“COMPARATIVE EVALUATION OF FIVE OSTEOSYNTHESIS MODALITIES FOR FIXATION OF UNILATERAL SUBCONDYLAR FRACTURE MANAGEMENT USING FINITE ELEMENT ANALYSIS”.

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CONTENTS

LIST OF TABLES

COLOUR PLATES

LIST OF ABBREVIATIONS

FEA	Finite Element Analysis
FEM	Finite Element Method
VM	Von Mises
Mpa	Mega pascals
N	Newton
mm	Millimeter
IMF	Inter-maxillary Fixation

INTRODUCTION

Facial fractures are common reason for emergency Department visits. Facial traumatic injuries can result in a variety of fracture patterns, which can occur alone or in conjunction with other injuries. The treating physician must be aware of the ABCs of the patient stabilization, as these injuries can compromise a patient's airway or to be attributed to cerebral and cervical spine injuries.[1]

In the maxillofacial complex, the mandible is the most fracture-prone bone.Mandibular fractures accounted for 42 percent among all maxillomandibular fractures, according to a current prevalence research in a European population.[2]

Symphysis and parasymphysis (15%), body (25%), angle(25%), ramus(3%), condyle(30%) and coronoid process(2%) are all possible fracture sites. condyle accounts for 17.2% to 52% of these. The subcondyle fracture is the most common unilateral fracture.[3]

Subcondylar fracture pattern are affected by mechanism of trauma that is motor vehicle accident (44.20%), cycling (24.61%), physical violence (8.12%) and falls having the highest rates (23.07%). [4]

The mandible anatomical structure assures that forces is dissipated over the length of the jaw, allowing the weakest region of the condyle neck to fracture and so preventing stresses from being transferred to the cranium. This is why condyle fractures are so common. This mechanism is due to the mandible's biomechanical behavior, which transfers forces to the condyle region either directly or indirectly through the symphysis or parasymphysis region.[3]

Condyle fractures are categorized into three based on their anatomical location; extracapsular condylar neck fracture, intracapsular condylar fracture and extracapsularsubcondylar fracture(Loukota et al., 2005; Wermker, 2009)In the same European study, condylar extra-capsular neck fractures accounted for 26 percent of all mandibular fractures, placing them highest among all forms of mandibular bone fractures. Morris et al., (2015) used data from one Texas hospital more than a 17 years period to find that condylar and subcondyle fractures accounting about 18.4 percent of maxillomandibular fracture, placing third following mandibular angle and symphysis fracture.[2]

Despite the prevalence of condylar fracture, there is no accepted "gold standard" treatment and the question of whether condylar fracture should be treated surgically or conservatively remains to be debated.Condylar fractures that aren't treated properly might cause a slew of long-term issues with Opening the mouth, jaw deviation and malocclusion. In long term it may result in Ankylosis or myofacial pain discomfort.

if there is severe bony dislocation outside of the TMJ capsule or even into adjacent structures, if there is a foreign particle inside the joint, or if there is bilateral condylar fracture, and if the mandible is edentulous or could not be managed with closed maxillomandibular fixation, Zide and Kent proposed criteria for when condyle fractures should be surgically intervened (MMF).[5]

New criteria indicate closed reduction in subcondylar fractures with ramus shortening less than 2mm and less than 10 degree of deviation. However, endoscopic or (ORIF) is required whenever the ramus length is shortened by more than 15mm or there is more than a 45 degree deviation.[5]

Open reduction, highly depends on the right application of the technique and fixation system to get good results. Because of a better understanding of the biomechanical principles of the mandible in relation to stress and strain pattern and significant advancements in plate and screw fixation device has been made leading to availability of number of designs of miniplates for ORIF.[6]

Fixation with kirscher wires, lag screws, intraosseous wiring and miniplates are some of the procedures utilized for open reducation and osteosynthesis for condylar fracture.[7]

Previous research has shown that using one straight miniplate with a nonparallel designs works better in biomechanical simulations than using two straight miniplates with such a parallel arrangement.

However, due to the limited operative accessibility insubcondylar region and smaller size of the bone fragments, just the bare minimum of hardware is required.2 straight miniplates, individually secured with 4 screws, might considerably weaken bone fragments and make surgery more difficult. Due to these limitations, new single miniplates featuring 3D designs that disperse the attaching screws in a nonparallel manner have emerged.

The ‘delta miniplate’, the ‘trapezoid miniplate’ as well as the ‘lambda miniplate’ are examples of such minniplates.[2]

Choosing the appropriate design and location of titanium miniplates to be employed in ORIF for subcondylar fracture in addition to offer optimuml stability is contentious topic that is the focus of the current investigation.[2]

We used finite element (FE) analysis to evaluate the efficiency of the five single three diamentional (3D) miniplates for stabilization of subcondylar fracture in this study.[2]

Engineers designed finite element analysis (FEM) to predict the mechanical behavior of structure such as buildings, aircraft and engine part. When structure is loaded, the response can be expressed in terms of stress and strains. Finite element method is another name for it.[8]

Structure, heat transfer, fluid movement and mass transport are common problem areas of interest. In most cases, solving these problems analytically necessitates solving equations for partially differential equations. The problem is expressed as a system of algebraic equations using the finite element approach.[9]

The method produces approximation unknown values at a discrete number of site across the domain. The problems are subdivided into finite element, which are smaller, simpler parts. These simple finite element equations are then combined into a bigger set of equations that represents the entire situation. The requirement to address difficult elasticity and structural analysis problem in a civil and aeronautical engineering led to the development of this technology.[9]

Because the maxillofacial skeleton is complicated in its micro and macro structure, material characteristics and physical conditions at different region of a single bone differ significantly, its stability of osteosynthesis can be predicted using this finite element analysis. These complex systems are decomposed into smaller mathematical equations by using finite element.

The finite modeling of the mandible can be done using 'finite element analysis' to calculate the inherent properties of the mandible and the vector of the masticatory system the following are some of the applications of FEM inmaxillofacial trauma;[9]

1. For the purpose of impact analysis.
2. Optimal placement and orientation of osteosynthesis devices.
3. Load, distribution throughout a fracture, as well as force magnitude and direction on osteosynthesis.

AIMS AND OBJECTIVES

PRIMARY OBJECTIVES-

To evaluate and compare the effectiveness of five osteosynthesis modality in fixation of unilateral subcondylar fracture using FEA.

OTHER OBJECTIVES –

To evaluate the effectiveness of lambda miniplate osteosynthesis system in fixation of unilateral subcondylar fractures by measuring the distribution of stress and strain using FEA.

To evaluate the effectiveness of strut miniplate osteosynthesis system in fixation of unilateral subcondylar fracture by measuring the distribution of stress and strain using FEA.

To evaluate the effectiveness of Rhombic miniplate osteosynthesis system in fixation of unilateral subcondylar fracture by measuring the distribution of stress and strain using FEA.

To evaluate the effectiveness of Delta miniplate osteosynthesis system in fixation of unilateral subcondylar fracture by measuring the distribution of stress and strain using FEA.

To evaluate the effectiveness of Trapazoid miniplate osteosynthesis system in fixation of unilateral subcondylar fracture by measuring the distribution of stress and strain using FEA.

To compare the effectiveness of Lambda,strut,Rhombic,Delta and Trapazoid miniplate osteosynthesis system in fixation of unilateral mandibular subcondylar fracture by measuring the distribution of stress and strain using FEA.

REVIEW OF LITERATURE

Hamill JP et al (1964)[10] A study of 67 patients with 107 incidence of mandibular fracture was undertaken by Hamill JP et al (1964). Angle fractures that were not displaced were treated with intermaxillary fixation alone, while fracture that was extensively displaced was treated with open reduction and interosseous wire stabilization. If sufficient teeth were present for acceptable intermaxillary fixation, anterior and midbody fractures were managed with closed reduction. Because of the significant pull of the muscles in that location, fracture of the anterior body with in region of the symphysis needed open reduction. Clinically infection and non-union had been found to be frequently related associated fractures communicating affected teeth. The study's findings indicated that the procedure be postponed until the oral tract created by the extraction has healed.

Murray JF and Hall HC (1975)[11] – A report on mandible fractures in motor vehicle crashes was presented by Murray JF and Hall HC in 1975. Fracture of an anterior alveolar bone, condylar necks, or missing teeth portions of both the body and symphysis were the most frequent. The proposec treatment included planning the surgery while taking into account the patients overall health, emergency treatment to keep the tongue forward in the event of obstruction, and repeated suctioning of blood and mucus from the oral and nasal passages. In a few cases, a tracheostomy was required. Stabilization of the mandible in young patients with teeth must also include maxillomandibular stabilization with wiring the teeth to occlusion, as well as interosseus wiring to stabilize unstable fragments.

Schettler D and RehrmannA[12] -23 cases of condylar fractures were studied throughout time and the results were published.A long rubber bridle was strung between a metal hook just at chin and long sagittal wave like,twisted wire intergrated in a had cap to facilitate forward expansion of the jaw.Osteosynthesis is only required when the rest of the mandible is fractures at the same time,and the tmj joint region and the rest of the mandible are regarded as separate entities in the management of condylar fractures .In all cases,mandibular mobility was achieved ,and displaced condyles spontaneously upright.But no need for any further warm up exercise sanders B et al (1977 A case of infectious osteonecrosis and degeneration of the mandibular condylar head was documented due to an untreated intracapsular fracture that had gone untreated for several months. Pain with in TMJ also on affected side and difficulty opening the mouth were the main clinical signs. The condylar head was found to be degraded and uneven on radiographs. To achieve a good outcome,the patient should be treated by surgical resection of a necrosis condylar head with debridement of both the region using a pre auricular approach.

Brown AE and Obied G (1984)[13] -internal fixation treatment fractures of a mandibular condyle was simplified,according to the study. The article examines the morbidity associated with conservative care of mandibular condylar fracture dislocation, as well as the theoretical benefits of open reduction. Kirschner wire were drilled through into condylar fragment and subsequently inlaid into the ramus, according to the new approach. The procedure was shown to have several advantages, including easy fragment manipulation and little risk to the facial nerve.

Fernandez JA and Mathog RH (1987)[14] -worked with a patient who hada significantly dislocated condyle and unstable mandibular fragment. Using an external device, a procedure for reducing and sustaining fixation was used. The advantage of direct sight of a reduction and immobilization of either the fracture was significant, despite the fact that the approach required a large surgical procedure and might potentially induce facial nerve injury.

Kitayama S (1989)[15] - the outcomes of cases managed with a new intraoral open reduction technique including screws inserted through the mandibular crest in condylar fractures were reported. Two weeks following surgery, the patient had a adequate mouth opening with no deviation, and there was no sign of condylar head necrosis or aberrant resorption. In the second example, the patient could fully open his mouth ten days following surgery without lateral deviation, and then in the third example, full mouth opening was achievable one week after surgery. Every mandibular crest broader than 5mm, as assessed by preoperative x-ray scan and macroscopic observation during surgery, requires screw fixation, according to the author.

Raveh J et al (1989)[16] -patients with 29 displaced condylar process fractures were included in the research. Only fractures involving entire displacement of the condyle from of the articulating fossa were managed with open reduction surgery.in spite of significant dislocation, the authors determined that the surgical method had a minimal rate of complications and that the patients joints functioned satisfactorily

Rubens BC et al (1990)[17] -a mandibular condylar fracture caused dislocation and erosion, resulting in a shorter vertical ramus and loss of posterior vertical facial height, according to a case study. To regain vertical ramus height, four patients had unilateral or bilateral mandible ramus osteotomies. Patient’s occlusal stability and function improved, and their vertical ramus height was restored, according to the findings

Stewart A and Bowerman JE (1991)[18] - Reported a case report upon two cases of mandibular condylar neck fractures. The proximal fragment was controlled during open reduction surgery by inserting a moul pin through into condylar neck, which allowed for easier extraction of a condylar head and realignment of a bone fragments. There was no postoperatively facial weakness noted in case 1. There was no signs of mandibular deviation and the occlusion was good. The interincisal distance in the second example was 36mm, while the interincisaldistance in the first case was 31mm. As a result, open reduction of condyle neck fractures with a Moule pin was found to be beneficial.

Sargent LA and Green Jr JF (1992)[19] -The utilisation of open reduction using plate and screw stabilization for the management of condylar fractures was investigated in this study. Open reduction and fixation were performed on 14 patients having 18 subcondylar fractures utilisingminiplates (12 patients) with lag screws (two patients). Bony union was achieved in all fractures after an average of 24 months, with no persistent facial nerve damage and satisfactory mouth opening .Condylar fractures could be accessed and treated using plates and screws without using intermaxillary fixation, according to the findings.

Silvennoinen U et al (1995)[20] carried out a study to see how effective an axially anchor screw system is for treating condylar process fractures. Seven adults were treated for misplaced condylar process fractures. In most cases, the recovery period was uneventful. All of them were pain-free, with appropriate occlusion and facial symmetry. The fracture reduction on radiographs was good. The condyles symmetrically translated when the mouth opened. In the majority of cases, there were no evidence of resorption or osteoarthrosis. Unsatisfactory reduction with one patient caused osteolysis just at fracture line and bone over the screw cracked, and the condyle and the screw slanted in a medial position in another patient, according to reports. The study found that employing an axial anchor to treat condylar process fractures was effective.

Iizuka T et al (1998)[21] -undertook a study to assess the long-term outcomes of open reduction without stabilization for dislocated condylar process fractures. On 27 patients with 29 treated joints, clinical and radiologic exams were done. Clinically, the findings were satisfactory. The posteroanterior radiograph revealed a little medial displacement of the condylar process. Radiologically, 48 percent of cases had an usual condylar configuration, and primary purpose was established in the remaining cases despite condylar alterations. Condylar processes that were fully exposed and devascularized showed more severe alterations than those with partial vascularization. The study concluded that surgical therapy of displaced condylar process fractures resulted in a favourable outcome.

Newma L (1998)[22] did a study on the long-term results of 61 individuals who had bilateral mandibular condyle fractures. Thirty-nine patients (21%) were addressed with wire maxillomandibular fixation for an average of 37 days, 13 (20%) were treated conservatively, and 9 (15%) were treated with ORIF because they had 10 shattered condyles (ORIF). The most prevalent complaint following treatment was chronic mouth opening limitation, which was much lower as in ORIF group (mean 44 mm) than in the maxillomandibular fixation group (mean 28 mm). ORIF has been the most satisfactory type of treatment if any of the condyle is dislocated, according to the findings.

Choi BH e al (2001)[23] Patients with condylar neck fractures were treated with three different plating procedures, and the results were compared. The study included 37 patients with 40 condylar neck fractures which were reduced and stabilisedutilising a method that involved facial nerve exposure. A single miniplate (17 fractures), a minidynamic compressive plate (13 fractures), or twin miniplates were used to stabilise the fractures (10 fractures). Only cases stabilised with a single miniplate or even a minidynamic compressive plate experienced plate break or screw loosening. When two miniplates were employed, there were no occurrences of insufficient stability. According to the findings, the 2-miniplate fixation approach provides functionally stable stabilisation for condylar neck fractures.

Wagner A et al (2002)[24] -did a study on the computed tomography scans as well as a sequential dissection of a cadaver jaw were utilised to examine human mandibular shape, specific bone strength pattern, and the placement and orientation of masticatory muscles in a finite element analysis. For bone regeneration of condylar neck fractures, Either or 2 miniplates with a diameter of 2.35 x 1.00 mm were shown to be inadequate fixation.In cases of unusual occlusion interactions in the molar area, the maximum stress values within the mandible &osteosynthetic implants were reported. The study recommended employing 2 plates for osteogenesis of condyle neck fractures in a single treatment, in combination with bicortically inserted screws as well as the rigidity of the a single titanium osseointegration plate.

Semann R et al (2007)[25] The mechanical stability caused by the improved shape of such a new condylar process plates in the management for condylar process fractures were verified using finite element analysis. Thirty-five patients with mandibular condylar fractures were treated. There were no plate fractures and no damage to a facial nerve. A screw cracking was noted in one case.Two of the patients had insufficient reduction but no functional impairment. It was concluded that the newly designed condylar process plate provided adequate mechanical rigidity to avoid plate fractures, and that comparisons to other condylar process osteosynthesis methods revealed significant differences, implying that a single Modus condylar plate produces results comparable to two miniplates.

Klatt J et al (2010)[26] - conducted a two-year follow-up research in 48 patients having condylar process fractures to assess the morbidity of a transparotid technique. The transparotid technique was used on all of the patients, using rigid internal fixation utilisingminiplates.None of the patients had issues with wound healing; two patients acquired a parotid gland fistula; and four patients developed facial nerve palsy that was entirely reversible after six weeks. The study concluded that for significantly displaced Class II fractures, a transparotid treatment for condylar fractures had been the best option. It's a good option for elderly patients who aren't candidates for maxillomandibular fixation.

