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3D locking mini-plate in mandible fracture – a review of literature

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1. INTRODUCTION-

The face is the part of the body that represents the physiognomy of an individual. Trauma to the face results in injuries to soft tissue, teeth and skeleton component of the face. The mandible is the most sensitive part of the body where scars and deformities are less tolerated.

The introduction of locking plate and screw system has certain theoretical advantage over the conventional plate and screw like screw loosening, greater stability across the fractured site, less precision required in plate adaptation and less alternation in osseous or occlusal relationship upon screw tightening.

2. Materials and method-

MEDLINE, EMBASE, CINAHL, and Web of Science were systematically searched for literature pertaining to the 3D locking plates, mandible fracture fixation. Qualitative and quantitative findings from relevant studies are presented.

3. Discussion-

A textbook written in 1180 by Salerno from Italy described the importance of establishing a proper occlusion. In 1492, Guglielmo Salicetti in his book Cyrurgia introduced the theory of maxilla- mandibular fixation by 'tie jaw'. In 1795, Chopart and Desault described the effects of elevator and depressor muscles on mandibular fragmants[6]. Michelet et al [3] (1973), reported the use of non-compression vitallium bone plate with mono cortical screw fixation, along with maxilla-mandibular fixation. Niederdellamann et al (1978), described a new kind of osteosynthesis plate, functionally stable internal fixation of mandibular fractures without the necessity of additional fixation elements. Pogrel M.A. et al (1986), used dynamic compression plates in 26 cases of mandibular fractures and discussed their advantages and disadvantages. He stated this method to be an alternative method of treatment for mandibular fracture without maxilla-mandibular fixation and rapid primary healing without any callous formation. But he also stated that it required wide oral incision and due to their bulks, the plate usually has to be removed. This technique is highly sensitive and demanding and severe disharmony in occlusion results in uneven compression, which could not be corrected in elastic traction.

Lindqvist christian et al (1986), reported about 45 patients with mandibular fractures where both centric and eccentric dynamic compression plates were used. He stated that the infection rate was quiet high-13% and both sensory and neurological disturbances were seen. Slight occlusal disharmony were registered in 23% of cases on a 22nd week postoperative follow up. Ian T Jackson et al (1986), studied about the use of champy's miniplate for osteosynthesis in craniofacial deformities and trauma. Amaratunga et al (1987), studied in 311 patients with mandibular fractures to ascertain the influence of jaw mobilization on mouth opening after the release of intermaxillary fixation. Tadahiko lizuka et al (1987), described a single crystal sapphire bone screw which had favorable properties such as chemical stability, mechanical strength and biocompatibilities. These were applied for rigid internal fixation of the sagittal split osteotomies. Chambers et al (1987), reviewed the record of Major J.W.E. Snawdoss on the treatment of mandibular fracture during

the 2nd world war. Notable features were high frequency civilian injuries, delay between injury and definitive. The lengthy period of infections and occurrence of delayed union. Theriot B.A. et al (1987), compared rigid osseous fixation of mandibular fractures with intraosseous wire fixation by the prospective study. He suggested that the small bone platting system was an alternative fixation method for wire fixation method.

Joram raveh et al (1987), confirmed the efficacy in 358 fractures managed by plate osteosynthesis using the intraoral approach. Bjorn Johansson et al (1988), studied about the miniplate osteosynthesis of infected mandibular fractures in 37 patients. Post-operative result reveals that the healing had occurred in almost all cases. John K Jones and Joseph E Van Stickels et al (1988), reviewed the basic tenets of rigid fixation and pointed out the advantages and disadvantage of each system.

Luhr et al (1988), described about the microplates of 0-5mm thickness provides rigid fixation of very thin bony structures, and at the same time minimal interference with the overlying soft tissue. Micha Peled et al (1989), studied in 76 patients with mandibular fracture treated by compression osteosynthesis. The study was a retrospective one which showed good results in 83% of the cases. L.E.Mobeg et al (1989), studied about metal from plates used in jaw fracture treatment. The study investigated the occurrence of corrosion associated with the use of metallic implants to stabilize the jaw fractures. Titanium concentration was high of all the element were found in tissue near the implants when compared with contralateral controls. Kyosti Oikarinen et al (1989), in their study 200 mandible fracture was evaluated respectively, with reference to the need for rigid internal fixation (AO platting) as indicated by ASIF organization. It was shown that the treatment was most typically IMF (50%), followed by gunning type splint (17%), wire (16%) and plate osteosynthesis (6%), and while 11% received no active treatment. W.P Smith[40] (1991) he concluded that in case of mandibular fracture in which miniplate osteosynthesis had been delayed beyond recommended time interval the incidence of wound dehiscence, wound infection and delayed union was found to be comparable to osteosynthesis performed within 24 hours.

