Orthodontics Anchorage in Mandibular Angle Fractures—A Brief Review

Siti Aisyah Abdul Halim¹, Ruslizam Daud², Ishak Ibrahim³, Fauziah Mat⁴, Nur Saifullah Kamaruddin⁴, Rohaizar Ismail⁵

¹Fracture and Damage Mechanics SIG, School of Mechatronic Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
Email: sitiaisyahabduhalim@rocketmail.com

²Klinik Pakar Bedah Mulut Dan Maksilofasial, Hospital Tuanku Fauziah, Jalan Tun Abdul Razak, 02600 Kangar, Perlis, Malaysia

Abstract. Maxillofacial fracture could be a quite common injury these days particularly in jaw angle. The healing process is physiologically complicated including each biological and mechanical aspects. Over the past decade, mandibular angle fracture simulation and modeling has been used to understand its details and mechanisms, to analyze specific clinical inquiry and to style healing approaches. This paper aims to review the history and also the most recent work on biological and mechanical properties of miniplate. This paper provides a short review of mandibular angle fracture, miniplate evolution, biomaterials utilized in miniplates, structure of miniplates and finite element analysis of miniplate in three dimensional (3D) model.

1. Introduction

Modern life's increasing pace, the increasing frequency of violence, sports injuries, high-speed travel, traffic accidents, wars and industrial trauma have caused a maxillofacial fracture. A maxillofacial fracture refers to any fracture to the face or jaw caused by physical force. Research on orthodontic anchorage of miniplates materials, methods and models has risen in latest years and is anticipated to grow in the future owing to current development in the worldwide orthodontics anchora

The mandible forms the lower jaw and the only moveable bone of the facial skeleton. Hence, the mandible is vulnerable to fracture due to its mechanically weak components. Several factors influence the mandibular fractures such as direction, severity and impact of force, the presence of soft tissue bulk and occlusal loading pattern. Biomechanical characteristics such as anatomic structures, mass and bone density creating weak areas are responsible to fractured in mandibular (Mannan, Farooq, & Mukhtar, 2018). The occurrence of mandibular fracture can occur either in unilateral symphysis, body, angle, condylar or bilateral condylar (Zhou, Lv, Yang, Li, & Li, 2016)

The mandibular angle fracture accomplish more complication compare to other mandibular fractures due to complex anatomical and biomechanical aspects including abrupt change in curvature, attachment of the masticatory muscles, a thin cross-sectional area and the presence of the third molars (Ellis, 1996). Interesting trends for mandibular angle fractures were stated that the patients with impacted mandibular third molar are significantly to have mandibular angle fracture (Asif, Alam, Haque, Rashdan, & Mahmoud, 2018).

Mandibular angle fractures pose a unique challenge for surgeons and in medical industries because they have the highest reported post-operative complication rate than other mandibular fractures. The ideal treatment of mandibular angle fractures remains subject to considerable debate. Therefore, anchorage orthodontics of miniplates become expeditiously necessary management of mandibular fractures. Orthodontics anchorage can be grouped into two based on function; devices for symmetrical tooth movements in all planes of spaces and an alternative towards orthognathic surgery. Apart from this, orthodontics anchorage can be classified into two main
categories based on its relation with bone. The first category consists of osseointegrated dental implants such as the orthodontic mini-implants, the retromolar implants and the palatal implants (Sugawara, 2014). The second category derives from the surgical mini-screws and miniplates (Sugawara, 2014). The differences between these both categorized is the size in diameter, smooth surface and stable differing from miniplates

Review the orthodontics anchorer evolution of miniplates for mandibular angle fractures, by discussing the existing miniplates modalities and defining the outcome measures in accordance with the recently published review on miniplates of mandibular angle fractures.