Kanno T et al (2011)[27] performed a research on 15 patients with linear condyle fractures to see if ORIF of condyle fractures of the jaw using a small novel angulated screwdriver approach without endoscopic assistance was effective and feasible.All patients had adequate anatomical reduction of a condylar segments upon focal occlusion, followed by quick functional recovery. All of the patients had good articular function in their temporomandibular joint, with no adverse clinical signs or deviation. According to the study, surgical intervention of linear condylar fractures of a mandible can be accomplished without endoscopic help utilising an intraoral approach and a smaller angulated screwdriver system, providing reliable clinical results as well as safe and less invasive surgery.

Wang G et al (2012)[28] exhibited the outcomes of a case that was processed with a CAD/CAM technique and titanium that was rapidly prototyped. The personalised titanium implants were designed and created using Computed tomography images, rapid prototyping, computer aided, 3-dimensional display, and

CAD/CAM. The operational scheme's 3D demo system displayed the procedure and evaluated the placement of the implant to ensure a flawless fit. The patients' morphologic symmetry, facial attractiveness, occlusion, and TMJ functioning all improved after surgery.

Aquilina P et al (2013)[8] A finite element analysis of the a simulation mandibule condylar fracture was built after stability of three commonly used plate fixing methods was investigated. Models for bone were created using linear elasticity and isotropic material characteristics. Using 2 parallel 2.0titanium miniplates instead of an one 2.0 titanium miniplate resulting in a much more stable arrangement having lower mean element stresses and displacements. When compared to utilising two miniplates in an offsetting pattern, employing two miniplates in such a parallel position resulted in lower stresses and displacements. As per a finite element model, these parallel titanium plates created a superior biomechanical effect.

Kozakiewicz M &Swiniarski J (2014)[29] A study revealed an A-shape miniplate designed for robust stabilisation of mandibule condyle neck fractures. Using finite element analysis, this plate was compared to a nine - hole trapezoid plate (FEAACP has a higher strength and much more stable stabilization than trapezoid plate, according to FEA. The outcome was aided by multipoint attachment at three sites on the plate, as well as stronger bars reinforced by the a semi-horizontal connecting bar. An A-shape condyle plate, as per the findings, could be used in multiple levels of condyle neck fracture & to stabilise a coronoidal bone fracture.

Aquilina P et al(2014)[30] Using pure titanium implants, researchers tested the stability with three plate attachment configurations. A simulated mandibule condyle fracture was modelled using finite element analysis. In case of mechanical performance, the 1.5-mm X plate was the most stable of the three 1.5-mm form miniplate combinations examined, and it behaved comparable to a single 2 milimeter straight 4 plate. The study found no evidence to justify the use of square and rectangle miniplate shapes in the Internal fixation of mandibule condyle fractures.

P. Aquilina et al (2015)[31] The stability of two patient-specific implants (PSIs) was investigated for open reduction and internal fixation of a mandible subcondyle fracture. To simulate a mandible subcondyle fracture, a series of finite element analyses were employed.The simulated condylar fracture's stabilisation and von Mises stresses decreased as the PSIs increased. PSI 1 has been the most secure of the plate designs tested, with mechanical properties similar to such a single 2milimeter straight four-hole miniplate.

Conci RA et al (2015)[32] A compression force over the mandibule condyle after reduction & fixation of mandibule condyle fracture also with neck screw and two other standard techniques was compared using 3-d finite element simulation. Three distinct approaches were used to secure the model: a 2mm miniplate and four screws, two miniplates (11.5-mm plate and one 2mm miniplate) using four screws, as well as a neck screw. In terms of fracture displacement, synthesis material deformation, as well as minimum and maximum load values, the 2-plate approach was more stable. The neck screw produced satisfactory results that have been similar to those obtained with a miniplate. According to the results of two independent miniplates compared to the control group using various fixation systems and procedures, the neck screw is an alternate for condyle fracture reduction.

Murakami K et al (2015)[33] Examine stress over Poly-L-lactic acid (PLLA) plate of 1.4 milimeter thickness and titanium miniplates of 1.0 & 1.4 mm thickness for mandibule symphysis fractures, even in the absence of conservatively handled unilateral condylar fractures, using finite element analysis. Peak loads on such miniplates were significantly higher in condylar process fracture models than in isolated symphysis fracture models, particularly in the defect condition There in contact condition, stress concentrations on all types of miniplates were lower than material strengths, but in the flaw situation, some of them have been greater. According to the results, a PLLA plate might theoretically withstand force in excellent symphysis fracture reduction, including for condyle fractures; but, in poor reductions, both the PLLA plate and the titanium miniplate may shatter.

Sikora M et al (2016)[34] demonstrated the findings of a study including 42 patients who had a unilateral condylar fracture and were treated with Delta miniplate secured by four 2mm screw to produce stable osteosynthesis. All of the patients had normal mandibular movement in all three planes, with an average range of abduction of 47 mm at the end of the treatment. In any case, there was no evidence of a Delta plate breaking.In 7percent of patients, one of the stabilizing screws detaches and partially removes from the bone, resulting in a hole in the plate. The Delta miniplate for stable osseointegration of subcondyle fractures has been found to produce entirely satisfactory treatment results, both radiologically and clinically, with almost little chance of the plate breaking.

Darwich MA et al (2016)[35] conducted a study to compare the results of five plating procedures for the management of unilateral mandibulesubcondyle fracture. Finite element approach was used to examine five titanium plating procedures for condylar fracture fixation ('1 straight miniplate, two parallel straight miniplates, two angulated straight miniplates, one trapezoidal miniplate, & one square miniplate'). A straight plate had worst results, causing the largest dislocation and strain on the cortical bone. The trapezoidal miniplate put the minimum strain on the cortical bone as well as became the most resistant to movement. As a result, the study suggests using a trapezoidal plate to treat a subcondylar fracture.

Murakami K et al (2017)[36] analysed a case with unilateral condylar fracture by constructing '3-dimensional finite element'b simulation based on computed tomography. 1 straight titanium miniplate, 2 straight titanium miniplates, two straight poly-L-lactic acid miniplates, and four-hole (box), five-hole (strut), and seven-hole (lambda) condylar miniplates were used to essentially diminish and fix the fracture, and the stresses that developed in these plates were studied.For all types of plates, the measured values of tensile von mises stress are within tensile strength. The measured values of compressive stress in one straight titaniumminiplate and two straight poly-L-lactic acid miniplates, on the other hand, were greater than the compressive strength. The five-hole (strut) plate had the lowest tension and compression stresses among the three types of subcondylar plates. The fixing five-hole (strut) plate was found to be the best option.

Albogha MH et al (2018)[2] compared the performance of 5, 3-Dimensional titanium miniplate designs ('lambdaminiplate, strutminiplate, deltaminiplate, rhombicminiplate, and trapezoidminiplate’) for subcondyle mandibule fracture repair. All 5 miniplates with screws were built into three-dimensional models and inserted into a realistically shattered mandible produced from a computerized tomography image of a living human. The researchers looked at patient-specific finite element models.The trapezoid miniplate had the lowest condyle head dislocation and thus the best fixation primary stabiliasation. The highest displacements, on the other side, were discovered within lambda as well as strut miniplates. Large strains in bone all around screws attaching the Delta miniplate were predicted by bone strains as a sign of secondary stability. The strut as well as lambda miniplates have significant stresses in them, indicating a high danger of miniplate fracture. The study projected considerable performance variations among the various designs of 3-dimensional miniplates, with the trapezoidplate performing best.

Zielinski R et al (2019)[37] conducted a study Using finite element analysis, compare the use of biodegradable & titanium "A" shape condylar plates for high level right condylar neck fractures. The anterior span around the first hole had the most stress on the bone surface. The first screw around the plate in the front bridge had the highest stress on screws, which was higher in titanium (150 Megapascal Pressure unit) than PLLA (114 MPa). The pressure on the bone in PLLA osseointegration is 2 times higher than that in titanium fixation, according to the findings. When pressure over bone is too excessive in small regions, it produces local bone deterioration around the fracture, which can delay or prevent healing.

Kolsuz N et al (2020)[38] compared Researchers investigated overall biomechanical stability of three alternative approaches for treating mandibular condyle fractures with synthetic polyurethane mandibles using servohydraulic test system and finite element simulation. Resistance to dislocation loads inducing fragment displacements of 1.75 and 3.5mm, as well as the highest resistance values before fixation system failure, were measured in thirty condyle necks of fiftee polyurethane mandible models.The biomechanical stability of three distinct procedures used to treat mandibule condyle fractures with synthetic polyurethane mandibles was examined using servohydraulic test system and simulated results (FEA). The greatest resistance values preceding fixation system failure were recorded in 30 condyle necks of fifty polyurethane mandible models, as well as resistance to dislocation stresses causing fragment separations of 1.75 and 3.5mm.

Liokatis P et al (2021)[39] Evaluated the efficiency of four titanium metal plates ('alpha, kappa, rhomboidal, and trapezoidal') used to treat condyle neck fractures using computerized finite element analysis. All 4 plates provide acceptable fastening for a 135 N load, with the rhomboidal and trapezoidal miniplates having a minor danger of screw loosening. The alpha & kappa plates performed better with a 500 N applied force, spreading the stresses in the bone more evenly and providing superior stiffness. The data suggest that when larger weights were applied, the alpha as well as kappa plates performed better. Trapezoidal and rhomboidal plates, on the other hand, were not suggested for condyle fractures, especially if higher functional loads were envisaged.

Liokatis P et al (2021)[40] conducted a study in which Four miniplates were used to treat a virtual condyle neck fracture in a mandible that was discovered on a CT scan (2 straight miniplates, lambda, strut, & trapezoidal). The displacements and stress distributions of pieces in titanium and bone were studied using finite element analysis. There was no evidence of material failure. All four plates provide enough fixing for a weight of 135 N. The lambda as well as strut plates had the best stiffness and the lowest bone stresses when loaded with 500 N.Around all screws, the 2 parallel miniplates had the lowest stiffness while the trapezoidal plate had the highest bone stresses. The findings suggested that 3-d plates (lambda & strut) perform better under larger loads, but trapezoidal plates have an increased chance of screw loosening & the 2 straight miniplates have higher fragment mobility.

MATERIAL AND METHODS

The study's computational resources

Hardware

The study was conducted on PC workshop with an intel core 2 duo processor running at 2.1 GHz, 16GB Of RAM, a 4GB graphics card, a 500 GB hard drive, and a 17 th monitor.

Software

RAPID FORM 2004 (INUS Technology. Seoul, South Korea)

CLOUD DATA POINTS are converted to SURFACES using software. IGES format is used to store the transformed SURFACES.

MIMICS 9.0

The ‘Interactive Medical Image Control System' (MIMICS) from Materialize is medical modeling software that allows you to visualize and segment CT/MRI images.

ANSYS 2021 R2 -Analysis System Software

This software is used to do finite element analysis on structures and fluids in a variety of fields, including civil, aerospace, automotive, manufacturing, and biomedical.

METHODOLOGY

The current in vitro analysis used the finite element approach to evaluate the stability and strength of the five plating system used to treat mandibular subcondylar fractures. The study requires the CT scan, which was performed in the Radiology Department and carried out the finite element modeling and analysis for the comparison of the five fixation systems mentioned above.

The steps of the finite element analysis

1. Ansys Modeling
2. Ansys Meshing
3. Material property data presentation
4. Loading configuration
5. Stress condition analysis and interpretation

INCLUSION CRITERIA –

CT scan of patient carried out for purpose other than mandibular fracture

EXCLUSION CRITERIA –

CT scan of patient having mandibular congenital or pathologic factors.

Construction of 3D model

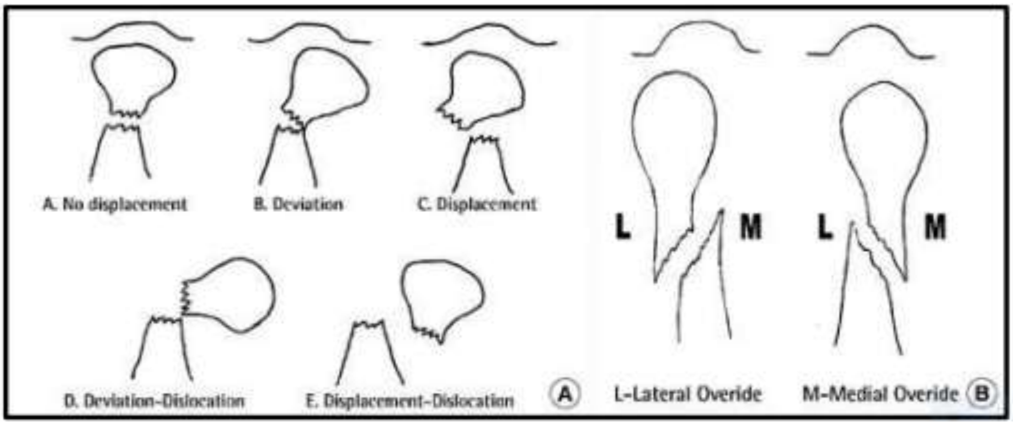
A CT scan of the skull (with BRIVO 16 slices) was obtained, and a 3D finite element model of mandibular bone was created from DICOM file data. With the use of MIMICS software, this DICOM data was transformed into an ANSYS model. The STL format was used to export data from mimics (cloud points and lines).

To construct the surfaces, data from MIMICS was loaded into RAPID FORM software and only surface data is used in the anatomic model. ANSYS 2021 software was used to create a model of the mandible with all of the teeth.

The left side of the mandibular subcondylar region was used for simulation study, and the subcondyla rregion was cut with a 0.25mm gap between the fracture fragments for the study.

It was categorized in accordance with the recommendations of the Lindhal's classification reference.[41] (Refer Table 1)

CLASSIFICATION OF CONDYLR FRACTURE OF MANDIBLE.



The constructed model consists of specific number of nodes and elements which defines the complexity of the model made. (Refer table 2)

Construction of the osteosynthesis model

A total of five separate digital models of the plating system under test were used. The STL models were built using the same processing method as the FEM model of the mandible mention above. Using the computer-aided Ansys Workbench 2021 3D surface models for five commercially available titanium miniplates were created. ‘Lambda miniplate, rhombic miniplate, delta miniplate, strut miniplate, trapezoid miniplate’ are the designs. The dimensional criteria were used to manufacture virtual screws.

To replicate overall osteosynthesis of the subcondyle fracture on the mandible model, virtual miniplates and screws were used. Plate models are 2mm thick and are stabilised by 8x2 mm screws both on condyle portion as well as the Ramus, applying the guidelines for functionally stable internal fixation, to handle tensile & compression function stresses that emerge on the bone as well as osteosynthesis material. The plates were adjusted to the shape of the bony surfaces of the mandible that were suitable for plate fixation without becoming warped, in order to prevent the plate from fracturing due to the weak point created on the plate.

Generation of mesh and material properties

On a typical non-fractured mandible model, mesh size was selected using a convergence test. Surface models were discretized in ANSYS 2021, with 58232 solid elements and 18472 nodes in each model. By translating the voxel Hounsfield Unit Value in a CT image to elastic modulus E and assigning it to the relevant element in the mesh, patient-specific bone elastic characteristics were utilized in the present FE models All miniplates and screws were given titanium alloy Ti-6Al-4V properties.

Properties of materials

The models were considered homogeneous, isotropic and linear elastic for the FEM analysis: homogeneous because all of their points have the same mechanical properties; isotropic because the mechanical properties do not change with direction in all points; and linear elastic because when tensions were removed, they returned to their original shape.

Young's modulus and Poison's ratio values for alveolar bone, cortical bone, plates and screws were also taken into account in our research.[42,43] Refer Table. 3

Loads and constraints-(Application of the forces)

A simple static force was applied perpendicular to the occlusal plane of the mandibular second molar and at the front teeth region. Wagner et al [24] coined the term ‘bite forces’ to describe the combination of these forces as well as the accompanying muscle reaction forces. The fracture interface was in touch but free to displace or separate and mandibular motions were limited in all directions at the condyles. The screw-plate interfaces were found to be perfectly in contact and firmly attached.

The plates were not considered to receive or transmit any force directly from the bone segments; rather, the force transfer chain was specified as proceeding from bone to screw, screw to plate and eventually back to the bone via the screws. To produce the genuine action of forces as occurs during mastication and at the moment of bite and occlusion, these biting and occlusal forces were administered ipsilaterally and contralaterally, and muscle reaction forces were computed solely on the epsilateral side of the fracture.

Only a fraction of the theoretical muscle capacity was used in our investigation, resulting in a designated chewing force in the front tooth and posterior teeth regions, which corresponded to Anderso and Van Eijden findings.[24]

The lateral pterigoid muscle was left out since its pulling direction is nearly parallel to the occlusal plane and aids in horizontal mandibular movement during mastication.[24] (Refere table no. 4).

Analysis of result

Using a ratio MPa (N/mm2), all five models were compared to the main tension. After calculating the reactionary forces of the masticatory muscles, the mean, maximum and minimum Von Mises Stresses were calculated. Following that, the tension distribution was assessed. A color scale with tension levels varied in MPa was employed, and each color map was presented on a different scale depending on the outcome. The tested models were compared after qualitative and quantitative analysis of the data to verify the patterns of behavior of the different approaches, taking into account the distribution of tensions and displacement (measured in mm).