Frans H M Kearns (1991), in his study regarding the stability of miniplate osteosynthesis in mandible, a three dimensional model was developed by this test he concludes in cases of jaw angle fracture neither bending nor torsional forces are sufficiently controlled by miniplate fixation but in case of canine region, it requires two plates instead of one plate to resist displacement of fracture fragment during functions. Edward Ellis[10] (1992), in his study he told various treatment method for fixation of mandibular angle: A) closed reduction or intraoral open reduction and non-rigid fixation; B) extra oral open reduction and internal fixation with AO/ASIF reconstruction bone plate; C) intra oral open reduction and internal fixation using solitary lag screws; D) intraoral open reduction and internal fixation using two 2mm mini- dynamic compression plates; E) Intraoral open reduction and internal fixation using 2.4mm mandibular dynamic compression plates; F) intraoral open reduction and internal fixation using non- compression miniplate; G) intraoral open reduction and internal fixation using single non- compression miniplate; H) intraoral open reduction and internal fixation using single malleable non-compression miniplate. Result of treatment shows that a use of either an extra oral open reduction or internal fixation with AO/ASIF reconstruction plate or intraoral open reduction and internal fixation using a single miniplate are associated with fewer complications.

JP Hayter [31] (1993), stated that rigid internal fixation is frequently used method of reduction and immobilization of mandibular fracture but high complications have been studied in rigid internal fixation. Edward Ellis III and Douglas P. Sinn et al[10] (1993), described about the use of 2 dynamic compression plates in 65 consecutive patients, who had fractures in the angle of the mandible which were treated by open reduction and were found to be relatively easy but the infection rate was unacceptable. Richard H Hang V et al (1993), studied the effect of screw number and length on two methods of tension band plating. Five trials each were with 4,8,16 mm in length and 2mm adaptation plate. Concluded that increase in the weight resisted up to three screws per segment, after which no additional benefit was realized. Veikko Tuovinen at el (1994), studied the stability of semi-rigid fixation for the treatment of maxillofacial fracture between

1986- 1991 on 229 patients with 441 isolated mandibular fracture were treated with miniplate fixation using the tension band principle of champy et al [2], conclusion made was that the mandibular fractures treated with semi rigid miniplate is a viable treatment option for the management of such injuries.

Uhthoff et al (1994), studied about the cortical porosis under the plates used for the fixation of fractures. The objectives of the study was to test the hypothesis that cortical necrosis is related to changes associated with porosis. Histomorphogenic study was done and the plates failed to show a significant positive correlation between the necrosis and porosis irrespective of the type of plate used. Porosis was always greater in the inner cortical sector, where no increased necrosis was noted, then in the outer cortical sector where the necrosis was present. G.J Kearns et al (1994), studied the rate of complication in rigid internal fixation of mandibular fracture and they concluded that there is a downward trend in the complication rate with increase in experience of surgeon with RIF.

Richard H. Haug et al [33] (1995), described about the intraoral open reduction of mandibular anterior fracture with the help of microplates and screws. Bung Ho Choi [52] (1995), in his study he used two miniplate fixation technique for more stable fixation and greater resistance against infection, strong support for argument was demonstrated in in-vitro and pilot clinical studies in two miniplate occlusal disturbances and infection two miniplate provides better stability in lower border of fracture line. TF Renton et al (1996), in his study he compared fracture ostoesynthesis by comparing three techniques. 205 patients assigned into three groups according to the type of fixation. 83 patient had miniplate fixation based on champy principle, 40 patients had rigid fixation according to champy's principle, 82 patients had transosseous wire fixation. Outcomes was measured and statistics indicates, higher concentration rate for the transosseous wire group compared with the miniplate groups, and morbidity was reduced in the group following champy's principle. Titanium miniplate appear as effective as miniplate constructed of other materials when champy's principles was followed.