2. Miniplates Evolution

Michelet et. al introduced an original technique to reduce osteosynthesis, osteotomies and immobilization of fractures of the facial skeleton (Michelet, Deymes, & Dessus, 1973). Later on modified Michelet's technique of mandibular osteosynthesis by Champy consists of monocortical juxta-alveolar and sub-apical osteosynthesis without compression and without inter-maxillary fixation (Champy M, Lodde JP, 1978). Iii & Walker (1994) have used 2.0 mm self-threading screws placed double and 2.0 mm non-compression miniplates through a transoral incision with transbuccal trochar instrumentation. Ellis (1996) uses a single miniplate to demonstrate the use of either extraoral open reduction and internal fixation with reconstruction plate AO / ASIF or intraoral open reduction and internal fixation (Ellis, 1996), following treatment of mandibular angle fracture with single, malleable and thin 2.0 mm miniplate (J. & E., 1999).

Survey conducted among surgeons shown that a single miniplate on the superior border of the mandible has become the preferred method of treatment in Arbeitsgemeinschaft fur Osteosynthesefragen (AO) faculty (Gear, Apasova, Schmitz, & Schubert, 2005). One of the most important developments in miniplates began in 2005, when three dimensional (3D) miniplate for mandibular angle fracture fixation been suggested by some researchers (Al-Moraissi, El-Sharkawy, El-Ghareh, & Chrancovic, 2014; Al-Mozaiek, Darwich, & Darwich, 2016; Alkan, Çelebi, Özden, Baş, & Inal, 2007; Guimond, Johnson, & Marchena, 2005; Kalfarentzos, Deligianni, Mitros, & Tyllianakis, 2009; Khiahani, Keyhan, Razmideh, Chaleh Chaleh, & Amirzade-Iranaq, 2018; Rastogi et al., 2017)

However, miniplate with Champy technique has gained the confidence of many surgeons. This miniplate was suitable for simple angle fracture which reduces surgical time and dissection, minimizes risk to the facial and inferior alveolar nerves and decreases complication rates (Saíto & Murr, 2008). The development of modern plate osteosynthesis non-corrosive materials like vitallium or titanium, plate with screws as small as 0.8 mm in diameter and small self-locking systems had recommended by researcher (Sauerbier, Schön, Otten, Schmelzeisen, & Gutwald, 2008). Recent progress in the past studies has focused on materials and techniques to improve quality and anchorage; and other important development in miniplates have been focused in three dimensional model using finite element (FE) analysis and postoperative complications

3. Biomaterial used in miniplates

There are two ideal requirements for implant biomaterials like miniplate. First ideal requirement is biological properties. Biological properties included provide effective osseointegration, should not be harmful to hard and soft tissue, should not contain the toxic diffusible substance and should be free from potentially sensitizing agent that may cause an allergic reaction. Miniplate biomaterials also should have no carcinogenic potential and should be tasteless and odorless. Second ideal requirements is physical properties which should be dimensionally stable and should possess adequate strength and resilience and resist biting or chewing (Bajaj et al., 2017).Miniplates are made of titanium or titanium alloys. Commericially pure titanium (C P Ti; ASTM F67) is widely been used as a material of choice for implants especially for miniplates. It is because this type of titanium usually suitable in mechanical properties and excellent biocompatibility. Mini screws were made of titanium alloy (Titanium-6Aluminum-4Vanadium; ASTM F-136) (Bajaj et al., 2017; Rangel Goulart, Takanori Kemmoku, Noritomi, & de Moraes, 2015). Along with this, there is some potential biomaterials for mandibular angle fractures fixation such as biodegradable miniplates. Biodegradable miniplates consists of self-reinforced poly(L-lactide-co-D,L-lactide) [P(L/DL)LA] copolymer BioSorb FX plates (Lee et al., 2010).

Hence, biomaterials with effective osteointegration, no carcinogenic potential, and resistance on biting or chewing should be chosen as material for miniplates.

4. Miniplates structure

Miniplates are manufactured with alloys of titanium or titanium and have different shapes and sizes. The miniplate structure consists of three parts, such as head, arm, and body. Within the mouth, the head part is exposed and physically situated outside the dental arches. The head exists in a diversity of forms, e.g. curved, bent and tubular.
Some head portion manipulated into the desired shape like a bendable stick. Meanwhile, The arm portion is transgingival and usually in rectangular or round shape (Sugawara, 2014). There are four basic shapes for body portion which T, L, Y and I (straight). Even though modifications regarding manipulates heads were extensively explored, but there is a few research in modifications of the body portions (Sugawara, 2014). (Sugawara, 2014).