COLOR PLATES

Fig 1 Solid Model (Iges)

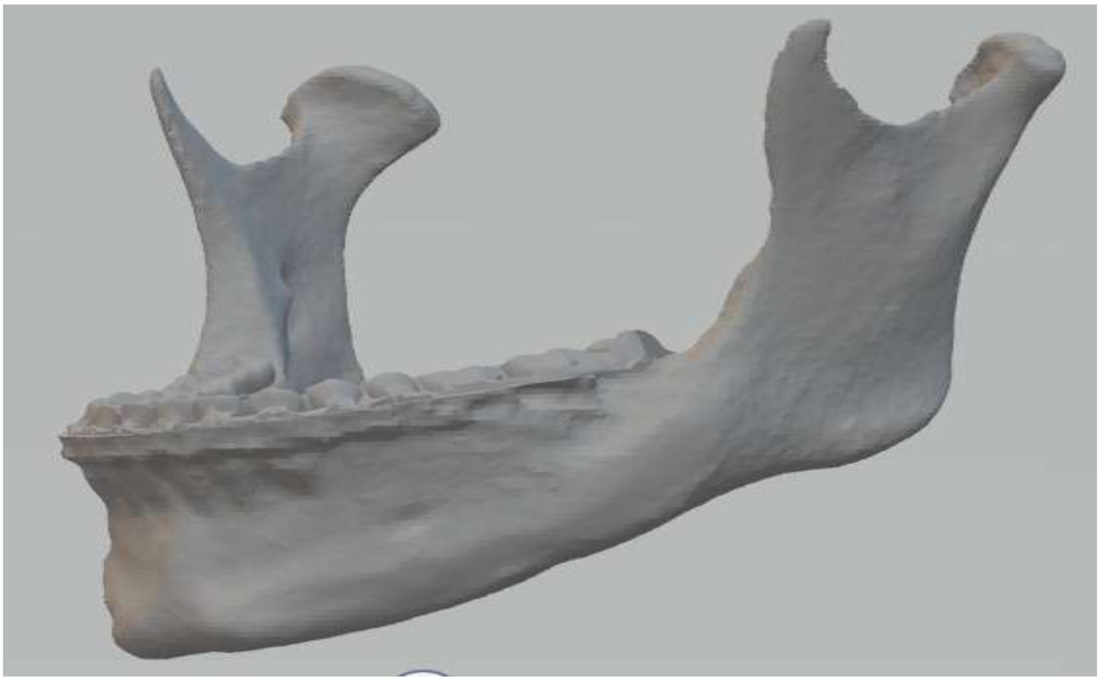


Fig 2: Mesh Model

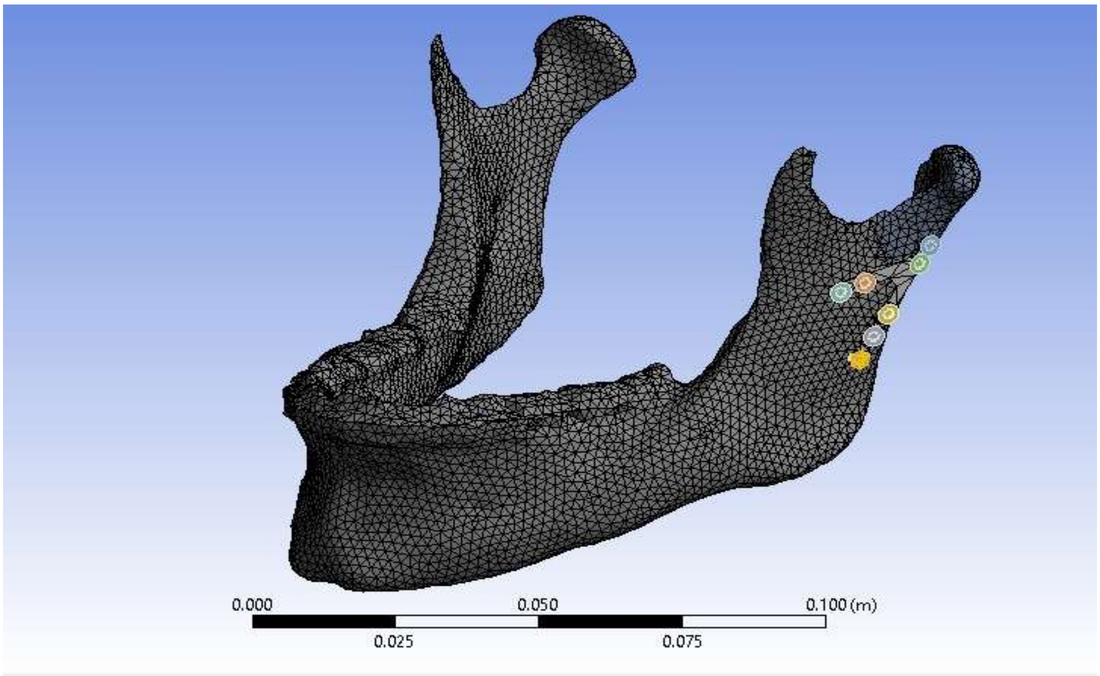


Fig 3 APPLICATION OF FORCES

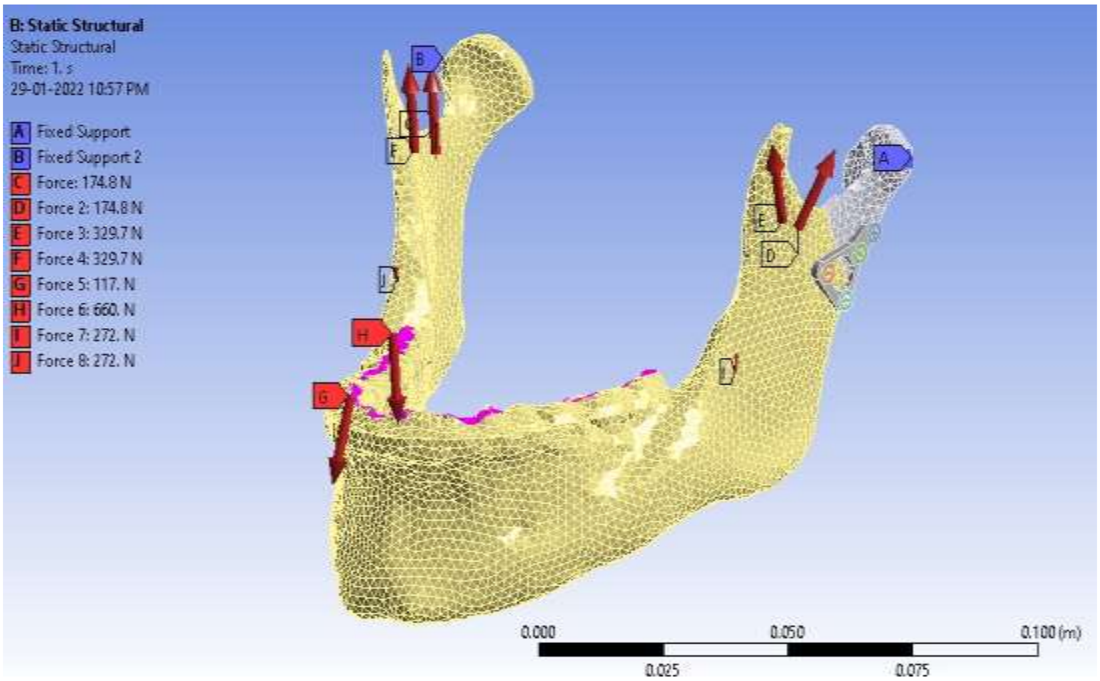


Fig 4 Strut Plate – Mesh Generation

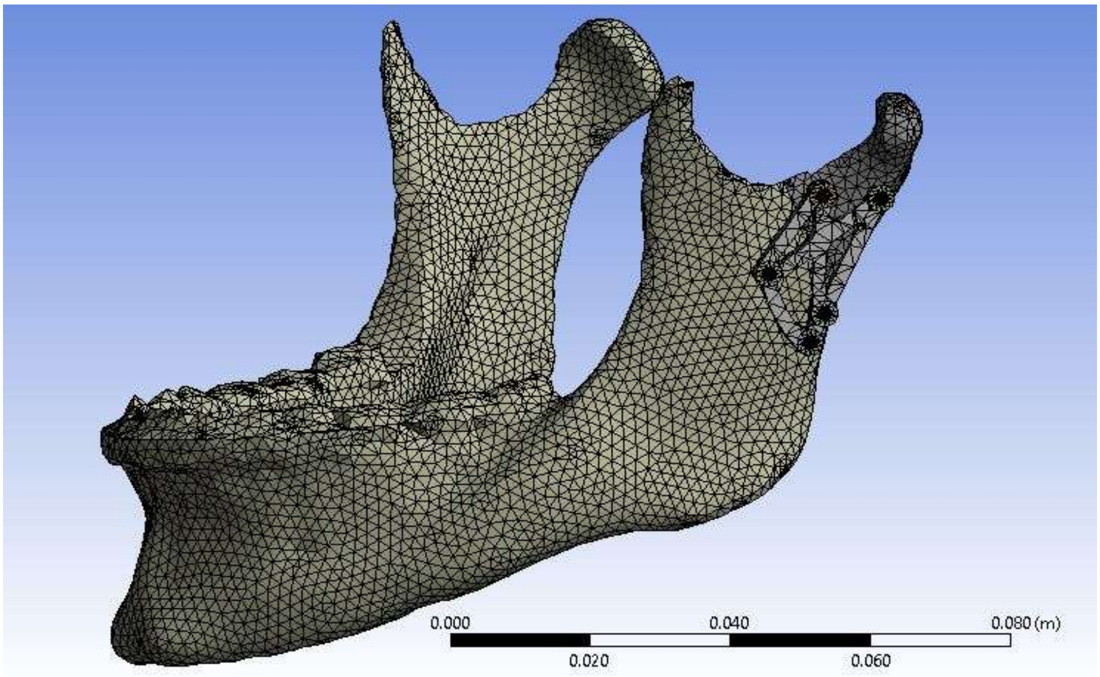


Fig 5 Strut plate –Application of forces

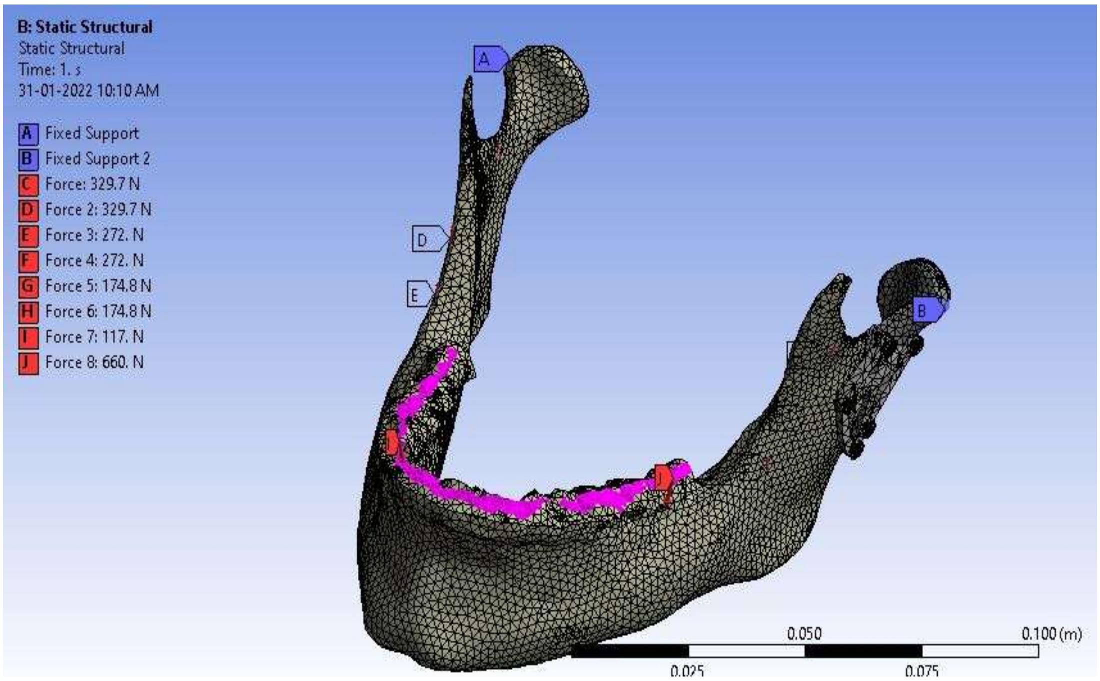


Fig 6 Strut plate-total Deformation

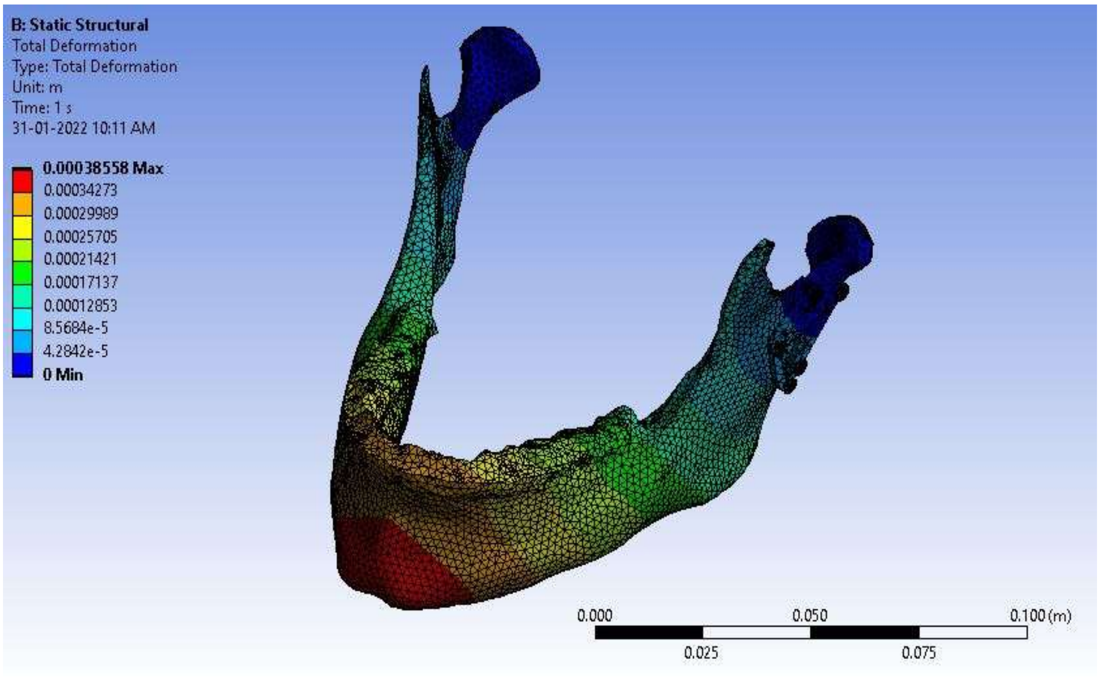


Fig 7 Strut plate-Von Mises Stresses over bone

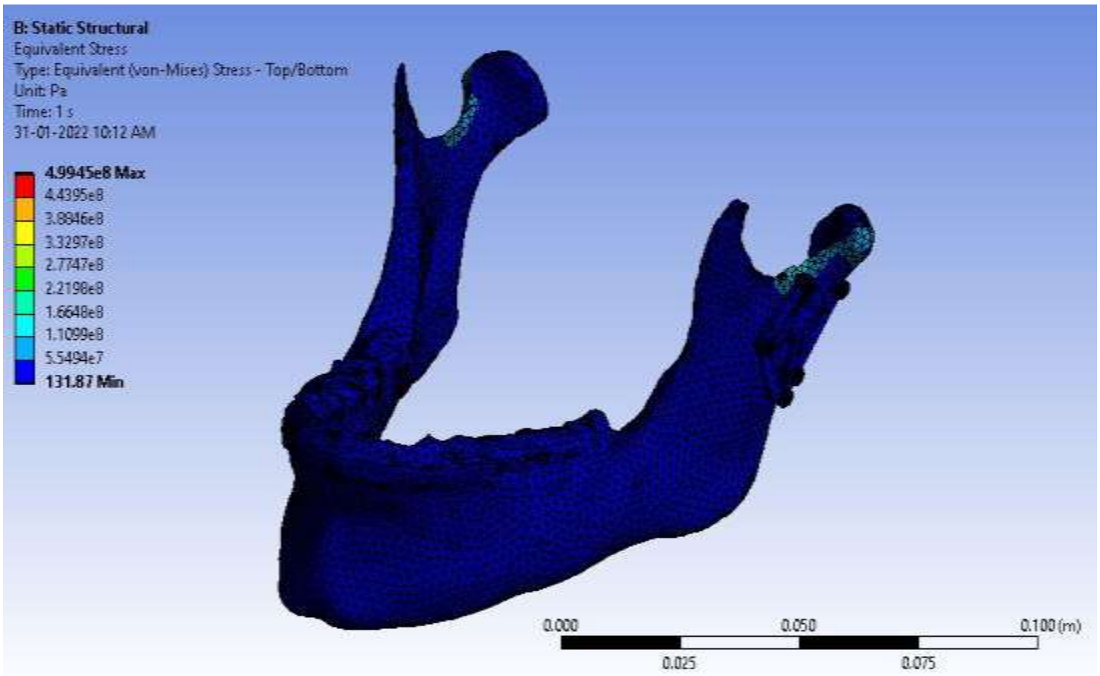


Fig 8 Strut plate-Von Mises Stresses over Plate

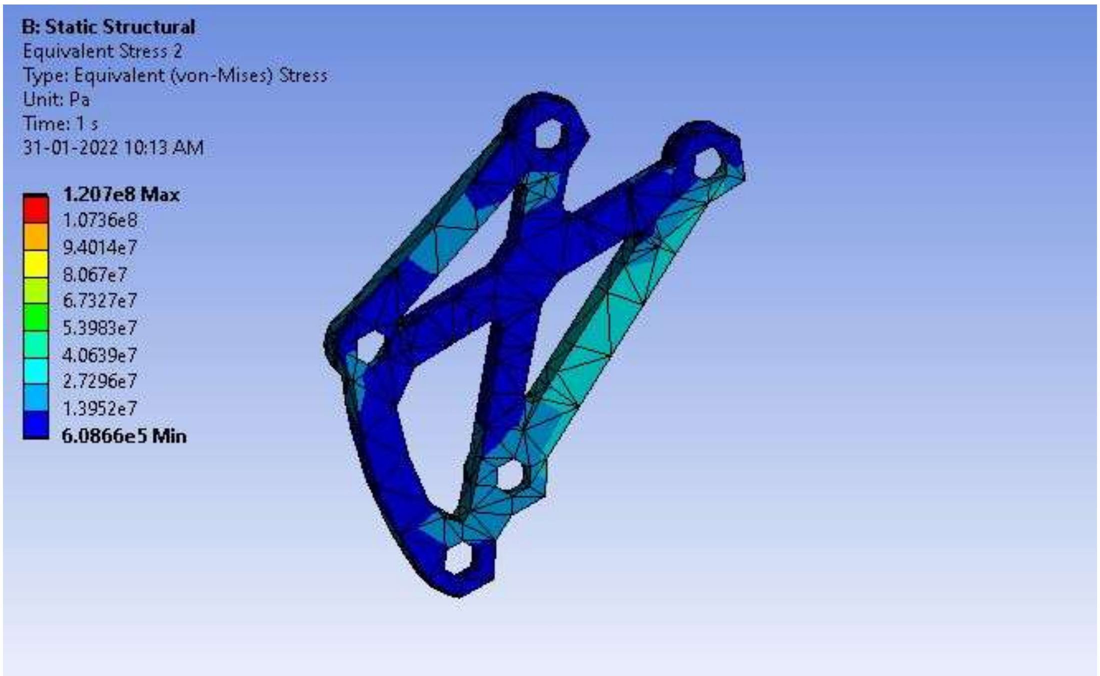


Fig 9 Strut plate-Von Mises Stresses over screws

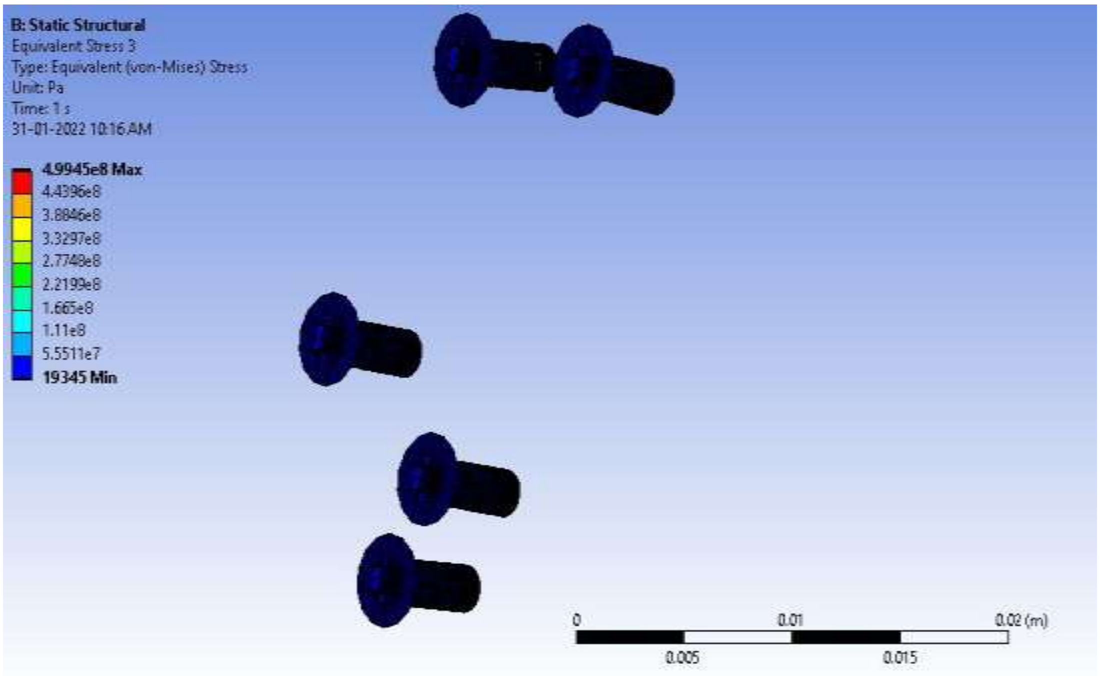


Fig 10 Lambda Plate – Mesh Generation

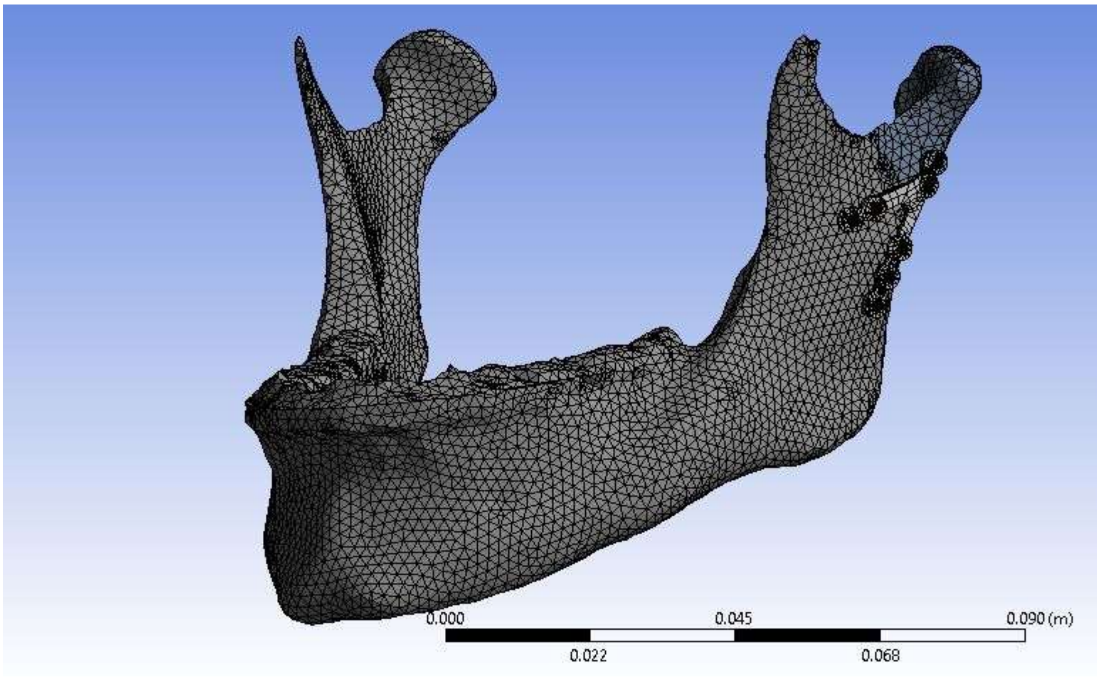


Fig 11 Lambda Plate – Force Application

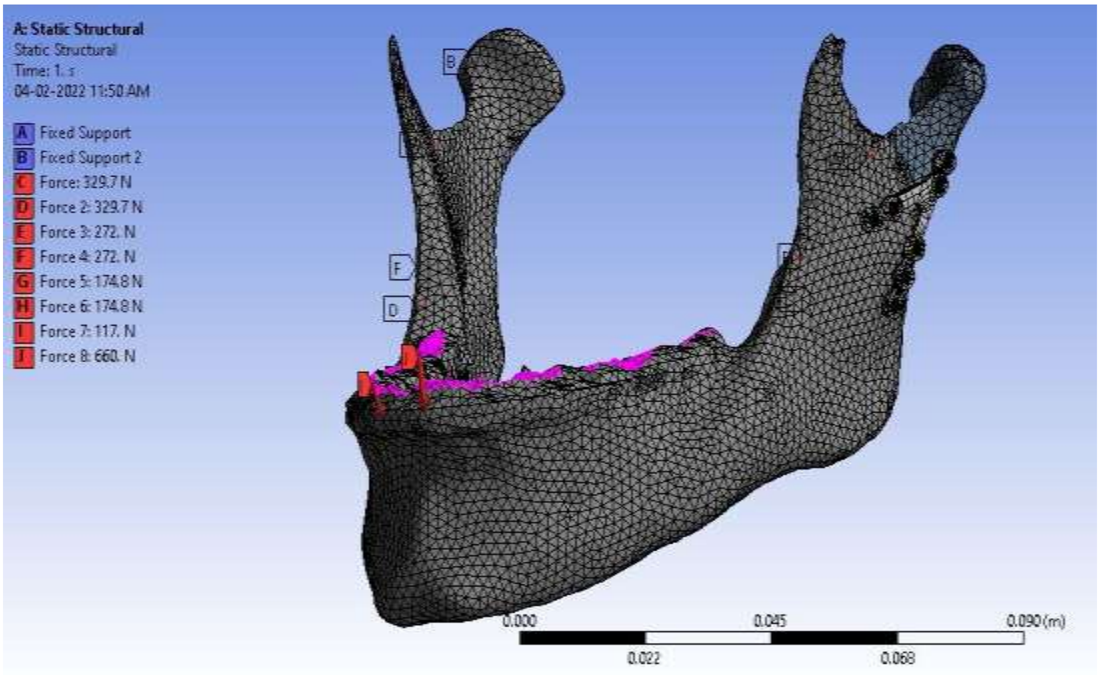


Fig 12 Lambda Plate – Total Deformation

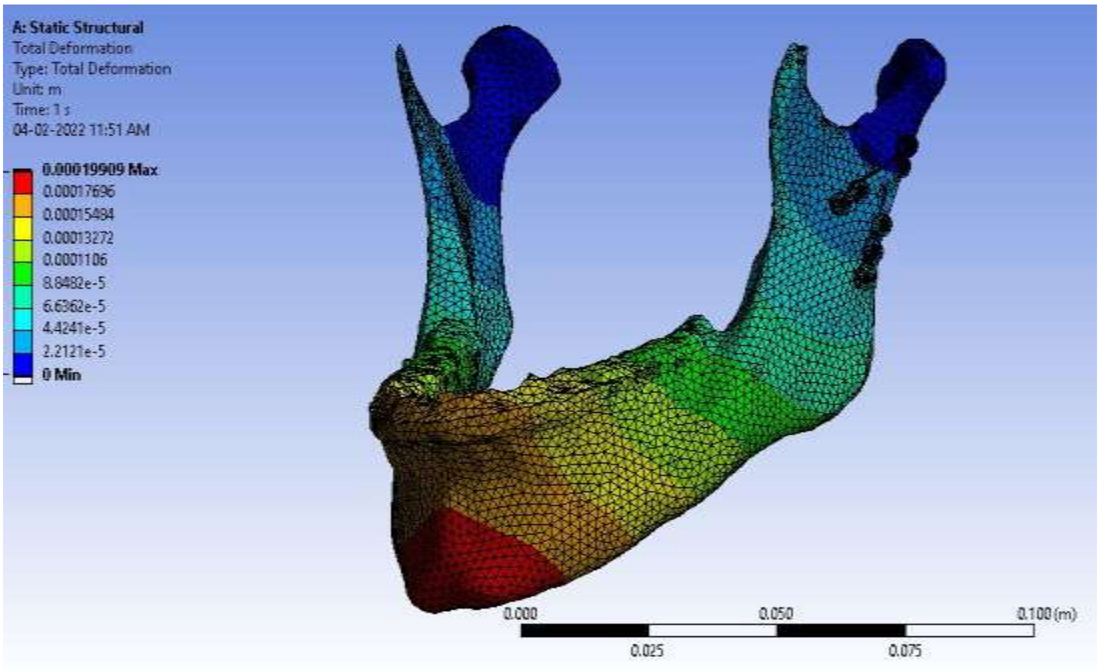


Fig 13 Lambda Plate – Von Mises stresses over the bone