IR Mathew et al (1996), in his study he characterized the surface of titanium and stainless miniplate and screws that has been used to stabilize fracture of mandible energy dispersive x-ray analysis was used to identify compositional variations of miniplate surface and Vickers hardness testing was done aluminium and silicon deposits were identified by edx analysis over flat surfaces there are extensive damage to screws head but there was no significant change in the surface characteristics of miniplate retrieved up to 24 weeks after implantation. Edward timothy JC and David J et al, (1996), compared miniplate used in the treatment of mandibular fractures. The purpose is to investigate the difference in mechanical properties of non-compression miniplate osteosynthesis of mandibular fracture and to determine whether these properties influence the treatment outcome while significant difference in stiffness were identified between the platting system no significant difference in treatment outcome were identified. Because of the variation in materials, designs properties, CT compatibility and the unit cost. It is important to regard all miniplate as equal and interchangeable.

Richard H Hflug et al (1996), in his study he presents evidence that refutes the current misconception regarding carcinogenesis, corrosion and stress protection investigation in animal model has shown that a relationship exist between commercially pure titanium and malignancy titanium and its alloy are the most corrosion resistant metal. E Riht et al (1996), reported the result of an experimental analysis performed on titanium miniplate and screw in order to gain a better understanding of dynamic forces in internal results, author proposes a new plate design in which the area subjected to more stress proximal to the bone section would be of miniplate thickness, the distal aspect being thinner as in microplate. It is suggested that this design would provide sufficient stability and a higher degree of anatomical adjustment to the system. Brain R smith et al [40] (1996), did a study on use of open reduction and rigid internal fixation in comminuted fractures. Concluded that ORIF of comminuted fractures has the benefit of restoring continuity and returning the patient to function earlier than close techniques although the disadvantage of ORIF include periosteal stripping the stability that can be accomplished with RIF apparently allows revascularization of comminuted segments.

Richard R Haug et al [33] (1996), compared the conventional technique of mandibular fracture platting with two biomechanically dissimilar technique in their ability to resist vertical loads similar to masticatory forces. The conventional group was stabilized with a thin tension band system at the superior border and thick stabilization plate system at the inferior border. The nontraditional group was stabilized with thick tension band system at the superior border and thin stabilization plate system at the inferior border. The two miniplate group were stabilized with a thin tension band system at the inferior border and concluded that all failures in his experiment occurred due to monocortical screws in the superior border of the tension band system. Young Kyun Kin et al (1997), investigated the tissue response associated with the titanium plates. Titanium miniplate were used to stabilize fracture bones and bone graft in 14 patient. Macroscopically visible pigmentation was found in 14% of the patients. He concluded that local macroscopic or microscopic tissue destruction was observed in hard and soft tissue near titanium miniplate. If the plates remain for a long time they will further cause tissue damage. These findings suggest that the titanium miniplate should be removed routinely after the bone healing. T.Kawai (1997), in his study he found out the best time to undertake radiological follow-up examination and remove fixation materials after fracture of the mandible. Radiographic fractures of healing are seen in 2, 2-3, 3-4 and 4 or more months. Ontogeny changes was the best radiographic criteria which predominates in 1-2months after injury in patient less than 18years and 2-3 months in older patient after osteogenic examination the fixation material should be removed after 22 month of injury.

Kazuhisa Bessho (1997), in his study PLLA miniplate provide efficient osteosynthesis of maxillo-skeleton. Herford AS (1998), in his study on the use of a locking reconstruction bone plate/screw system for mandibular surgery concluded that the use of a locking plate/ screw system was found to be simple, and it offers advantage over the conventional bone plate by not requiring the plate to be compressed to the bone to provide stability.

Gosain et al (1998), in their study about biomechanical evaluation of titanium, biodegrable plates and screws and cyanoacrylate glue fixation system in craniofacial surgery concluded that titanium miniplate were the strongest form of fixation tested in both distraction and compression across the central gap.