5. Finite Element Analysis of Miniplate Fixation
Finite Element Analysis (FEA) in dental started in 1973, finite element analysis were usud to investigate the state of stress for a homogeneous and non-homogeneous tooth (Thresher & Saito, 1973). Now, the popularity of FEA has drastically grown especially in miniplates and screws for mandibular angle fractures. At 2003, 8-noded hexahedral elements three dimensional (3D) mandible were generated in FEA by Cox et.al (Cox, Kohn, & Impelluso, 2003). Later on, in 2008 a fixation in mandibular angle fractures computational model developed by Arbag et.al using finite elements in order to calculate mechanical stress occurring in osteosynthesis plates (Arbag, Korkmaz, Ozturk, & Uyar, 2008).

In addition, FEA also capable to identify the optimize shape and fixation technique for a certain type of mandible fracture at corpus. In the future development of osteosynthesis materials and techniques, authors also agreed that FEA enables savings in term of time, material and animal experiments (Arbag et al., 2008).

Besides, FEA had been used to determine optimal modalities and plates configuration for intraoral and transoral approaches. Authors introduced four types of miniplate design such as 6-hole non compression miniplate, 6-hole single plate/Champy’s technique, 3D strut plate and 2 parallel 4-hole non compression miniplates. This analysis included segmental displacement and Von Mises Stress evaluation of 3D reconstruction of the human mandible (Coskunses et al., 2015).

In silico 3-dimensional FEA was introduced in year 2017. In silico FEA is an approach to identify an ideal design as it let on mechanical stress or strain distribution visualization and quantification of the marginal bone of dental implant fixtures and implant components (Ko, Rocha, & Larson, 2012). Yamaguchi et al. (2017) investigate the effect of fixation methods and different materials on the state of stress and displacement in reconstruction plate (Yamaguchi et al., 2017).

With topological optimization approach, Liu et.al created a three-dimensional (3D) FEA model virtual mandible using CT images with a mimic angle fracture and 1 mm gap between two bone segments in order to design a customized plate (Liu, Fan, Jiang, & Baur, 2017).

Ayali & Erkmen conducted 3D FEA for favourable mandibular angle fracture and unfavourable mandibular angle fractures (Ayali & Erkmen, 2017, 2018). Khiabani et al. also suggested 3D FEA to reach the best mastication power by determine the optimal method for mini-plating in fracture of the mandible angle. The usage of two miniplates in two different planes had been recommended by reason of the fracture of the lower angle of the jaw and reconstruction the optimal mastication force in patients (Khiabani et al., 2018).

FEA has a long history of in orthodonties, the development of 3D FEA has been an interesting research subject in the area. Throughout research in recent years, FEA technology has been constantly improving and providing a 3D FEA model of miniplates with an exceptional level of effectiveness, convenience and affordability. Several designs of 3D model of miniplates have been evaluated and also been tested. As such, more research on a better model in materials, surface treatment technologies, design parameters, and reliability analysis techniques is still needed to improve the outcomes.

6. Conclusions
The introduction of miniplates as orthodontic anchorage had a tremendous impact on the field of dentistry. The devices themselves are evolving that might support the best combination of ease of placement, least invasive procedure and best physical design properties to deliver optimum mechanical forces.

7. Acknowledgment
The author would like to acknowledge the support from the Fundamental Research Grant Scheme (FRGS) under a grant number of FRGS/1/2018/TK03/UNIMAP/02/8 from the Ministry of Higher Education Malaysia.

References
[1] Al-Moraissi E A, El-Sharkawy T M, El-Ghareeb T I and Chrcanovic B R 2014 Three-dimensional versus standard miniplate fixation in the management of mandibular angle fractures: a systematic review and meta-analysis International Journal of Oral & Maxillofacial Surgery 43 (6) 708–716.
[2] Al-Mozaieck M Y A-S, Darwich K and Darwich M A 2016 3D Finite element analysis of miniplate fixation techniques in mandibular angle fractures Journal of the Indian Dental Association 9 (12) 10–18.