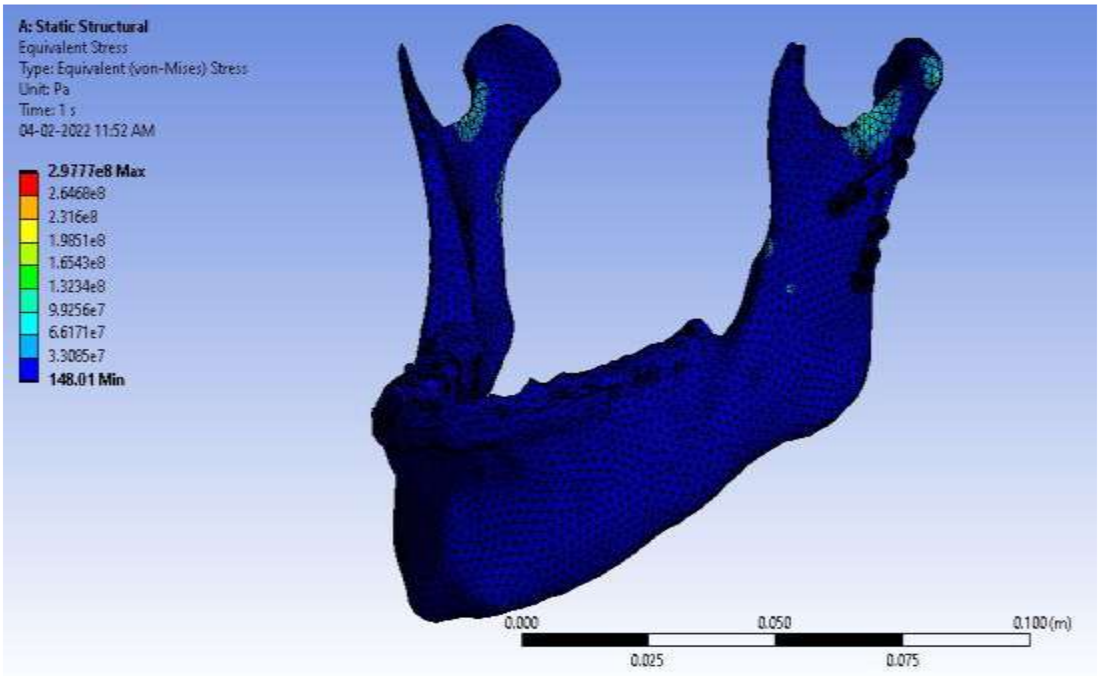


Fig 14 Lambda Plate – Von Mises stresses over the plate

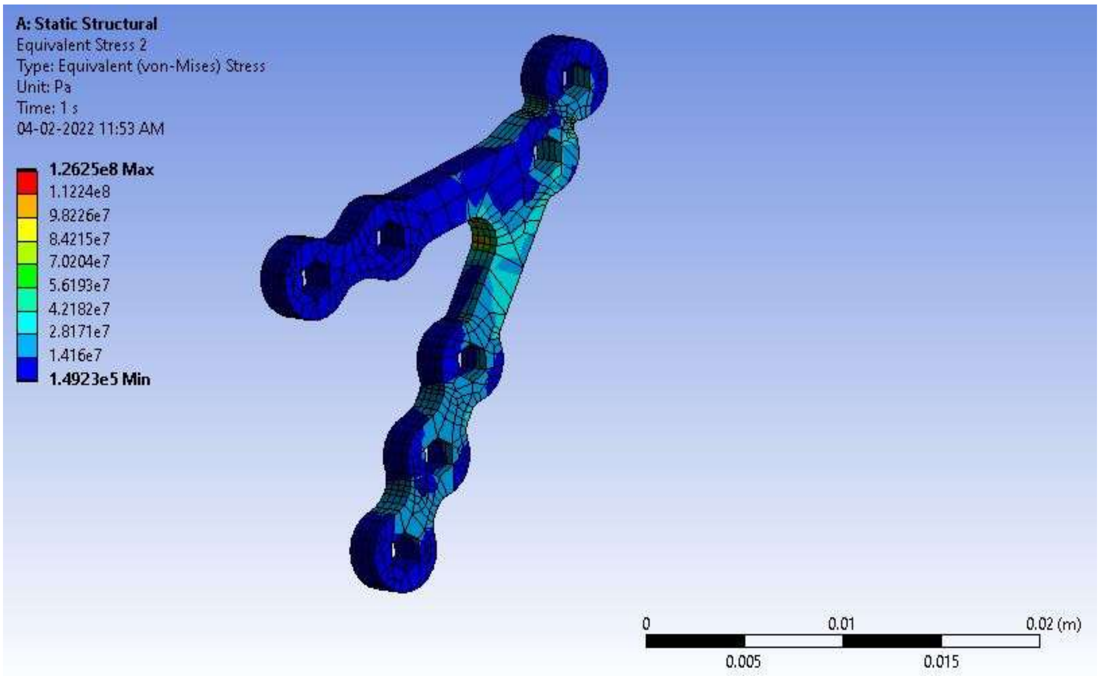


Fig 15 Lambda Plate – Von Mises stresses over the screws

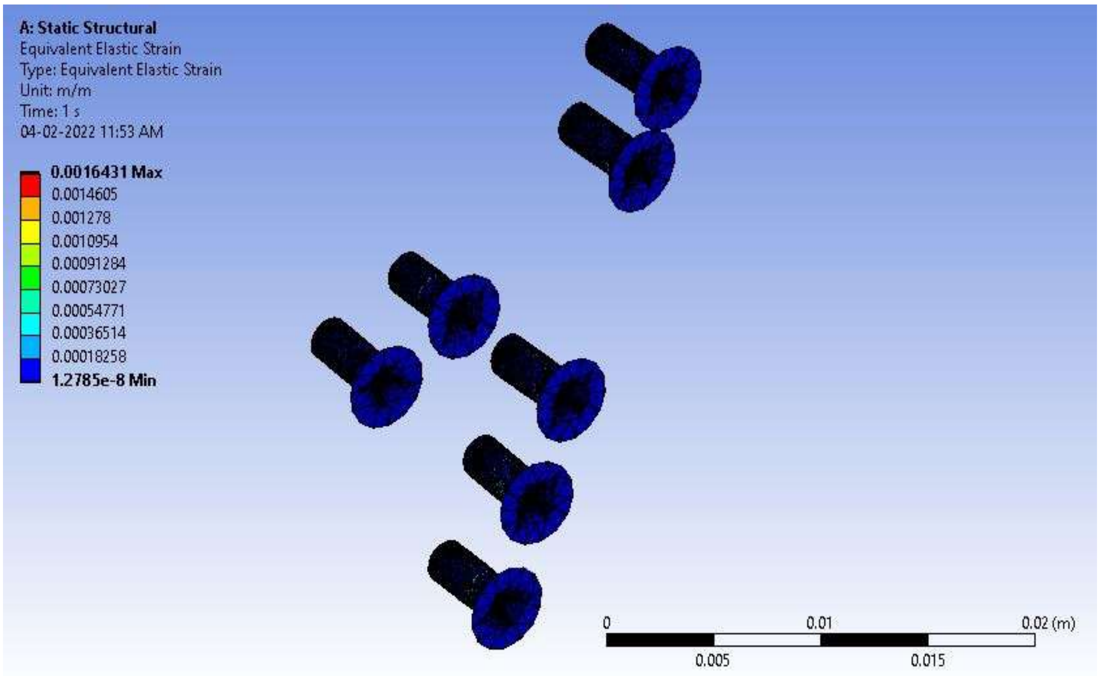


Fig 16 Delta Plate – Mesh Generation

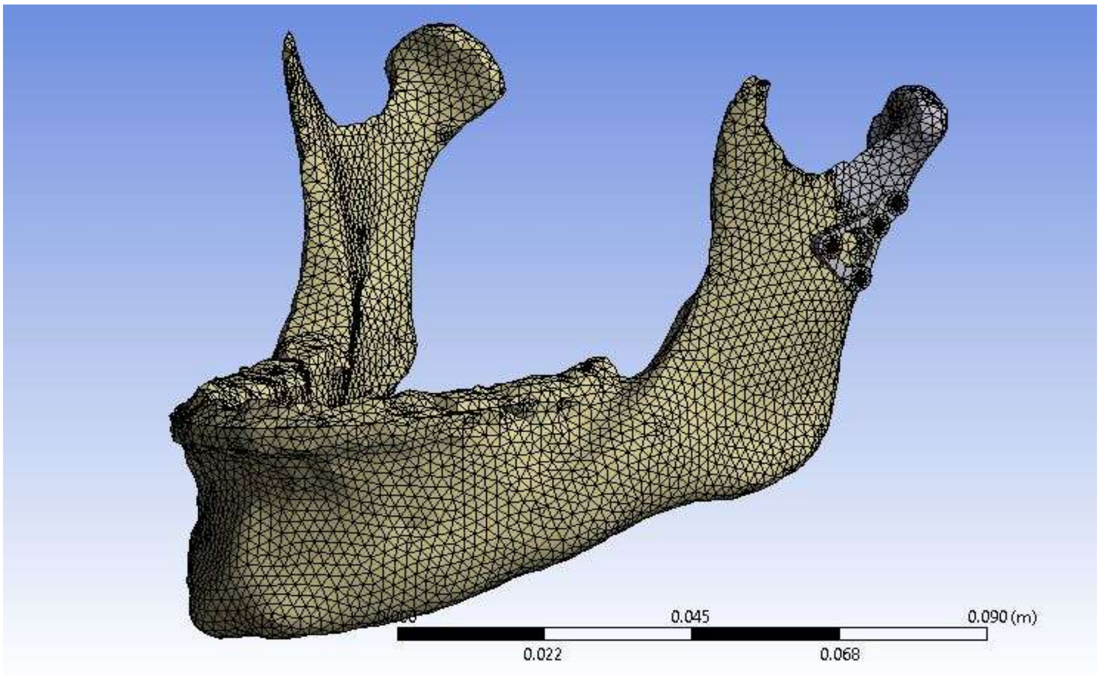


Fig 17 Delta Plate – Force Application

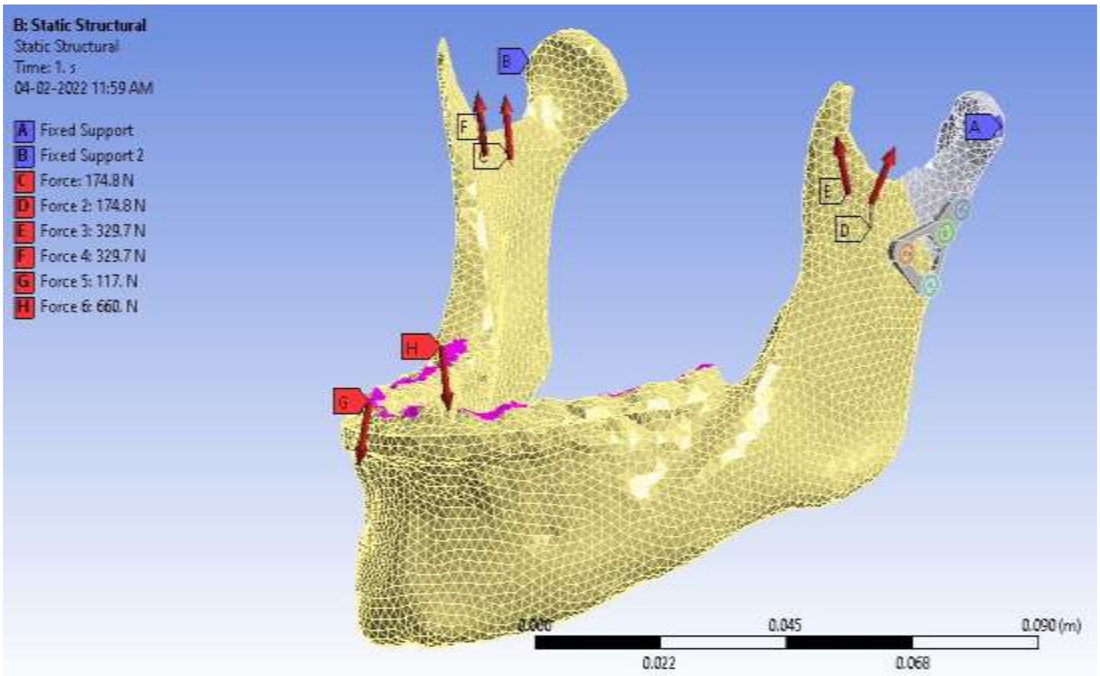


Fig 18 Delta Plate – Total Deformation

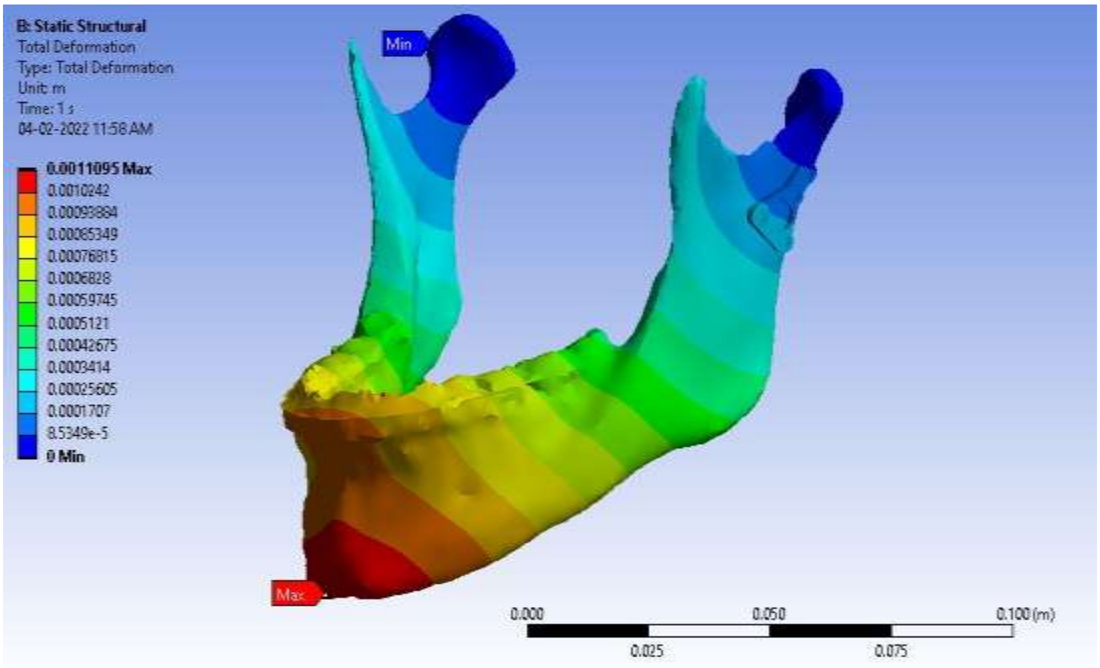


Fig 19 Delta Plate – Von Mises stresses over the bone

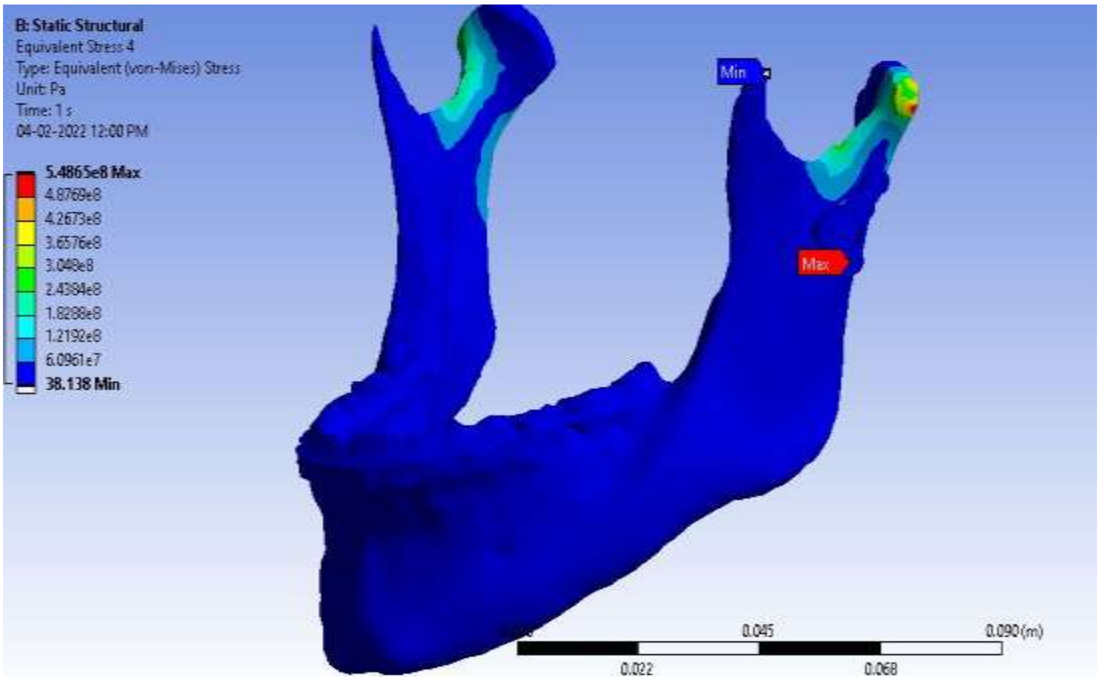


Fig 20 Delta Plate – Von Mises stresses over the plate

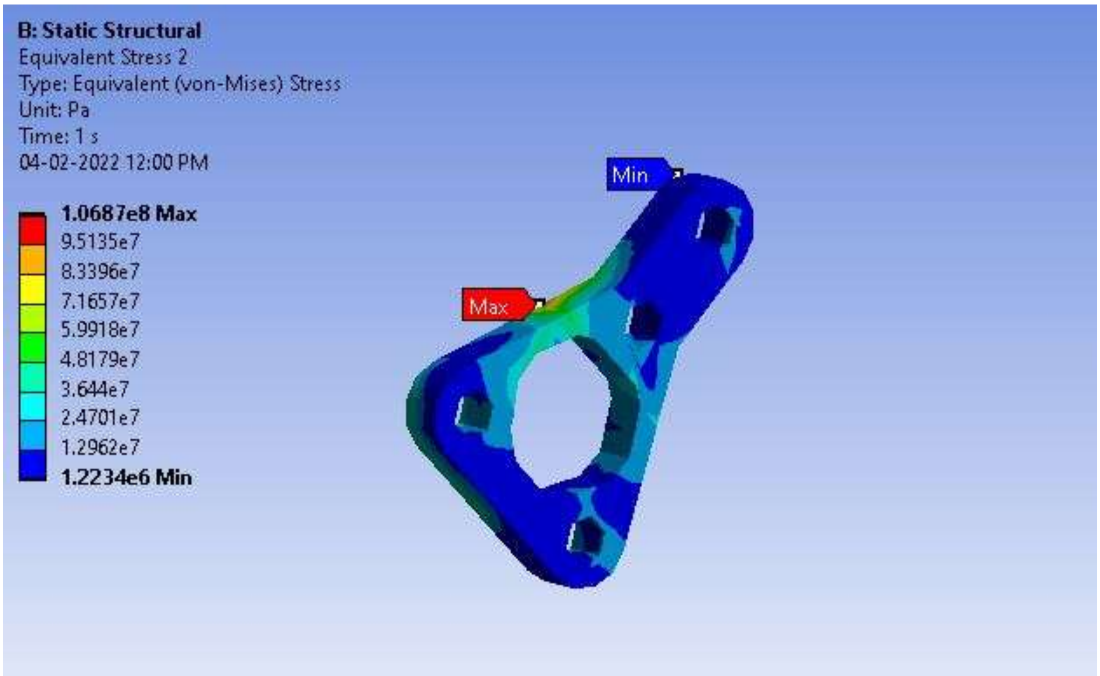


Fig 21 Delta Plate – Von Mises stresses over the screws

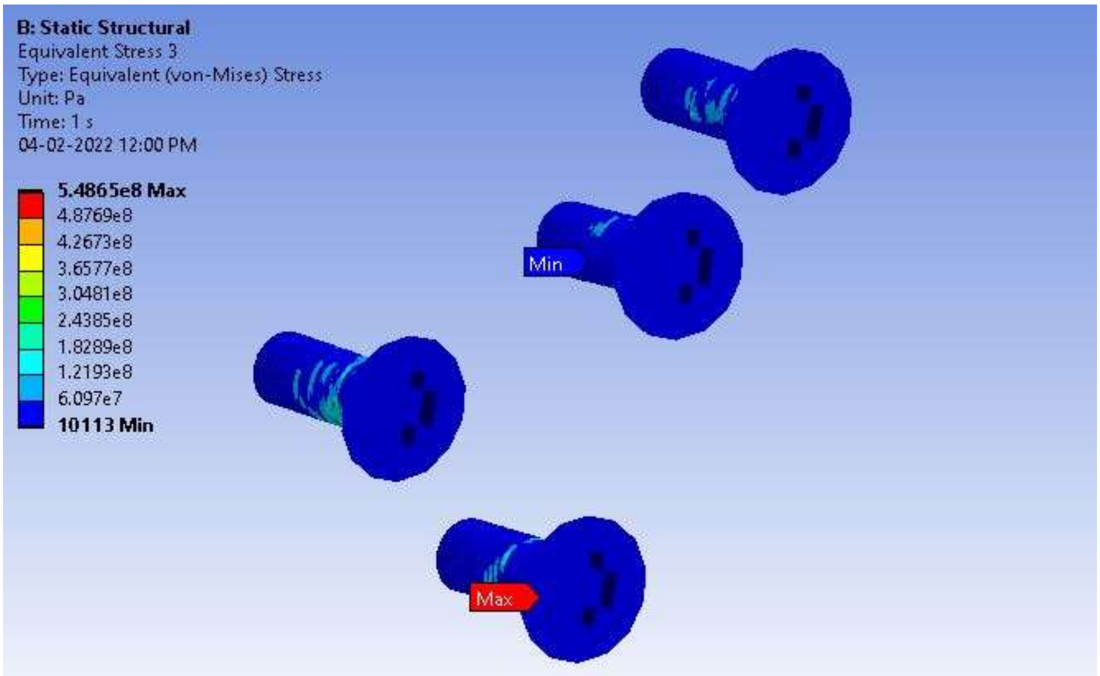


Fig 22 Trapezoid Plate – Mesh Generation

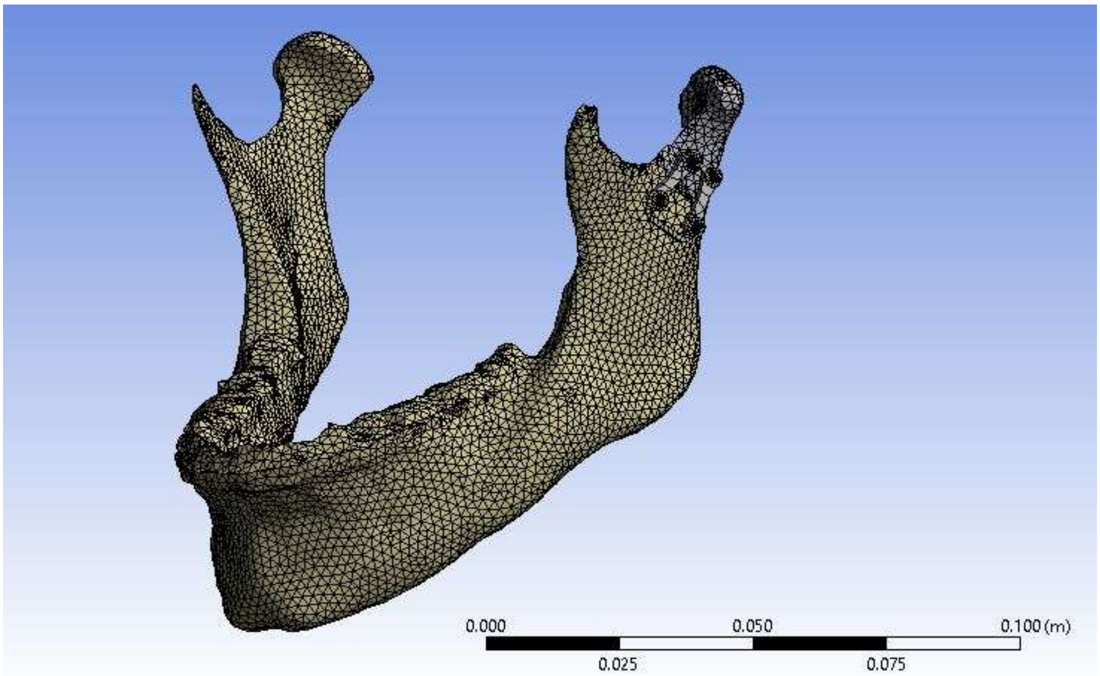


Fig 23 Trapezoid Plate – Force Application

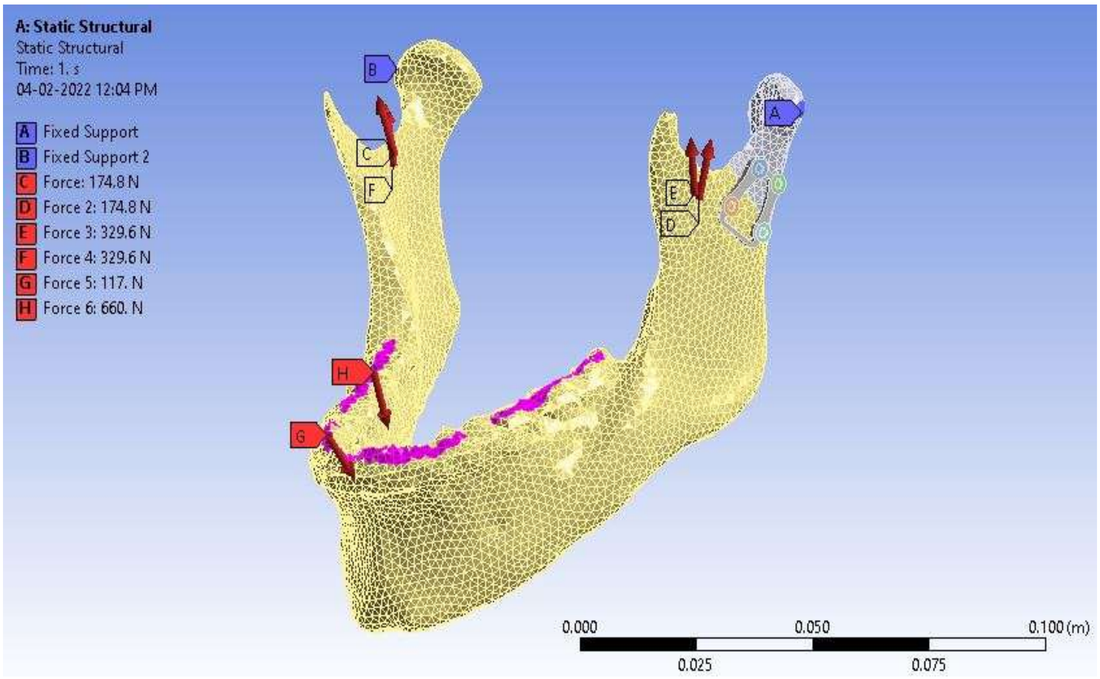


Fig 24 Trapezoid Plate – Total Deformation

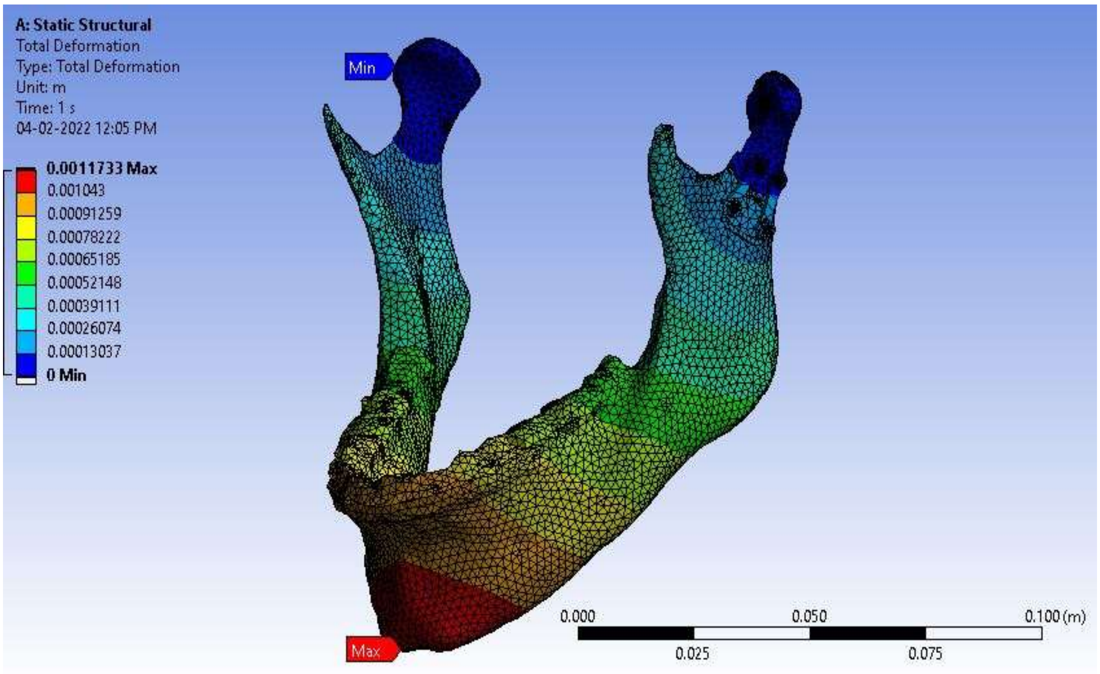