Gutwald [7] in 1999, investigation was performed using 16 cadaver mandibles. Strain gauges were applied to the mandibles which were then subjected to cranial, caudal and torsional forces. They concluded that a higher stability was achieved with locking plates. Chiodo et al (2000), performed a laboratory study to determine any difference in performance and found no statistical difference between the locking and conventional 2 mm mandibular plate. Hisaniri Hirari et al (2001), studied the conditions of bone adjacent to the titanium bone screws by histological method in patient treated for mandibular fracture specimen were obtained from 14 patients and examined with light microscopy. The mean ratio of direct contact between the bone and the titanium bone screw were also analyzed using a computer aided image analyzer. Result showed formation of new bone around the titanium bone screws in all cases. In areas of cortical bone, partial interposition of soft tissue was rarely observed. In areas of cancellous bone partial interposition of soft tissue was noted. The mean ratio of direct contact between all of the adjacent bone and the surface of the titanium bone screw was 64.4%. In conclusion titanium bone and the surface of the titanium bone screws used for mandibular fracture fixation develop almost complete contact with new bone with some metallosis present. Kaan yerit et al (2002), in his study self-reinforced biodegradable osteosynthesis materials provide a reliable and sufficient alternative to conventional titanium plate system. RX Lingfort JW Frame et al (2002), in their study about surface analysis of titanium maxillofacial plate and screws retrieved from patients were compared with the control sample. There was no signs of corrosion or surface deterioration on the retrieved plates and screws which had seen in the tissues for between one month and thirteen years. There was no evidence from this study to support the routine of titanium maxillofacial miniplate due to corrosion up to period of thirteen years. H.Schliephake et al (2002), in their study on bone growth factors; maxillofacial skeletal reconstruction, reviewed that all the growth factors have a fundamental role in growth and development. In postnatal skeletal regeneration PGDF plays an important role in inducing proliferation of undifferentiated mesenchymal cells. It is an important mediator of bone healing and remodeling during

trauma and infection, IGF have an important role in general growth and maintenance of the body skeleton. TGF alone in skeletal reconstruction appears to be associated with uncertain result. BMP, particularly BMP7 appears to be most effective growth factor in terms of osteogenesis an osseous defect repair.

Ellis E [10] (2002), in his study of the use of a 2.0mm locking plate/ screw system for mandibular fracture surgery, the use of a 2.0mm locking plate was found to be simple and to provide sound fixation in all cases. Kirkpatrick D (2003), in his study on infections associated with the locking reconstruction plates, a retrospective review stated the use of locking reconstruction plate can facilitate the management of complicated fracture, however it does not eliminate the complications. Postoperative infection are related to numerous factor, including the postoperative incidence of infection, smoking and proper use of plate. Paolo scolozzi et al (2003), states the use of 2-4mm AO titanium reconstruction plates for mandibular fracture without the use of IMF, the use of AO reconstruction plates in which the bone can no longer buttress compression forces.

Leslie R. Halpern et al [30] (2004), had done open reduction and internal fixation fracture displacement of 5mm or more and a normal preoperative neurosensory examination were associated with an increased risk for deterioration of the ion after the mandibular fracture treatment and factors that affect prognosis. Collins CP [9] (2004), randomized clinical trial comparing 2.0mm locking plate to standard 2.0mm standard plate in treatment of mandibular fracture stated that mandibular fracture treated with 2.0mm locking plates and standard 2.0mm plate present similar short term complication rate. B.H Choi et al [52] (2005), they conducted a study to determine the incidence of post-operative complications in the use of mandibular fracture reduction forceps. 46 patients were included in the study of which 23 patients with mandibular fracture were reduced using mandibular angle reduction forceps and in 23 patients the mandibular angle fractures the reduction were achieved with IMF. The post reduction radiograph revealed that the reduction forceps group had higher proportions of precise anatomic alignment of fracture compared to IMF group. They concluded in their study that use of mandibular angle reduction forceps decreases the incidence of post-surgical complication.

Chiodo TA (2006), in his report on failure strength of 2.0mm locking vs 2.0mm conventional mandibular plates; a laboratory model stated that in this laboratory model, no significant difference was found between the two plate system. Although studies have shown locking plate to be more rigid, this study suggested that the type and degree of failure depends on the type of bone and surgical technique when using 2.0mm mandibular plate. Ueki K [51] (2008), in his study on the skeletal stability after mandibular setback surgery, bicortical fixation using a 2.0mm locking plate system versus monocortical fixation using locking plate system stated that the locking plate system provided better stability. Lazow SK (2009), in his study on mandibular fracture, transoral 2.0mm locking plate and 1 week intermaxillary stabilization provides better stability. Oguz Y (2009), in his study on stability of locking and 2.0mm miniplate system after sagittal split ramus osteotomy, finite element analysis concluded that the locking plate system spreads the load over the plate and screws and diminishes the amount of force transferred to each unit. Seemann R [29] (2009), through his study on comparison of locking and non-locking plates in the treatment of mandibular condyle fracture promoted a better stabilization of bone segment.