[3] Alkan A, Çelebi N, Özden B, Baş B and İnal S 2007 Biomechanical comparison of different plating techniques in repair of mandibular angle fractures Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology 104 (6) 752–756. https://doi.org/10.1016/j.tripleo.2007.03.014

[4] Arbag H, Korkmaz H H, Ozturk K and Uyar Y 2008 Comparative evaluation of different miniplates for internal fixation of mandible fractures using finite element analysis Journal of Oral and Maxillofacial Surgery 66 (12) 1225–1232. https://doi.org/10.1016/j.joms.2005.11.092

[5] Asif J A, Alam M K, Haque S, Rashdan N H B M and Mahmoud M 2018 The correlation between mandibular third molar and mandibular angle fracture among patients in Hospital Universiti Sains Malaysia Oral Surgery 11 (3) 189–194. https://doi.org/10.1111/oris.12342

[6] Ayali A and Erkmen E 2017 Biomechanical evaluation of different plating methods used in mandibular angle fractures with 3-dimensional finite element analysis: favorable fractures Journal of Oral and Maxillofacial Surgery 75 (7) 1464–1474. https://doi.org/10.1016/j.joms.2017.02.028

[7] Ayali A and Erkmen E 2018 Three-Dimensional finite element analysis of different plating techniques for unfavorable mandibular angle fractures Journal of Craniofacial Surgery 29 (3) 1–5. https://doi.org/10.1097/SCS.0000000000004327

[8] Bajaj R, Shenoy U, Banerjee S, Hazare A, Karia H and Atulkar M 2017 Implants in orthodontics- a brief review International Journal of Oral Health and Medical Research 3 (5) 92–97.

[9] Champy M, Loddé J P, Schmitt R, Jaeger J H and Muster D 1978 Mandibular osteosynthesis by miniature screwed plates via a buccal approach Journal of Maxillofacial Surgery 6 (1) 14–21.  

[10] Coskunses F M, Kocyigit I D, Atil F, Tekin U, Suer B T et al. 2015 Finite-element analysis of a new designed miniplate which is used via intraoral approach to the mandible angle fracture: Comparison of the different fixation techniques Journal of Craniofacial Surgery 26 (5) e445–e448. https://doi.org/10.1097/SCS.000000000001890

[11] Cox T, Kohn M W and Impelluso T 2003 Computerized analysis of resorbable polymer plates and screws for the rigid fixation of mandibular angle fractures Journal of Oral and Maxillofacial Surgery 61 (4) 481–487. https://doi.org/10.1053/joms.2003.50094

[12] Ellis E 3rd 1996 Treatment methods for fractures of the mandibular angle The Journal of Cranio-Maxillofacial Trauma 2 (1) 28–36. https://doi.org/10.1016/S0901-5027(99)80152-0

[13] Gear A J L, Apasova E, Schmitz J P and Schubert W 2005 Treatment modalities for mandibular angle fractures Journal of Oral and Maxillofacial Surgery 63 (5) 655–663. https://doi.org/10.1016/j.joms.2004.02.016

[14] Giovacchini F, Paradiso D, Bensi C, Belli S, Lomurno G and Tullio A 2018 Association between third molar and mandibular angle fracture: A systematic review and meta-analysis Journal of Cranio-Maxillofacial Surgery 46 (4) 558–565. https://doi.org/10.1016/j.joms.2017.12.011

[15] Guimond C, Johnson J V and Marchena J M 2005 Fixation of mandibular angle fractures with a 2.0-mm 3-dimensional curved angle strut plate Journal of Oral and Maxillofacial Surgery 62 (5) 209–214. https://doi.org/10.1016/j.joms.2004.03.018

[16] Potter J and Ellis E 3rd 1999 Treatment of mandibular angle fractures with a malleable noncompression miniplate Journal of Oral and Maxillofacial Surgery 57 (3) 288–293.

