlusal forces.

Results

The V-shaped plate had favourable results within permissible limits on the application of load on both the incisors and molars during analysis of fractures of the symphysis and parasymphysis (Tables 1 and 2).

As the plate is 2-dimensional, it is easier to negotiate the mental nerve than it is when using a 3-dimensional plate (Fig. 2). A single plate with the modified V design, 2-dimensional stability and an interlocking mechanism therefore provides adequate support across the fracture. With this evidence, clinical trials are necessary to confirm our results.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patient's permission

Not required.

References

1. Tams J, Van Loon JP, Otten B, et al. A computer study of biodegradable plates for internal fixation of mandibular angle fractures. *J Oral Maxillofac Surg* 2001;**59**:404–8.
2. Perren SM. Physical and biological aspects of fracture healing with special reference to internal fixation. *Clin Orthop Relat Res* 1979;**138**:175–96.
3. Lovald ST, Khraishi T, Wagner J, et al. Comparison of plate-screw systems used in mandibular fracture reduction: finite element analysis. *J Biomech Eng* 2006;**128**:654–62.
4. Wagner A, Krach W, Schicho K, et al. A 3-dimensional finite-element analysis investigating the biomechanical behavior of the mandible and plate osteosynthesis in cases of fractures of the condylar process. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002;**94**:678–86.
5. Tate G, Ellis 3rd E, Throckmorton GS. Bite forces in patients treated for mandibular angle fractures: implications for fixation recommendations. *J Oral Maxillofac Surg* 1994;**52**:734–6.