Ribeiro- Junior [50] (2010), in his study on the in vitro biomechanical evaluation of the use of conventional and locking plate/ screw system for sagittal split ramus osteotomy stated that placement of 2.0mm diameter bi-cortical screws in the retromolar region, associated with or without the conventional and locking miniplate with the monocortical screw promoted a better stabilization of bone segment. Locking plate performed the better in respect to bone fixation in all groups. Sebastian sauerbier [49] (2010), in his study on the clinical aspect of a 2.0mm locking plate system for mandibular fracture surgery stated that the use of 2.0mm locking plate system with its advantages of improved handling characteristic, increased stability, shorter surgical time and the preservation of bony perfusion is a viable alternative to conventional miniplate in the management of mandibular fractures. Syed linamdar zakaullah et al (2011), evaluated the short term result of patients treated with low-profile titanium miniplate for fractures of the mandible were treated by open

reduction and internal fixation using thin, low profile titanium miniplate and 1.3mm self-threading screws. Patients were evaluated for complications during a 6 month follow-up period and the result were, 1 patient (5%) experience wound dehiscence and was managed by daily irrigation and antibiotic medications. His conclusion was that low- profile titanium miniplate can be adequately used for internal fixation in selective mandibular fracture.

Vijay Ebenezer et al [25] (2011), concluded from his study, fixation of mandibular fracture with 3D miniplate provides 3D stability because of its design, ease of technique during fixation of fracture fragments and carried low morbidity and infection rate that may prove to be comparable to the standard platting systems. The only probable limitation of these plates may be excessive implant material due to the extra vertical bars incorporated for countering the torque forces. Deepak et al [46] (2011), to study the versatile nature and the biocompatibility of the titanium material and to determine the usefulness of titanium miniplate over the stainless steel plate in the management of fracture of mandible. Titanium plate were found to be very ideal in the management of mandibular fracture. Titanium plate were more compatible when compared to stainless steel plate as evidenced by the rate of infection. In all cases the plate were performed to be rigid, stable and satisfactory for use in facial skeleton. Titanium plate being more malleable were easily adapted to the varying contours of the mandible which clinically translated into reduced time requiring for plating.

Naiya V. Pathak et al [47] (2015), a comparative study of fixation, with stainless steel and titanium miniplate for fracture of the mandible. It was carried out to compare the efficacy of stainless steel miniplate with titanium miniplate for adaptability, effect on fracture line and complications. Out of 20 cases of mandibular fracture, in 10 cases stainless steel miniplate and in other 10 cases titanium miniplate were used for open reduction and internal fixation. Follow up was done at interval of 6, 12 and 48 weeks and then every 6 months. The titanium miniplate are more malleable and easily adapted to bone as compared to stainless steel. They showed excellent handling properties and good stability of fracture fragment.

Denny George et al [43] (2015), 3D titanium miniplate with locking screw are better in fracture stabilization for anterior mandibular fractures when compared with titanium miniplate. Other postoperative findings show similar changes in both groups. Pavan kumar et al [39] (2016), observed in his study that the locking plate/screw system offers significant advantages over the conventional plating system. The precise adaptation required for using conventional plate is not needed when this locking plate/screw system is used. Locking plate/ screw system provides better stability than the conventional plate/screw system. Yadav and Agarwal et al [45] (2017), bone plate system acts as an internal–external fixator, which results in better distribution of the load and prevents load concentration on a single screw, thus decreasing the risk of a screw loosening and stripping. 3-D locking plate/screw system fulfill the treatment goals of adequate reduction, fixation and stabilization of fracture of mandible. 3-D locking plating system adequately reduces the fracture without much need for adaptation and hence reduces the intra-operative time.