[17] Kalfarentzos E F, Deligianni D, Mitros G and Tylianakis M 2009 Biomechanical evaluation of plating techniques for fixing mandibular angle fractures: The introduction of a new 3D plate approach Oral and Maxillofacial Surgery 13 (3) 139–144. https://doi.org/10.1007/s10006-009-0163-7

[18] Khiabani K, Keyhan S O, Razmdideh R, Chaleh Chaleh Z and Amirzade-Iranaq M H 2018 Effect of different miniplate osteosynthesis in different mandibular angle fracture patterns on bite force: A 3D finite element analysis Journal of Oral and Maxillofacial Surgery, Medicine, and Pathology 30 (4) 324–329. https://doi.org/10.1016/j.ajoms.2018.02.014

[19] Ko C C, Rocha E P and Larson M 2012 Past, present and future of finite element analysis in dentistry Finite Element Analysis - From Biomedical Applications to Industrial Developments (Lanczos 1962). https://doi.org/10.5772/38037

[20] Lee H B, Oh J S, Kim S G, Kim H K, Moon S Y, Kim Y K et al 2010 Comparison of titanium and biodegradable miniplates for fixation of mandibular fractures Journal of Oral and Maxillofacial Surgery 68 (9) 2065–2069. https://doi.org/10.1016/j.joms.2009.08.004

[21] Liu Y F, Fan Y Y, Jiang X F and Baur D A 2017 A customized fixation plate with novel structure designed
by topological optimization for mandibular angle fracture based on finite element analysis BioMedical Engineering Online 16 (1) 1–17. https://doi.org/10.1186/s12938-017-0422-z

[22] Mannan R, Farooq A and Mukhtar H 2018 Comparison of single vs double miniplates in the management of mandibular angle fractures Pakistan Journal of Medical and Health Sciences 12 (2) 662–664. https://doi.org/10.1016/j.arthro.2008.04.076

[23] Michelet F X, Deymes J and Dessus B 1973 Osteosynthesis with miniaturized screwed plates in maxillofacial surgery Journal of Maxillofacial Surgery 1 (C) 79–84. https://doi.org/10.1016/S0301-0503(73)80017-7

[24] Rangel Goulart D, Takanori Kemmoku D, Noritomi P Y and de Moraes M 2015 Development of a titanium plate for mandibular angle fractures with a bone defect in the lower border: finite element analysis and mechanical test Journal of Oral and Maxillofacial Research 6 (3) 1–7. https://doi.org/10.5037/jomr.2015.6305

[25] Rastogi S, Paul S, Kukreja S, Aggarwal K, Choudhury R, Bhugra A et al. 2017 Treatment of mandibular angle fractures with single three-dimensional locking miniplates without maxillomandibular fixation: how much fixation is required? Craniomaxillofacial Trauma & Reconstruction 10 (03) 188–196. https://doi.org/10.1055/s-0037-1600904

[26] Saito D M and Murr A H 2008 Internal fixation of mandibular angle fractures with the Champy technique Operative Techniques in Otolaryngology - Head and Neck Surgery 19 (2) 123–127. https://doi.org/10.1016/j.otot.2008.04.006

[27] Sauerbier S, Schön R, Otten J E, Schmelzeisen R and Gutwald R 2008 The development of plate osteosynthesis for the treatment of fractures of the mandibular body - A literature review Journal of Cranio-Maxillofacial Surgery 36 (5) 251–259. https://doi.org/10.1016/j.jcms.2007.08.011

[28] Sugawara J 2014 Temporary skeletal anchorage devices: The case for miniplates American Journal of Orthodontics and Dentofacial Orthopedics 145 (5) 443–449. https://doi.org/10.1016/j.ajodo.2014.03.010

[29] Thresher R W and Saito G E 1973 The stress analysis of human teeth Journal of Biomechanics 6 (5) 443–449. https://doi.org/10.1016/0021-9290(73)90003-1

[30] Yamaguchi S, Anchieta R B, Guastaldi F P S, Tovar N, Tawara D, Imazato S and Coelho P G 2017 In silico analysis of the biomechanical stability of commercially pure ti and ti-15mo plates for the treatment of mandibular angle fracture Journal of Oral and Maxillofacial Surgery 75 (5) 1004.e1-1004.e9. https://doi.org/10.1016/j.joms.2016.12.043

[31] Zhou H, Lv K, Yang R, Li Z and Li Z 2016 Mechanics in the production of mandibular fractures: a clinical Plos One 11 (2) 1–11. https://doi.org/10.1371/journal.pone.0149553