Fig 25 Trapezoid Plate – Von Mises stresses over the bone

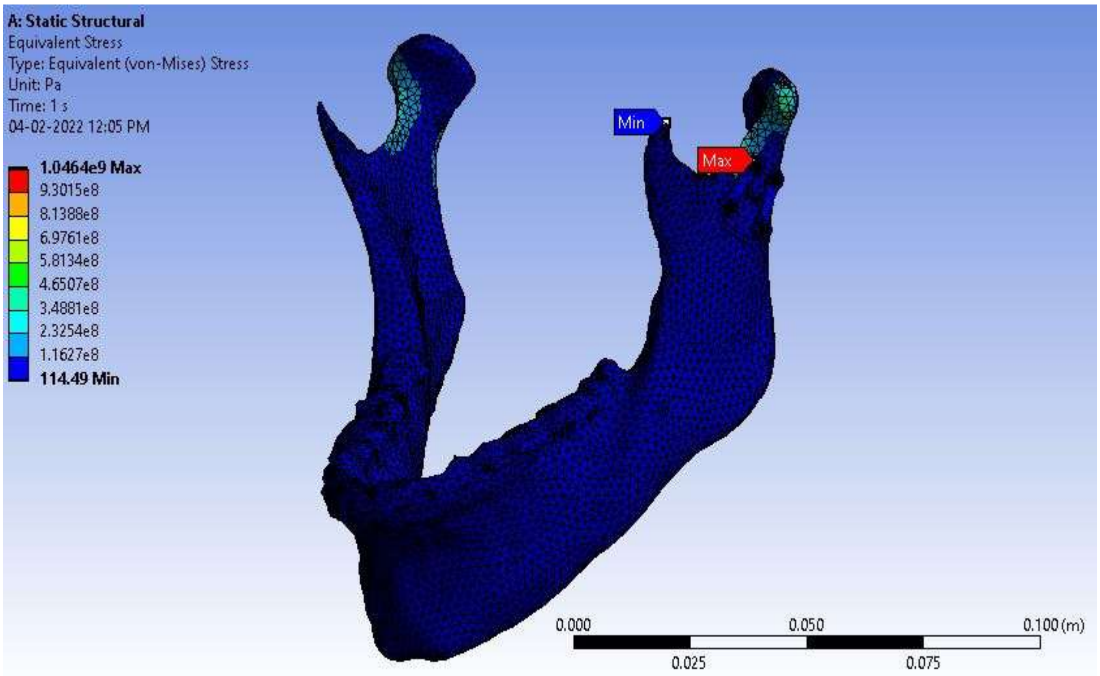


Fig 26 Trapezoid Plate – Von Mises stresses over the plate

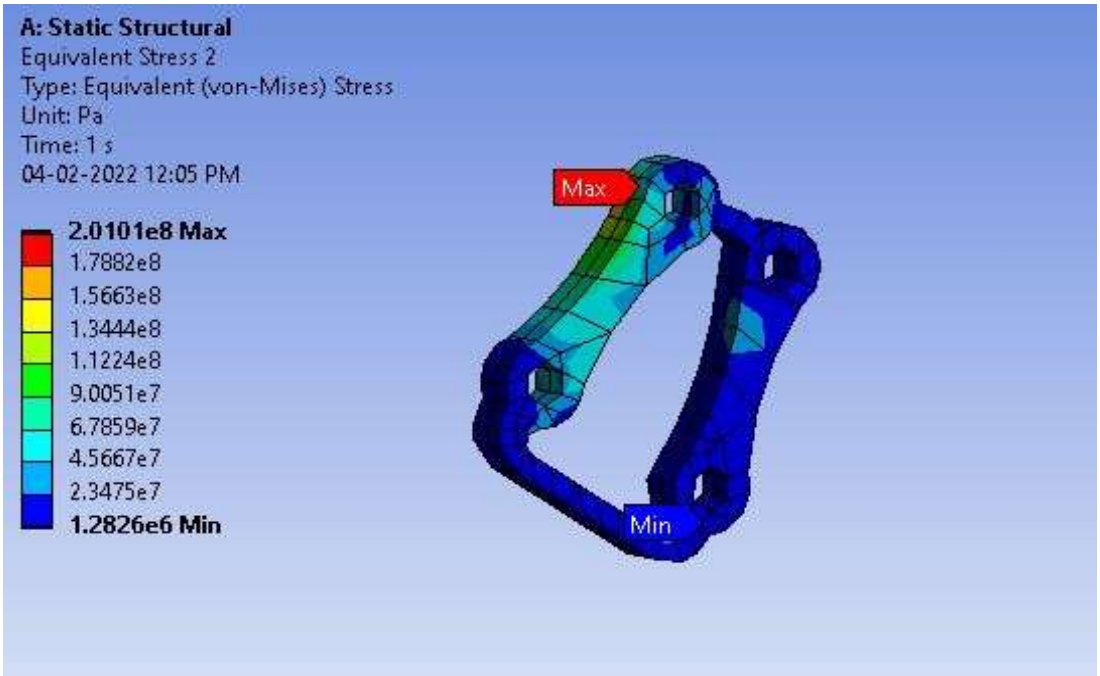


Fig 27 Trapezoid Plate – Von Mises stresses over the screws

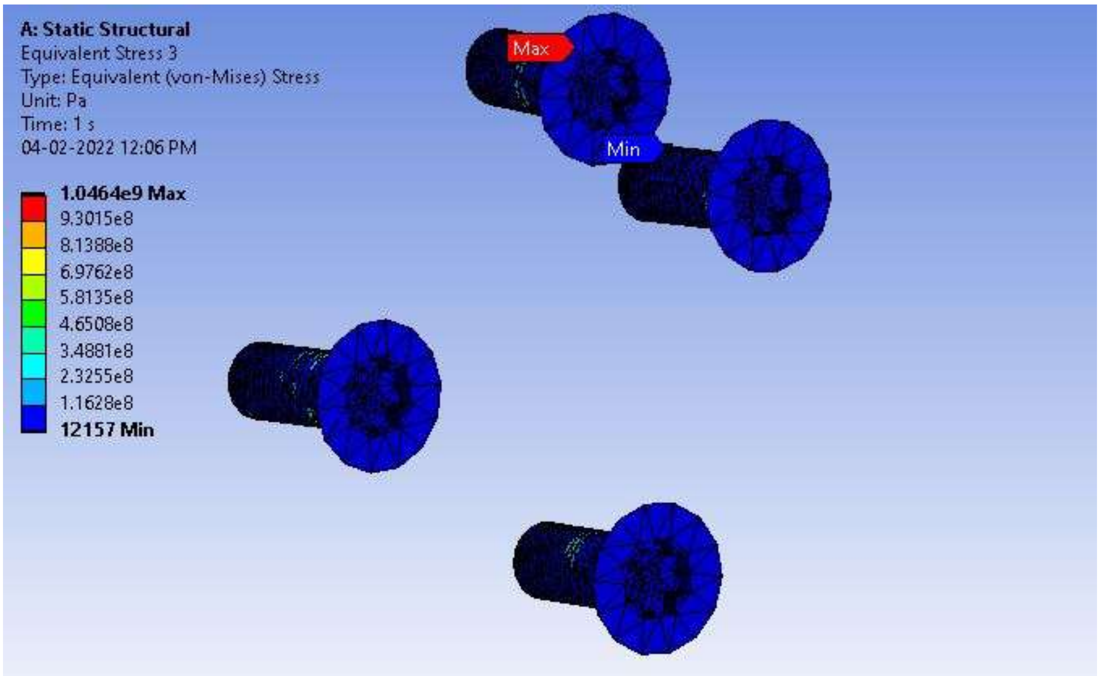


Fig 28 Rhombic Plate – Mesh Generation

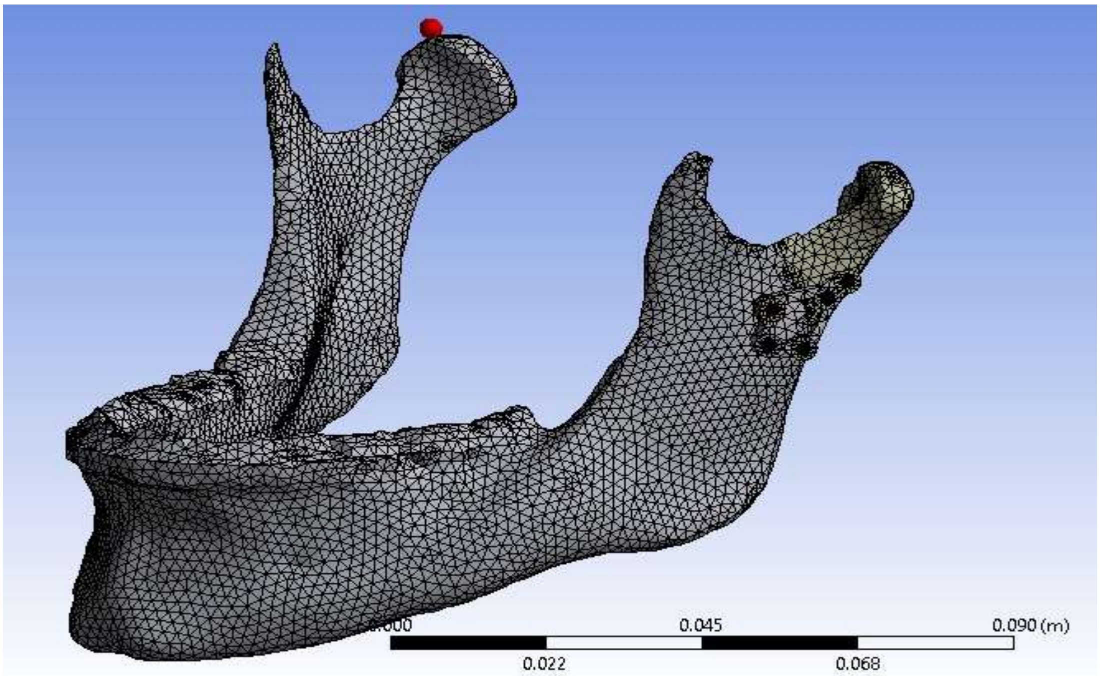


Fig 29 Rhombic Plate – Force Application

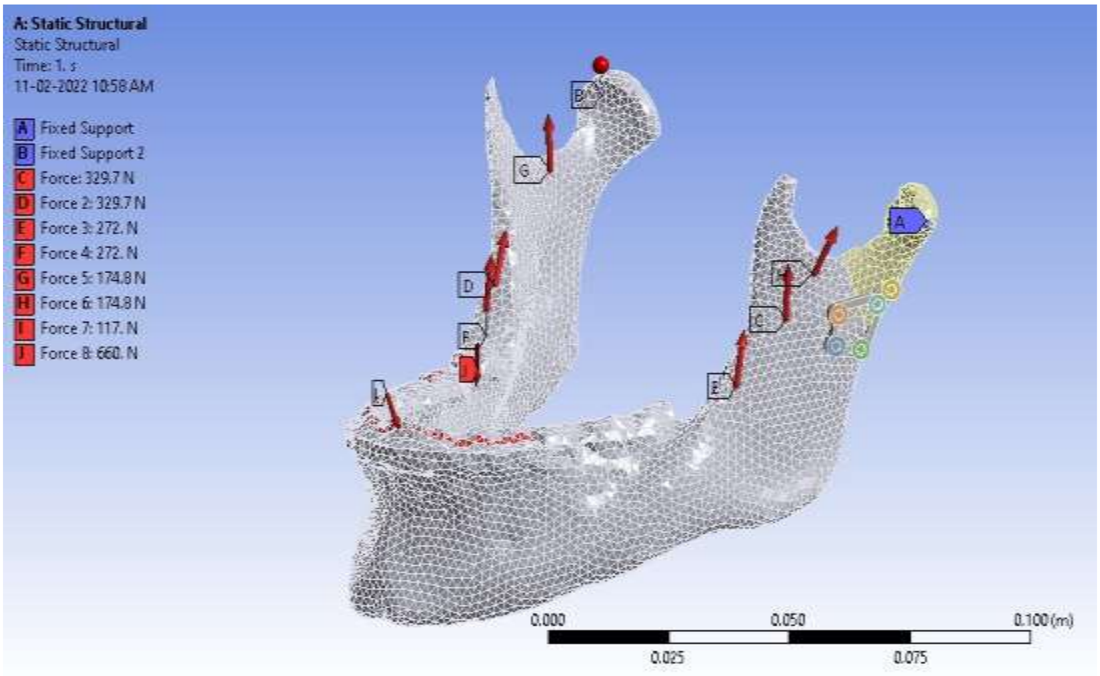


Fig 30 Rhombic Plate – Total Deformation

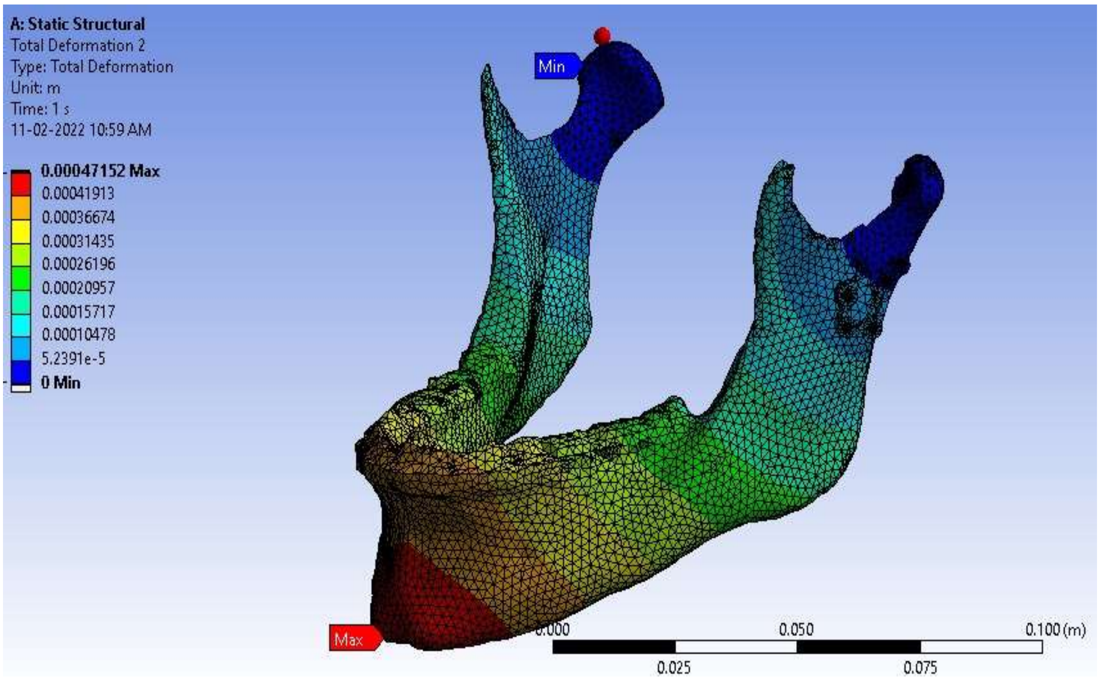


Fig 31 Rhombic Plate – Von Mises stresses over the bone

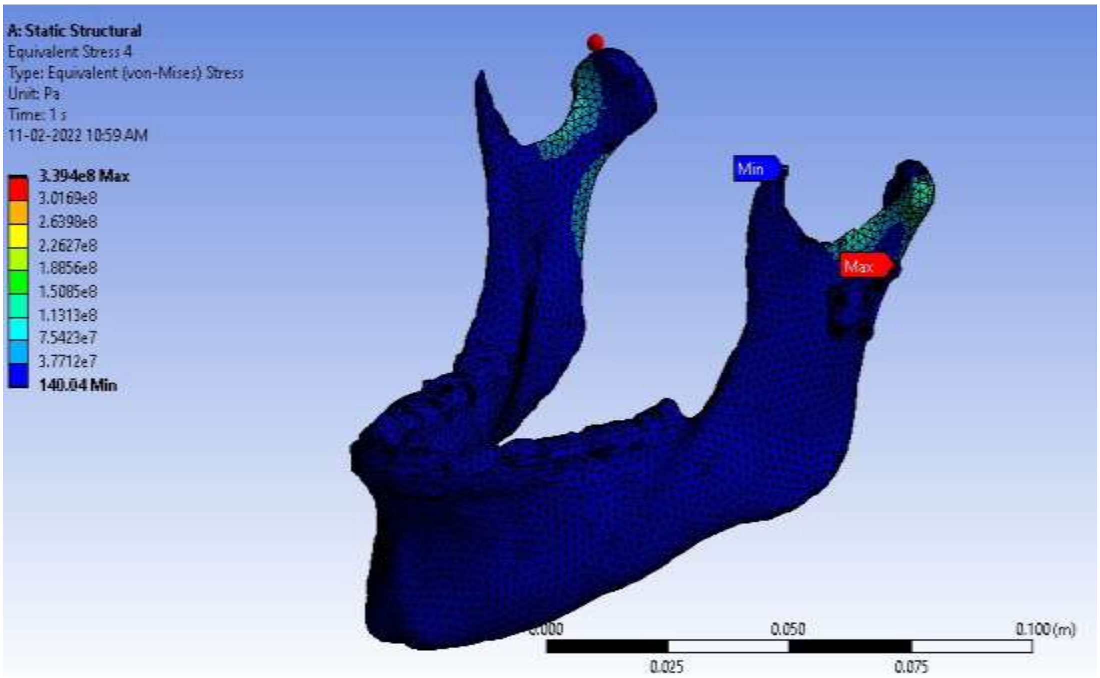


Fig 32 Rhombic Plate – Von Mises stresses over the plate

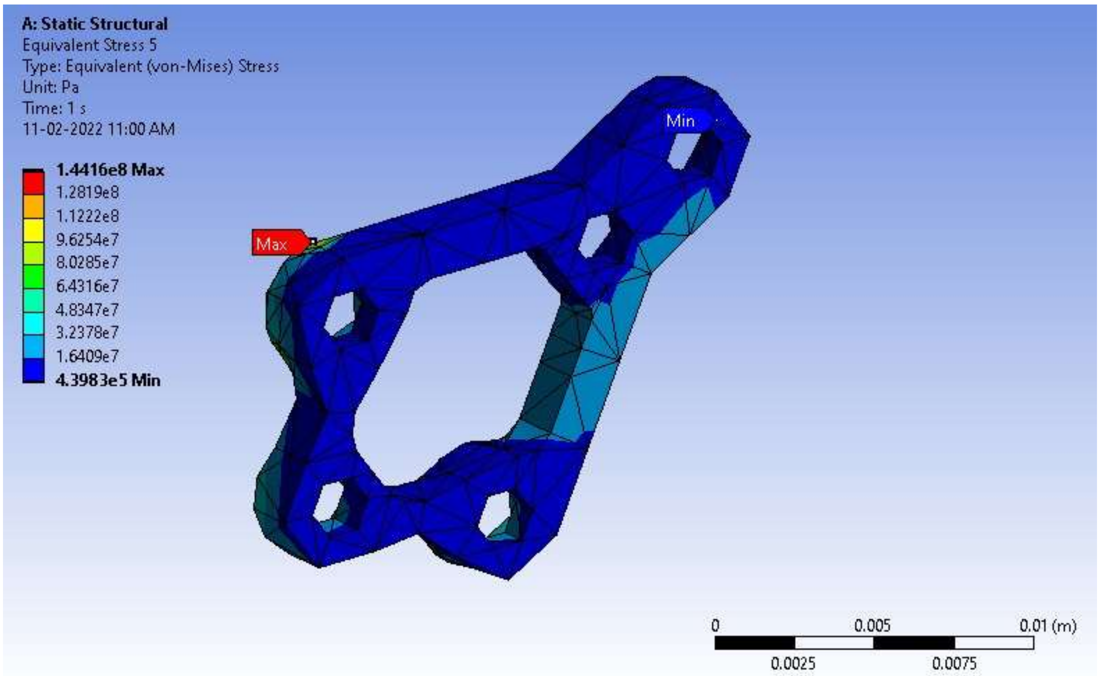
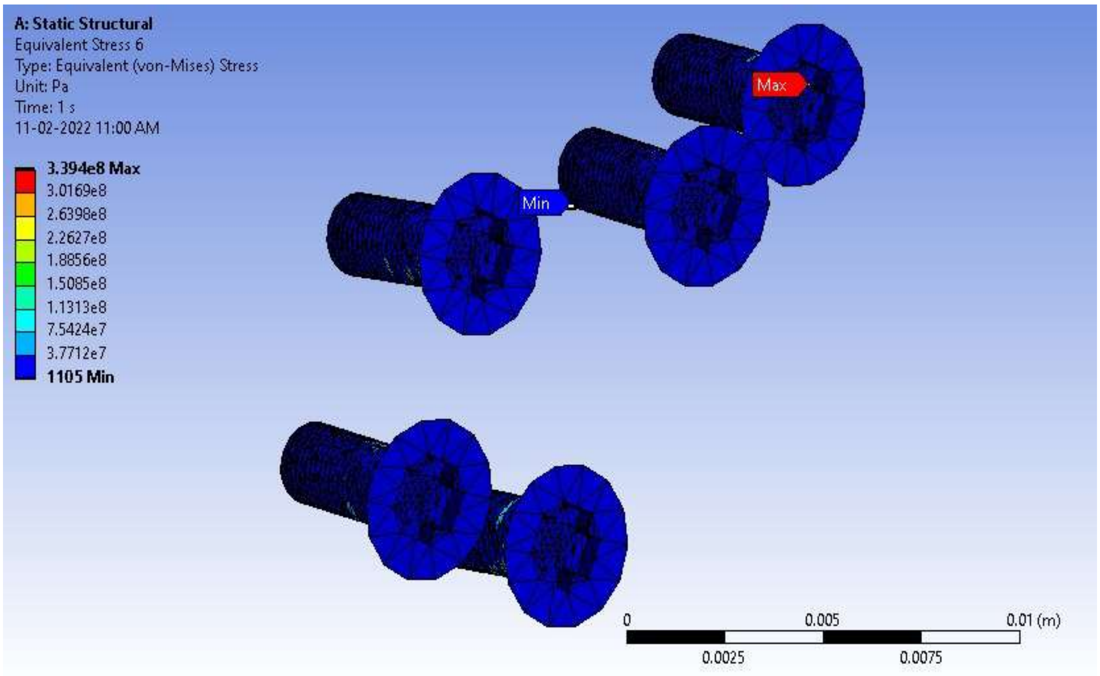


Fig 33 Rhombic Plate – Von Mises stresses over the screws



RESULTS

Analysis of displacement