Bipin S. Sadhwani et al [34] (2018), the results of this study suggest that the treatment of mandibular fractures (symphysis, para symphysis, and angle) with 3-dimensional plates provided 3-dimensional stability and carried low morbidity and infection rates. The only probable limitations of 3-dimensional plates were excessive implant material due to the extra vertical bars incorporated for countering the torque forces. Nilima J Budhraja, Ramakrishna S. Shenoi et al [36] (2018), study was to evaluate the efficacy of 2-mm 3D locking miniplate in the management of anterior mandibular fracture and to compare it with Champy's miniplate. The result of the study can conclude that there is no major difference between both systems in terms of treatment outcome. Patiguli Wusiman et al [48] (2019), did a systematic and meta-analysis study on three-dimensional versus standard miniplate, lag screws versus miniplate, locking plate versus non-locking miniplate in the management of mandibular fractures. The results of the three-Dimensional versus Standard miniplate showed that 3-dimensional miniplate is the best option for mandibular fracture. Regarding Lag screw versus Miniplate results of the meta-analysis found that the use of lag screw is superior to using miniplate in reducing the incidence of postoperative complication. And in regards to locking miniplate

versus non-locking miniplate, the analysis indicates that the 2.0-mm locking miniplate is a prospective fixation system in the treatment of maxillofacial fractures.

4. Conclusion-

The art of surgery demands that we evaluate the risk and benefits of each treatment modality and apply it appropriately for each patient. From time to time the internal fixators are being modified to overcome existing shortcomings.

To conclude, these findings our study suggest that the use of 3D miniplate for parasymphysis fractures fixation was efficacious enough to bear the masticatory load during osteosynthesis of the fracture. Operative time is shorter because of simultaneous stabilization at both superior and inferior borders and less implant material is used in parasymphysis region. Comparatively more cost-effective than two-dimensional titanium miniplate osteosynthesis technique, less surgical exposure of the underlying fracture site, with a minimal traction of the surrounding soft tissue.

5. REFERENCE-

[1] Spiessel B (1972) rigid internal fixation of fractures of lower jaw. Reconstr Surg Traumtol 13:124–140.
[2] Champy M, Lodde JP, Schmitt R et al (1978) Mandibular osteosynthesis by miniature screwed plates via a buccal approach. J Maxillofac Surg 6:14–21.
[3] Michelet FX, Deymes J, Dessus B (1973) Osteosynthesis with miniaturized screwed plates in maxillofacial Surgery. J Maxillofac Surg 1:79.
[4] Cawood JL (1985) Small plate osteosynthesis of mandibular fractures. Br J Oral Maxillofac Surg 23:77–91.
[5] Kroon HM, Mathison M, Cordey JR, Rahn BR (1991) the use of miniplate in mandibular fractures. J Craniomaxillofac Surg 19:199.
[6] Farmand M (1995) Three-dimensional plate fixation of fractures and osteotomies. Facial Plast Surg Clin North Am 3(1):39–56.
[7] Gutwald R, Alpert B, Schmelzeisen R (2003) Principle & stability of locking plates. Keio J Med 52:21.
[8] Coletti DP, Caccamese JF, Norby C et al (2007) Comparative analysis of the threaded & tapered locking reconstruction plates. J Oral Maxillofac Surg 65:2587. 9. Guimond C, Johnson J, Marchena J (2005) Fixation of mandibular angle fractures with a 2.0 mm 3-dimensional curved angle strut plate. J Oral Maxillofac Surg 63:209.
[9] Collins CP, Leonard GP, Tolas A et al (2004) A prospective randomized clinical trial comparing 2.0 mm locking plates to 2.0 mm standard plates in treatment of mandible fractures. J Oral Maxillofac Surg 62:1392.
[10] Ellis E, Graham J (2002) Use of a 2.0-mm locking plate/screw system for mandibular fracture surgery. J Oral Maxillofac Surg 60:642.
[11] Wittenberg JM, Mukherjee DP, Smith BR, Kruse RN (1997) Biomechanical evaluation of new fixation devices for mandibular angle fractures. Int J Oral Maxillofac Surg 26:68–73.
[12] Bui P, Demian N, Beetar P (2009) Infection rate in mandibular angle fractures treated with a 2.0 mm 8-hole curved strut plate. J Oral Maxillofac Surg 67:804–808.
[13] Parmar S, Menat S, Raghani M, Kapadia T (2007) Three dimensional miniplate rigid fixation in fracture mandible. J Maxillofac Oral Surg 6(2):14.
[14] Pektas ZO, Bayram B, Balcik C, Develi T (2011) Effects of different mandibular fracture patterns on the stability of miniplate screw fixation in angle mandibular fractures. IJOMS 41:339–343.
[15] Malhotra K, Sharma A, Giraddi G (2012) Versatility of titanium 3D plate in comparison with conventional miniplate fixation for the management of mandibular fracture. JMOS 11(3):284–290.
[16] Kroon FH, Mathisson M, Cordey JR, Rahn BA. The use of miniplate in mandibular fractures. J Craniomaxillofac Surg. 1991; 19(5):199-204.

[17] Jain MK, Sankar K, Ramesh C, Bhatta R.Management of mandibular interforaminal fractures using 3 dimensional locking and standard titanium miniplate - a comparative preliminary report of 10 cases. J Craniomaxillofac Surg. 2012; 40(8):475-8
[18] Harjani B, Singh RK, Pal US, Singh G.Locking v/s non-locking reconstruction plates in mandibular reconstruction. Natl J Maxillofac Surg. 2012; 3(2):159–65.
[19] Prabhakar C, Shetty JR, Hemavathy OR, Guruprasd Y. Efficacy of 2.0-mm locking miniplate in the management of mandibular fractures without maxillomandibular fixation. Natl J Maxillofac Surg. 2011; 2(1):28-32.
[20] Pereira-Filho VA, da Silva BN, Nunes Reis JM, SpinNeto R, Real Gabrielli MF, Monnazzi MS. Effect of the number of screws on the stability of locking mandibular reconstruction plates. Int J Oral Maxillofac Surg. 2013;42(6):732-5.
[21] Virendra Singh, PuneetPuri, Sanjay Arya, Sunita Malik, AmrishBhagol. Conventional versus 3-dimensional miniplate in management of mandibular fracture: a prospective randomized study. Otolaryngol Head Neck Surg .2012; 147(3):450–455
[22] Balakrishnan R, Vijay Ebenezer Abu Dakir. Three dimensional titanium mini plates in management of mandibular fractures. Biomed Pharmacol J .2014;7(1):241–246
[23] Dhananjay H Barde, Anupama Mudhol, Fareedi Mukram Ali, Madan RS, Sanjay Kar, FarheenUstaad .Efficacy of 3-dimensional plates over Champys miniplate in mandibular anterior fractures.J Int Oral Health .2014;6(1):20–26
[24] Guimond C, Johnson J, Marchena J (2005) Fixation of mandibular angle fractures with a 2.0 mm 3-dimensional curved angle strut plate. J Oral Maxillofac Surg 63:209
[25] Ebenezer V, Ramalingam B (2011) Three-dimensional miniplate fixation in mandibular angle fractures. IJMD 1(2):89–93 17.
[26] Fordyce AM, Lalani Z, Songra AK, Hildreth AJ, Carton ATM, Hawkesford JE (1999) Intermaxillary fixation is not usually necessary to reduce mandibular fractures. BJOMS 37:52–57.
[27] Singh V, Kumar I, Bhagol A (2011) Comparative evaluation of 2.0 mm locking plate system vs 2.0 mm non locking plate system for mandibular fracture: a prospective randomized study. Int J Oral Maxillofac Surg 40:372–377
[28] Sai Krishna D, Sujeethkumarshetty, Marimallappa TR (2009) A comparison between 2.0 mm standard and 2.0 mm locking miniplate in the management of mandibular fractures. J Maxillofac Oral Surg 8:145–149
[29] Seemann R, Frerich B, Muller S, Koenke R, Ploder O, Schicho K, Piffko J (2009) Comparison of locking and nonlocking plates in the treatment of mandibular condyle fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 108:328–334
[30] Halpern LR, Kaban LB, Dodson TB (2004) Perioperative neurosensory changes associated with treatment of mandibular fractures. J Oral Maxillofac Surg 62:576–581
[31] Hayter JP, Cawood JI (1993) the functional case for miniplate in maxillofacial surgery. Int J Oral Maxillofac Surg 22(4):91–96
[32] Prabhakar (2018) Locking miniplate in mandibular fractures. National Journal of Maxillofacial Surgery 2(1): 31- 35.
[33] Haug RH, Prather J, Indrasano AT. An epidemiologic survey of facial fractures and concomitant injuries. J Oral Maxillofac Surg 1990;48:926-34.
[34] Bipin S. Sadhwani, Sonal Anchlia. A Conventional 2.0 mm miniplate versus 3-D plates in mandibular fractures. Annals of Maxillofacial Surgery 2013; 39(2).
[35] Feledy J, Caterson EJ, Steger S et al (2004) Treatment of mandibular angle fractures with a matrix miniplate. A preliminary report. Plast Reconstr Surg 114:1711
[36] Nilima J. Budhraja, Ramakrishna S. Shenoi, Samprati J. Badjate, Kshitij O. Bang, Pranav D. Ingole, Vrinda S. Kolte (2018) Three-dimensional Locking Plate and Conventional Miniplate in the Treatment of Mandibular Anterior Fractures. Ann Maxillofac Surg 2018;8:73-7.
[37] Gear AJ, Apasova E, SchmitzJP.Treatment modalities for mandibular fractures. J Oral Maxillofac Surg 2005;63:655-63.