All the five miniplates studied in the present study behaved in the same manner quantitatively. The miniplates showed a difference with respect to displacement values. There was difference in the values of relative displacement with respect to the five miniplates. The difference was also observed for maximum stress, strain and total deformity on the miniplates and the screws.

The values of relative displacement between the fractures segments were calculated at the time of application of loading forces. The applied loading forces used in this study were the reactionary forces of the masticatory muscles namely; temporalis (329.2N), masseter (272N) and medial pterygoid (174.8N) while mastication.[24] Simultaneous loading of the biting and the occlusal forces were used. The biting forces that were applied in the anterior teeth region were 117 N, and occlusal forces applied at the second molar teeth region were 660 N on both the sides.[44]

The displacement of the segments in all five miniplates was as follows (Table no.5):

Lambdaminiplate: With the use of lambda miniplate, The fractured fragments had a relative displacement of 0.1628 mm at the fracture point.

Strut plate: With the use of strut miniplate,The fractured fragments had a relative displacement of 0.1490 mm at the fracture point.

Rhombic plate: With the use of rhombic miniplate,The fractured fragments had a relative displacement of 0.1624mm at the fracture point.

Delta miniplates: With the use of deltaminiplate, The fractured fragments had a relative displacement of 0.1559 mm at the fracture point.

Trapezoid miniplates: With the use of trapezoidminiplate, The fractured fragments had a relative displacement of 0.1631mm at the fracture point.

The values of the relative displacement with the five miniplates showed that the maximum displacement of the fracture fragments was observed with the trapezoid miniplate. This was followed by lambda miniplate, rhombic plate and delta miniplate. The strut plate showed the least amount of relative displacement of the fracture fragments indicating that the strut plate provides a stable fixation over lambda miniplate, rhombic plate, delta miniplate and trapezoid miniplate.