[38] Alkan A, Celebi N, Ozden B, Baş B, Inal S. Biomechanical comparison of different plating techniques in repair of mandibular angle fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:752-6.
[39] Pavan Kumar, K. A. Jeevan Kumar. Study of Efficacy and the comparison between 2.0 mm Locking Plating System and 2.0 mm Standard Plating System in Mandibular Fractures. J. Maxillofac. Oral Surg. (July–Sept 2015) 14(3):799–807
[40] Smith WP (1991) Delayed miniplate osteosynthesis for mandibular fractures. Br J Oral Maxillofac Surg 29(2):73–76.
[41] Nayak SS, Pushpalatha C, Tammanavar PS, Naduwinmani SL, Mohan M. Efficacy of locking plates/screw system in mandibular fracture surgery. J Contemp Dent Pract. 2013;14 (2):222–226.
[42] Kolli Yada Giri, Puneet Sahu, Sanjay Rastogi. Bite Force Evaluation of Conventional Plating System Versus Locking Plating System for Mandibular Fracture. J. Maxillofac. Oral Surg. (Oct–Dec 2015) 14(4):972–978.
[43] Denny George, V.Suresh, R.Sathya Narayanan. A Comparative Study Between Titanium Mini Plates And 3 Dimensional Titanium Plates With Locking Screws Using Bite Force Evaluation For Management Of Anterior Mandibular Fractures. Journal of Scientific Dentistry, 6(2), 2016.
[44] Mahaboob Shaik, Effectiveness of 2.0 mm Standard and 2.0 mm Locking Miniplates in Management of Mandibular Fractures: A Clinical Comparative Study. J. Maxillofac. Oral Surg. (Jan–Mar 2014) 13(1):47–52.
[45] Yadav S, Agarwal A. 3-D locking titanium miniplates in management of mandibular fracture: A prospective clinical study. J Dent Specialities.2015;3(1):64-67
[46] Deepak S, manjula S. Comparison of titanium bone plates and screws vs. Stainless steel bone plates and screws in the management of mandibular fractures – a long term clinical study. International journal of clinical dental science, vol 2, no 3 (2011)
[47] Naiya V. Pathak, Ashish O. Sachdeva. A comparative study between stainless steel and titanium mini plate fixation in fracture of mandible. Int J Int Med Res. 2015; 2(3): 47-52
[48] Patiguli Wusiman, Dilidaer Taxifulati. Three-dimensional versus standard miniplate, lag screws versus miniplates, locking plate versus non-locking miniplates: Management of mandibular fractures, a systematic review and meta-analysis. J Dent Sci. 2019 Mar; 14(1): 66–80.
[49] Sauerbier S, Kuenz J, Hauptmann S. Clinical aspects of a 2.0-mm locking plate system for mandibular fracture surgery. J Craniomaxillofac Surg. 2010 Oct;38(7):501-4.
[50] Ribeiro-Junior PD, Magro-Filho O. In vitro biomechanical evaluation of the use of conventional and locking miniplate/screw systems for sagittal split ramus osteotomy. J Oral Maxillofac Surg. 2010 Apr; 68(4):724-30.
[51] Ueki K, Hashiba Y,Skeletal stability after mandibular setback surgery: bicortical fixation using a 2.0-mm locking plate system versus monocortical fixation using a nonlocking plate system. J Oral Maxillofac Surg. 2008 May; 66(5):900-4.
[52] Choi BH, Kim KN, Kang HS. Clinical and in vitro evaluation of mandibular angle fracture fixation with the two-miniplate system. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:692-5.
[53] Arjun Singh, K. V. Arunkumar. Standard 3D Titanium Miniplate Versus Locking 3D Miniplate in Fracture of Mandible: A Prospective Comparative Study. J. Maxillofac. Oral Surg
[54] Zix J, Lieger O, Iizuka T (2007) Use of straight and curved 3-dimensional titanium miniplates for fracture fixation at the mandibular angle. JOMS 65:1758–1763