Analysis of VM stresses and strain

The VM stresses which occurs in plates and screws were calculated in(MPa) at the time of the loading forces of masticatory muscle and the biteforces. These stresses were colour coded showing the values of the stresses. The stresses occurred in plating systems were as follows (Table no.6):

On miniplates

Lambda miniplate: The VM stresses and the strain observed in the lambda miniplate were 297MPa and 0.6 respectively. The stresses were uniformly distributed over the plates and the screws and were also transmitted uniformly over the bone. Fig. 14

Strut plate: The VM stresses and the strain observed in the strut plate were 120MPa and 0.618 respectively. The stresses were uniformly distributed over the bone through plates and screws. Fig.8

Rhombic plate: The VM stresses and the strain observed in the rhombic plate were 144MPa and 0.801 respectively. The concentration of VM stress was observed to be more around the rhombic plate. Fig.32

Delta miniplate: The VM stresses and the strain observed in the delta miniplate were 548MPa and 0.5 respectively. The concentration of VM stress was observed to be more around the delta miniplate. Fig.20

Trapezoid miniplate: The VM stresses and the strain observed in the trapezoid miniplate were 201MPa and 1.1 respectively. The concentration of VM stress was observed to be more around the trapezoid miniplate. Fig.26

Overall, the maximum stress was observed with the delta miniplate and then lambda miniplate. This was followed by trapezoid miniplate, rhombic miniplate and strut miniplate.The least amount of stress was present with strut plate. Thus strut plate showed less VM stress over other miniplates used.

With respect to the VM strains, the maximum strain was observed with Trapezoid plate. This was followed by Rhombic plate,strut pate, lambda miniplate and delta plate. The least amount of strain was observed with Delta miniplate.

On screws

Screws used with Lambda miniplate: The VM stresses and the strain observed in the screws used with the lambda miniplate were 126MPa and 1.6 respectively. The stresses were uniformly distributed over the screws and were also transmitted uniformly over the bone. Fig.15

Screws used with Strut plate: The VM stresses and the strainobservedin the screws used with the strut plate were 499MPa and 2.63 respectively. The stresses were uniformly distributed over the bone through the screws. Fig.9

Screws used with Rhombic plate: The VM stresses and the strain observed in the screws used with the rhombic plate were 339MPa and 1.862 respectively. The stresses were more concentrated near the head of the screws and least in the thread area of the screw used with rhombic plate. Fig.33

Screws used with Delta miniplate: The VM stresses and the strain observed in the screws used with the delta miniplate were 106MPa and 3.1 respectively. The maximum stresses and strains were concentrated near the head of the screws while least in the thread area. Fig.21

Screws used with Trapezoid miniplate: The VM stresses and the strain observed in the screws used with the trapezoid miniplate were 1040MPa and 5.6 respectively. The maximum stresses and strains were concentrated near the head of the screws while least in the thread area.Fig.27

Overall, the maximum stress was observed in the screws used with the trapezoid miniplate. This was followed by screws used with strut plate, rhombic pate and the screws used with lambda miniplate. The least amount of stress was present with the screws used with delta miniplate. Thus screws used with delta miniplate showed less VM stress over screws used with other miniplates.

With respect to the VM strains, the maximum strain was observed screws used with trapezoid miniplate. This was followed by screws used with delta miniplate, strut plate and screws used with rhombic plate. The least amount of strain was observed in the screws used with lambda miniplate.

There was no standard distribution of stress and strain with respect to miniplates and the screws used. For some plates like, lambda miniplate and delta miniplate, the VM stresses were more in the plates and less in the screws used. While in case of strut plate, rhombic plate, trapezoid miniplate, the VM stresses were more in the screws used along with these plates compared to the stresses over these plates alone.

Analysis of total deformation

The total deformation was obtained with respect to all five plates/miniplates and screws. The results were as follows:

Lambda miniplate and screws used: The total deformation observed with lambda miniplate was 0.19mm while that observed with the screw was 0.05mm. the maximum deformation was concentrated in the symphysis area of mandible decreasing posteriorly with least deformation observed in condylar area. Fig.12

Strut plate and screws used: The total deformation observed with strut plate was 0.38mm while that observed with the screw was 0.0822mm. The maximum deformation was concentrated in the symphysis area of mandible decreasing posteriorly with least deformation observed in condylar area. Fig.6

Rhombic plate and screws used: The total deformation observed with rhombic plate was 0.47mm while that observed with the screw was 0.094mm. The maximum deformation was concentrated in the symphysis area of mandible decreasing posteriorly with least deformation observed in condylar area. Fig.30

Delta miniplate and screws used: The total deformation observed with delta miniplate was 1.1mm while that observed with the screw was 0.22mm. The maximum deformation was concentrated in the symphysis area of mandible decreasing posteriorly with least deformation observed in condylar area. Fig18

Trapezoid miniplate and screws used: The total deformation observed with trapezoid miniplate was 1.1mm while that observed with the screw was 0.21mm. The maximum deformation was concentrated in the symphysis area of mandible decreasing posteriorly with least deformation observed in condylar area. Fig.24

Overall, the total deformation was highest with deltaminiplate and trapezoid miniplate followed by rhombic miniplate, and strut plate. The lambda miniplate presented with the least total deformation. With respect to the screws used, the highest deformation was observed with the screws used along delta miniplate followed by screws used along trapezoid miniplate, screws used along rhombic plate and screws used along strut plate. The least amount of deformation was observed with screws used along lambda mini plate.

DISCUSSION

In comparison to other maxillofacial fractures, the frequency of mandible condylar fracture was 17.2 percent - 52 percent.[3.] For the treatment of these condyle fractures, new procedures or technologies were required. Because the treatment of condyle fracture has been a contentious issue for decades, a decision must be made about whether to go for a close reduction or an ‘open reduction and internal fixation’ for a mandible condyle fracture. The open treatment produces better post - operative results in terms of normal jaw function unfortunately, the dilemma of which type of plates (s) and how many plates (s) to employ for fixing mandible condyle fractures emerges.

Biomechanical, clinical, radiological, as well as FEA studies have all been done in the past to examine the various plate systems used in the management of condyle fractures. [2,8,19,16,29,32,39,40]

FEA models had previously been utilized to assess the various plating techniques that are employed in the management of mandible condyle fractures. In terms of constraining the nodes as well as the elements needed to build the whole model, the model utilized in our study outperformed earlier models. The mandible was created in our research model to mimic the true anatomical behavior of the human TMJ joint during mastication.

High functional forces act on the mandible, causing internal tensile as well as compressive strains. It is suggested that the only way to achieve successful osteosynthesis of mandibule fractures is to reduce the harmful tensile strains (Champy et al., 1978). Meyer et al. (2002) attempted to determine the tensile and compressive lines just at condyle area, and discovered the tension lines going below it and parallel to the ramus's sigmoid notch.

These biomechanical concepts, in combination with tensile testing of straight miniplates, clearly demonstrated that single straight miniplate is insufficient for rigid fixation of a subcondyle fracture, and that 2 straight miniplates of non-parallel configuration are required to counter both compressive and tensile strains. Newer 3-dimensional single miniplates have been created in the last decade, and some have been found to be have mechanical performance comparable to or better than 2 straight non-parallel miniplates. The main benefit of such single miniplates is that they make the surgical operation easier. Using finite element simulation, a non-invasive method that has been demonstrated to just be effective for predicting mechanical behaviour of bone, we examined five designs of these miniplates in the current investigation.

In our study, the homogenous FEA model has 18950 nodes in the Lambda plate model, 18323 nodes in the Strut plate model,18445 nodes in the Rhombic plate model , 18427 nodes in the Delta plate model, 18524 nodes in the Trapezoid Plate model. When compared to other biomechanical models, the structure of our study model has the benefit of achieving a physiologically accurate pattern of loading by estimating overall reactionary forces of the mastication muscles.

Previously, research had shown open reduction and internal fixation were more efficient than closed reduction in certain situations.[10] The research about which type of internal fixation is most appropriate is still going on.

According to published report, using a single miniplate, 2 miniplates in parallel or two plates angulated, the use of strut plate was most stable in fixing condyle fractures.[8, 35,40.] We compared the 5 plating systems which are being used for fixation of the condyle fractures of the mandible. The structural model is rigid enough to withstand all applied muscle forces and biting forces and occlusal forces in this study.

After applying the loading forces of a biting forces on the anterior teeth area (117N), occlusal forces on second molar teeth area ipsilateral and contralateral (660N), and reactionary forces of a temporalis muscle (329.2N), masseter muscle (174.8N), and medial pterygoid muscle (174.8N), the VM stresses with in plating system, screws, and tension distribution of a forces were calculated in this study (272.0N) .[24, 44]

Lambda miniplate-: The VM stresses and the strain observed in the lambda miniplate were 297MPa and 0.6 respectively. Fig.14 The stresses were uniformly distributed over the plates and the screws and were also transmitted uniformly over the bone. Overall, the maximum stress was observed with the lambda miniplate. With the use of lambda miniplate, the relative displacement of the fractured fragments at the fracture site was 0.1628 mm.

The study by Liokatis P et.al. showed that the highest strains were found on the lambda as well as strut plates, however no structural failure was recorded. In comparison to a trapezoidal and two parallel plates, the strut and lambda plates are preferable for the stabilization of condyle neck fractures, according to our data.[40]

Strut plate: The VM stresses and the strain observed in the strut plate were 120MPa and 0.618 respectively.Fig.8 The stresses were uniformly distributed over the bone through plates and screws. The least amount of stress was present with strut plate. Thus strut plate showed less VM stress over other miniplates used. With the use of strut miniplate, the relative displacement of the fractured fragments at the fracture site was 0.01490 mm. The strut plate showed the least amount of relative displacement of the fracture fragments indicating that the strut plate provides a stable fixation over lambda miniplate, rhombic plate, delta miniplate and trapezoid miniplate.

The study by Liokatis P et.al.showed that the highest strains were found on the lambda as well as strut plates, however no structural failure was recorded. In comparison to a trapezoidal and two parallel plates, the strut and lambda plates are preferable for the stabilization of condyle neck fractures, according to our data.[40]

Rhombic plate: The VM stresses and the strain observed in the rhombic plate were 144MPa and 0.801 respectively. Fig.32. The concentration of VM stress was observed to be more around the rhombic plate. With the use of rhombic miniplate, the relative displacement of the fractured fragments at the fracture site was 0.1624 mm.

The study by Liokatis P et.al.Showed that For the rhomboidal as well as trapezoidal plates, all four plates provide acceptable fixing with a modest danger of screw loosening.[39]

Albogha MH et al. suggested that the strain values surrounding the 2 screws in the distal fragment were generally high in miniplates with a vertical arrangement of a two screws ('lambda, rhombic, and delta miniplates').[2]

Delta miniplate: The VM stresses and the strain observed in the delta miniplate were 548MPa and 0.5 respectively. The concentration of VM stress was observed to be more around the delta miniplate. Fig.20 Overall, the maximum stress was observed with the delta miniplate. With the use of delta miniplate, the relative displacement of the fractured fragments at the fracture site was 0.1559 mm. The least amount of strain was observed with Delta miniplate.

Sikora M et al (2016) Suggested that the. The Delta plate for stable osseointegration of condyle fractures ensures completely excellent management results, both radiologically and clinically, and there is virtually little risk of the plate breaking.[34]

Trapezoid miniplate: The VM stresses and the strain observed in the trapezoid miniplate were 201MPa and 1.1 respectively. The concentration of VM stress was observed to be more around the trapezoid miniplate. Fig.26

With the use of trapezoid miniplate, the relative displacement of the fractured fragments at the fracture site was 0.1631 mm

The values of the relative displacement with the five miniplates showed that the maximum displacement of the fracture fragments was observed with the trapezoid miniplate.

Albogha MH et al. The study projected considerable performance variations among the various designs of three-dimensional miniplates, with the trapezoid miniplate performing best.[2]

The results of the current finite element simulations projected considerable mechanical variations among the miniplates detailed here, with the strut miniplate having the best performance.

After we have compared all of these stress, displacement, and strain distribution values. In line with several other research evaluating various fixation techniques for mandibular condyle fractures. [8,,35,39,40] The findings of these prior research support the findings of the current investigation, which show that the use of strut miniplates in the repair of mandibular condyle fractures is more stable.

In comparison to the other fixation methods studied, the results obtained from our investigation favoured the past studies reports that using strut miniplate was more stable and yielded good results.[40] The results were obtained on vitro, as even more clinical research is required to determine the stability of the mentioned fixation mechanism.

SUMMARY

The type, shape and size of plating systems utilized determine the treatment of face fractures. The finite element approach can be used to simulate these plating systems. In which a 3-dimensional finite element model of a human skull and/or mandible can be created, and plating systems could be examined for their stability properties. A model of the mandible and skull was created for our FEM investigation in order to approximate the exact anatomical position as well as operating mechanism.

The focus of this research was to compare five plating systems that were utilised to treat a mandible subcondyle fracture.

‘Lambda miniplate, Strut miniplate, Rhombic Miniplate, Delta Miniplate as well as Trapezoid Miniplate’ were the Five plating systems that were compared.Following the application of a loading forces, the VM stresses in plates, screws, and the tension that happened on the same were determined. The biting force

at the anterior teeth region (117 N), occlusal forces ipsi-laterally as well as contra-laterally, and other loading forces were applied to the models (660 N). [44] With the exception of the lateral pterygoid muscle, reactionary forces of mastication muscles were computed.

Overall, the maximum stress was observed with the delta miniplate and then lambda miniplate. This was followed by trapezoid miniplate, rhombic miniplate and strut miniplate. The least amount of stress was present with strut plate. Thus strut plate showed less VM stress over other miniplates used.

The values of the relative displacement with the five miniplates showed that the maximum displacement of the fracture fragments was observed with the trapezoid miniplate. This was followed by lambda miniplate, rhombic plate and delta miniplate. The strut plate showed the least amount of relative displacement of the fracture fragments indicating that the strut plate provides a stable fixation over lambda miniplate, rhombi plate, delta miniplate and trapezoid miniplate.

CONCLUSION

The stability of the fixation systems employed in the treatment of mandibular condyle fractures was evaluated using finite element analysis. For each fixation mechanism employed, the collected values and outcomes were examined. The strut plate showed the least amount of relative displacement of the fracture fragments indicating that the strut plate provides a stable fixation over lambda miniplate, rhombi plate, delta miniplate and trapezoid miniplate.

LIMITATIONS OF THE STUDY

Individual differences need the employment of distinct mechanics as well as force systems for every individual. Even with perfect mechanics & correct force systems, the biomechanical effect of the force system varies after the fracture is fixed, and changes are required during the operation of the fixation system for the fixing of the condyle fracture. At this time, the state of our understanding makes it impossible to determine what exactly happens over a period of time when fixation systems are applied. This disadvantage also applies to the current investigation. Because of changes of force systems and physiological response, forces and stresses might differ before and after fracture fixation.

Other limitations to this study were the use of constant values for biting forces; nevertheless, occlusal forces may differ from person to person after surgery. Clinical applications as well as simulation studies may differ due to these limitations. It's really impossible that simulate an exact mathematical model for validate each situation due to these distinct variations. Because the forces used in this investigation were static I contrast to dynamic forces which are actually exerted during various movements therefore , more clinical trials are needed to affirm the conclusions of the 'finite element analysis' before correlating them to actual clinical situation.

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TABLE 1. Lindahl's Classification

Based on anatomic location of the fracture (level of condylar fracture)	**Based on the relationship of the condylar segment to the mandibular fragment**
Condylar head	Non displaced
Condylar neck	Deviated
Sub-condylar	Displaced with medial or lateral overlap
	Displacement with anterior or posterior overlap
	No contact between the fracture segments

TABLE 2. ELEMENTS NODES OF THE FEA MODELS.

Type of Osteosynthesis	**Elements**	**Nodes**
Lamdaminiplate	58655	18950
Strut plate	58185	18323
Rhombic plate	58654	18445
Delta miniplate	58232	18472
Trapezoid miniplate	58134	18524

TABLE 3. Young's modulus and Poison's ratio

	Young's modulus(MPa)	**Poisson's ratio**
Alveolar bone	13000	0.29
Cortical bone	11000	0.29
Titanium	96000	0.36

TABLE 4. Reactionary forces of the masticatory muscles and their proportion of the whole acting force.

Masticatory muscles	**Force(N)**
Temporalis	329.2
Masseter	272
Medial pterygoid	174.8

TABLE 5. DISPLACEMENT OF THE FRACTURED FRAGMENTS AT THE FRACTURE SITE.

Osteosynthesis type	**Displacement (mm)**
Lamdaminiplate	0.1628
Strut plate	0.1490
Rhombic plate	0.1624
Delta miniplate	0.1559
Trapezoid miniplate	0.1631

TABLE 6. MAXIMUM TENSION OVER THE PLATES AND SCREWS

Plates and Screws	**Von-mises stress**	**Von-mises strain**	**Total deformation**
Lamdaminiplate	297 MPa	0.6	0.19 mm
Strut plate	120 MPa	0.618	0.38 mm
Rhombic plate	144 MPa	0.801	0.47 mm
Delta miniplate	548 Mpa	0.5	1.1 mm
Trapezoid miniplate	201 Mpa	1.1	1.1 mm
Screws-Lamdaminiplate	126 Mpa	1.6	0.05 mm
Screws-Strut miniplate	499 Mpa	2.63	0.0822 mm
Screws-Rhombic miniplate	339 MPa	1.862	0.094 mm
Screws-Delta miniplate	106 MPa	3.1	0.22 mm
Screws-Trapezoid miniplate	1040 MPa	5.6	0.21 mm